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Bank for International Settlements
Press & Communications
CH-4002 Basel, Switzerland

E-mail: publications@bis.org

Fax: +41 61 280 9100 and +41 61 280 8100

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Foreword

The papers in this volume were presented and discussed at the Autumn Central Bank Economists' Meeting held at the BIS on 15-16 October 2001. The meeting focused on recent changes in market functioning and their impact on central bank policy. A number of structural developments seem to have had a significant influence on the functioning of financial markets. The most important of these developments are the introduction of the euro, the spread of electronic trading, changes in the constellation and behaviour of market participants and falling supplies of government debt. There is some evidence that such structural changes resulted in shifts in liquidity among different market segments and, moreover, that liquidity is less robust than in the past. The process of price formation and the information conveyed by prices also appears to have been affected. This poses various challenges for central bank policy, including how best to gauge market expectations and conduct monetary policy operations.

List of meeting participants

Reserve Bank of Australia	Luci Ellis	ellisl@rba.gov.au
Austrian National Bank	Michael Boss Martin Scheicher	michael.boss@oenb.co.at martin.scheicher@oenb.co.at
National Bank of Belgium	Michel Dombrecht Marina Emiris	michel.dombrecht@nbb.be marina.emiris@nbb.be
Central Bank of Brazil	Joel Bogdanski	joel.bogdanski@bcb.gov.br
Bank of Canada	Alexandra Lai Ron Parker	laia@bankofcanada.ca rparker@bank-banque-canada.ca
European Central Bank	Arnaud Marès Jorge Sicilia	arnaud.mares@ecb.int jorge.sicilia@ecb.int
Bank of France	Françoise Drumetz François Haas	francoise.drumetz@banque-france.fr francois.haas@banque-france.fr
Deutsche Bundesbank	Christian Upper Thomas Werner	christian.upper@bundesbank.de thomas.werner@bundesbank.de
Hong Kong Monetary Authority	Stefan Gerlach Guorong Jiang	stefan_gerlach@hkma.gov.hk guorong_jiang@hkma.gov.hk
Bank of Italy	Aviram Levy Roberto Violi	levy.aviram@insedia.interbusiness.it violi.roberto@insedia.interbusiness.it
Bank of Japan	Hiroshi Nakaso	hiroshi.nakaso@boj.or.jp
Netherlands Bank	Ad Visser Peter Vlaar	a.visser@dnb.nl p.j.g.vlaar@dnb.nl
Bank of Spain	Juan Ayuso Roberto Blanco	ayuso@bde.es rblanco@bde.es
Sveriges Riksbank	Hans Dillén	hans.dillen@riksbank.se
Swiss National Bank	Hans-Jürg Büttler Thomas Jordan	hans-juerg.buettler@snb.ch thomas.jordan@snb.ch
Bank of England	Bill Allen Ian Marsh	bill.allen@bankofengland.co.uk ian.marsh@bankofengland.co.uk
Federal Reserve System	Alain Chaboud Brian Sack	alain.p.chaboud@frb.gov brian.p.sack@frb.gov
Bank for International Settlements	William White (Chairman) Renato Filosa Claudio Borio Eli Remolona Marvin Barth Benjamin Cohen Philip Wooldridge	william.white@bis.org renato.filosa@bis.org claudio.borio@bis.org eli.remolona@bis.org marvin.barth@bis.org bcohen@imf.org philip.wooldridge@bis.org

Changes in market functioning and central bank policy: an overview of the issues

Marvin J Barth III, Eli M Remolona and Philip D Wooldridge,[1]
Bank for International Settlements

1. Introduction

In recent years, financial markets have experienced a number of developments that have had a major impact on the way they function. The launch of the euro, the introduction of electronic trading platforms, shifts in the constellation and behaviour of market participants, and changes in relative supplies of different assets have all had a significant influence on the structure and quality of financial markets. Changes in market functioning have in turn posed challenges for central banks' policies, ranging from strategic to operational.

This paper provides an overview of how the functioning of financial markets in industrial countries has changed in recent years and analyses some of the implications of these changes. The focus is primarily on issues of concern to central banks. Its main objective is to provide an overall framework in which the specific contributions to this volume can be more easily located. In the process, it also brings together recent work carried out at the BIS bearing on the questions at hand.

The paper is structured as follows. Section 2 briefly defines market functioning, identifies the issues addressed and explains their interrelationships. Section 3 describes the main forces for change in market functioning during the last few years. Section 4 focuses on shifts in market liquidity. While central banks have always had an interest in market liquidity, the issue has become much more prominent in recent years. In particular, this section seeks to understand how recent structural developments have influenced the liquidity of different market segments, in tranquil as well as stressful conditions. Section 5 considers how structural developments may have affected pricing relationships. The focus here is on the implications for the relationship between the pricing of different instruments and the information contained in these prices. Issues addressed include what pricing relationships can tell us about the degree of integration in the euro markets, the changing information content of default-free yield curves and the pricing of credit risk. The evolving significance of liquidity premia is one of the aspects highlighted. Section 6 then turns to selected implications of these changes for central bank policy. It traces some of the implications for central bank policies on market liquidity, for the transmission mechanism, for the ability of central banks to use the information contained in asset prices as a guide to policy, and for the strategy and tactics of their domestic and foreign currency operations.

2. Market functioning: the basic concepts

As used in this paper, market functioning refers to the processes through which financial markets provide liquidity and form prices. While "market microstructure", as defined in the academic literature, focuses on the mechanics of price formation, including how prices are set to reflect new information, functioning is about the effectiveness and reliability of those mechanics.[2] Hence, a well functioning

[1] Thanks are due to Claudio Borio for helpful comments and Anna Cobau for expert statistical assistance. The views expressed in this paper are those of the authors and do not necessarily reflect the views of the BIS.

[2] This definition of market microstructure is from Dufour and Engle (2000). They further point out that the literature focuses on the problem of how market-makers learn, from observing trading activity, the information held by informed traders. A key question is to understand the price setting problem faced by intermediaries in a situation where some traders may have superior information. See also O'Hara (2001). O'Hara (1995), Madhavan (2000) and Lyons (2001) survey the literature in this area.

market may be said to be one that provides robust liquidity and in which prices serve as informative signals about fundamentals. Whether a market functions well in turn depends on how its microstructure adjusts to such things as changes in asset supplies, shifts in the constellation and behaviour of market participants, and new channels of information.

The distinction between fundamentals and liquidity is important. In general, *fundamentals* can be defined as the factors that are relevant to investment decisions but are *exogenous* to the market's microstructure. In the case of government bond markets, for instance, fundamentals would include expectations about macroeconomic developments. In the case of equity markets, the fundamentals would involve the prospective earnings of individual companies. The risk attitudes of investors are part of fundamentals too. By contrast, *liquidity*, loosely defined as the ability to execute transactions at short notice, low cost and with little impact on price, *depends on* the market's microstructure. A well functioning market would be characterised by maximal and stable liquidity. In such a market, prices would not be driven by shifts in liquidity and would entirely reflect fundamentals.[3]

Of course, this characterisation of a well functioning market is just an ideal benchmark. Liquidity services are highly valued and costly to produce. And the costs of producing them vary across market segments and over time with changing conditions. Prices, therefore, will generally incorporate a significant liquidity component. As discussed further below, in recent years that component has received increasing attention from market participants and central banks alike.

How can we tell if a market is liquid? Harris (1990) proposes four operational criteria to measure liquidity.[4] *Width*: is the price wedge between buyers and sellers (or bid-ask spread) narrow? *Depth*: are large trades executed routinely without price changes? *Immediacy*: are large trades executed promptly without price changes? *Resilience*: if prices move due to an order imbalance, do these prices return quickly to normal? Some of these criteria are relatively straightforward to measure, such as width. Others, probably the more important, are much harder to identify, notably depth. Moreover, once liquidity is allowed to vary over time, there is no assurance that markets that are liquid in tranquil conditions will retain liquidity under stress. In fact, some of the factors that increase liquidity in tranquil conditions may actually make it more vulnerable under stress and even sow the seeds of that distress (see below). This makes it all the more important to identify what factors actually promote *robust* liquidity. For, ultimately, it is robustness that market participants and policymakers care about.

Against this background the following sections explore the factors that influence market functioning and their manifestation in liquidity patterns and pricing. This is an area where our understanding is rather limited and continuously revised in the light of experience. For instance, not long ago the conventional wisdom was that relative supplies would have little impact on relative prices. The evidence in recent years has challenged that prevailing view with a vengeance. Likewise, most of the academic literature on the determinants of liquidity focuses on the implications of asymmetric information about the underlying value of the asset transacted. By contrast, in the next few pages risk management practices of financial institutions play a much more important role.

3. Developments driving changes in market functioning

Financial markets are continuously being reshaped by various forces. The period since the late 1990s has been no exception. It has witnessed a number of developments which have already had a major impact on the structure and operation of markets but whose full potential is still unclear. The most important of these developments have been the introduction of the euro, the growth of electronic trading, shifts in the constellation and behaviour of market participants, and changes in the supply of

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3 According to the above definition, a well functioning market is characterised with no reference to the accuracy of the market expectations reflected in prices. In other words, the definition says nothing about whether prices converge to their true, full information values or whether they support an efficient allocation of resources and risk. Issues of “informational efficiency” and “market efficiency” are not addressed in this paper. Strictly speaking, expectations, too, could depend on microstructure. In that case, one could think of fundamentals as the expectations that would result in a frictionless market, ie one where liquidity was maximal.

4 Muranaga and Shimizu (1999) adopt these four measures as their definition of liquidity. See also CGFS (1999a).

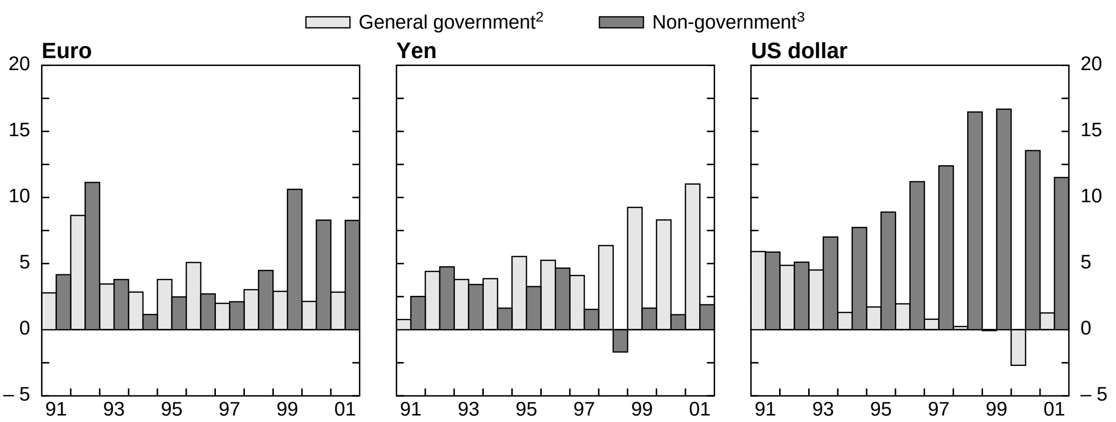
instruments. Foreign exchange markets, fixed income markets and markets in Europe have arguably been the most visibly affected. But no market has been left untouched.

The introduction of the euro

The replacement of 11 European currencies with a single currency in January 1999 had a profound impact on financial markets in the euro area, especially fixed income markets. The integration of securities markets across the euro area had begun well before the launch of the single currency, but the actual introduction of the euro greatly accelerated the process. Integrated bond and money markets emerged within a few weeks of the launch of the euro, aided by the creation of pan-European trading platforms and the harmonisation of market conventions (ECB (2001b)). Equity and repo markets were slower to break out of the segmentation that had characterised them prior to monetary union, held back by remaining differences in tax and legal systems and the absence of a common settlement system (ECB (2001a, c)). In foreign exchange markets, the euro quickly took on the role played by its predecessor currencies (Galati and Tsatsaronis (2001)).

Monetary union led many investors to adopt a euro area-wide perspective in place of a national one when deciding their portfolio allocations. Such a broadening of the investor base for euro-denominated securities enhanced the attractiveness of market-based methods of financing. This is evident from the doubling of the net issuance of debt securities by banks, corporations and other non-government borrowers in the two years following monetary union, to 9% of GDP (Graph 1). The diversity of instruments and issuers active in euro securities markets also increased appreciably over this period.

Graph 1
Net issuance of debt securities[1]
As a percentage of nominal GDP



[1] Net issuance of money market instruments and bonds in domestic and international markets. [2] Central governments, local governments and central banks. Data exclude issues by foreign governments. [3] Non-financial corporations, financial institutions, government-sponsored enterprises and supranational institutions.

Sources: Bank of England; Dealogic; Euroclear; ISMA; Thomson Financial Securities Data; national data; BIS calculations.

Electronic trading

Another potentially far-reaching development in financial markets was the establishment of electronic trading platforms as a viable, if not superior, alternative to traditional means of trading. Some markets moved towards automated order routing, trade execution and information dissemination as early as the 1980s, but it was in the late 1990s that the electronic revolution was most impressive and visible. While its adoption across different markets has been very uneven, electronic trading has influenced the functioning of all financial markets to some extent.

The foreign exchange market and derivatives exchanges were among the first to be transformed by new digital and telecommunications technologies. By 2001, up to 70% of interbank trading in the major foreign currency pairs was conducted through electronic brokers, compared to approximately 10% in 1995 (Galati (2001)). In derivatives markets, the shift in the trading of the bund futures contract from the London International Financial Futures and Options Exchange, which then still relied on open outcry, to Eurex, an electronic exchange, decisively demonstrated the advantages of electronic trading. The new technologies have now spread to money and bond markets, led by government markets, which have historically been the most actively traded segment. Equity markets too have seen electronic trading steadily displace floor trading.

Recent technological innovations are affecting the functioning of financial markets in two fundamental ways.[5] First, they are sharply reducing the costs of transacting and of obtaining information. Transactions can be executed quickly, settlement can be completely automated, and some platforms allow for automatic hedging and arbitrage through direct links with futures markets. Perhaps more importantly, dealers can instantly identify the best available price, monitor quotes continuously, and if the order book is disclosed, even construct demand or supply schedules.Second, the new electronic systems are altering the relationship between dealers and end investors. In particular, they are blurring the demarcation between the inter-dealer market and the dealer-customer market. Some electronic platforms restrict participation to dealers and thereby maintain the traditional separation. Such inter-dealer systems typically require participants to fulfil market-making obligations, and exclude corporate and institutional customers. Single-dealer platforms, in which wholesale customers transact through a single bank's trading network, also perpetuate the segmentation of markets. By contrast, multi-dealer and open systems more closely integrate the inter-dealer and dealer-customer markets. Both multi-dealer and open platforms are open to all market participants who meet minimum eligibility requirements. But whereas open systems allow all participants to post prices, multi-dealer systems permit only dealers to post prices; all other participants are price takers.

As shown in Table 1, a multiplicity of proprietary systems are currently in operation (and many others have already failed). Eventually electronic trading in fixed income and foreign exchange markets is likely to concentrate in just a few systems. However, it is not yet clear which type of platform will come to dominate. The impact of electronic trading on market functioning could well depend on which type emerges as the market favourite.

Table 1

Selected electronic trading platforms

Type of platform	Equities	Fixed income securities	Foreign exchange
Single-dealer		Autobahn (Deutsche) eXpress (JP Morgan) PrimeTrade (CSFB)	FX Trader (UBS Warburg) iFX Manager (BoNY) WebET (Goldman Sachs)
Inter-dealer		BrokerTec eSpeed EuroMTS	EBS Reuters Dealing 2000-2
Multi-dealer		Bloomberg BondTrader MarketAxess TradeWeb	Currenex FXall FX Connect
Open	Euronext Hong Kong Exchange Instinet	Eurex SWX Eurobond	

Sources: Bond Market Association (2001), Claessens et al (2001), O'Hara (2001), Rutter et al (2002).

[5] A report by the Committee on the Global Financial System (CGFS (2001a)) provides a more detailed examination of the potential impact of electronic trading on the structure, dynamics and stability of financial markets. See also Allen and Hawkins (2002) and Allen et al (2001).

Constellation and behaviour of market participants

The current shape of financial markets has also been influenced by shifts in the diversity of investors and strategies active in markets. Bank mergers, financial crises and the growth of institutional investors have affected not only the constellation of market players, but also the risk management practices and investment strategies that these players follow.

Over the past decade, there have been a large number of mergers and acquisitions in the financial services sector of most industrial countries.[6] This has affected market functioning in a variety of ways. First, there are now fewer banks that can quote two-way prices. For example, whereas in the mid-1990s there were more than 50 global players in the foreign exchange market that were able to make markets in any currency pair at any time, there are currently no more than 20 (Galati (2001)). Second, financial consolidation frequently results in a withdrawal of risk (economic) capital allocated to market-making activities. Third, consolidation can make it more difficult to diversify counterparty credit risk. Particularly in over-the-counter derivatives markets, trading is highly concentrated among a handful of dealers. For example, following the merger of Chase Manhattan and JP Morgan in 2000, the combined entity's share of the interest rate swap market equalled nearly 25% (Swaps Monitor (2000)). Likewise, mergers invariably lead to lower credit limits than the sum of the limits that customers had assigned to the unmerged entities. This increases the probability that credit limits will become binding, and so may restrain customers' trading activity.[7] Finally, consolidation may increase oligopolistic practices and the possibility of "gaming", not least in money markets.

While financial sector consolidation has reduced the number of dealers, other types of players have become more active in financial markets. In particular, institutional investors - pension funds, insurance companies, mutual funds, and other non-bank financial intermediaries - play a more prominent role today. For example, between 1995 and 2000, the total number of mutual funds in existence worldwide (excluding funds of funds) increased by 53% to 53,450, and assets under management increased by 126% to $12.2 trillion (Investment Company Institute (2001)). The euro area arguably experienced the greatest change. Bank deposits and other low-risk investments were traditionally the savings vehicle of choice in the euro area, but retail and other investors are increasingly placing their funds with professional asset managers. The result has been more diversified portfolios and a growing appetite for credit risk (BIS (2001b)).

Changes in the range of players active in markets have been accompanied by changes in risk management practices. To a large extent, these latter changes were precipitated by traumatic events, most notably the near collapse of Long-Term Capital Management (LTCM) in September 1998. In a report on the events of 1998, the Committee on the Global Financial System (CGFS (1999b)) notes that the LTCM crisis exposed the shortcomings of certain financing, trading and hedging techniques common in markets at that time. This led market participants to re-examine their risk management practices. For example, increased sensitivity to liquidity risk and to correlations across risks made market participants less willing to take directional positions in expectation of a rise or fall in a specific asset's price. The demise of global macro hedge funds in the wake of the LTCM crisis - three of the most celebrated hedge funds (LTCM, Tiger and Quantum) closed or restructured - is indicative of this change in investment philosophy (Tsatsaronis (2000a) and Graph 2). One consequence has been a reduction in the number of players likely to take a contrarian view.

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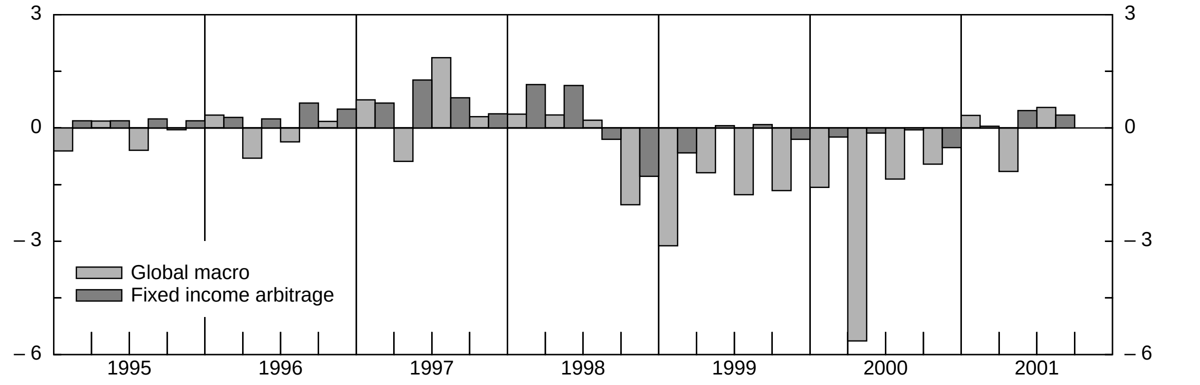
[6] A report by the finance ministry and central bank deputies of the Group of Ten (G10 (2001)) provides an exhaustive discussion of financial sector consolidation and its effects. Hawkins and Mihaljek (2001) examine financial sector consolidation in emerging economies.

[7] The eventual outcome could be the migration of over-the-counter trading to an organised exchange, where a central clearing house could act as the counterparty to all trades (McCauley (2001)).

Graph 2

Flows into hedge funds

In billions of US dollars



Source: TASS.

Other traumatic events that left a lasting imprint on market participants' risk management practices included the first ever corporate bond defaults in Japan and unexpected declines in the supply of US Treasury securities. Yaohan, a large Japanese retailer, defaulted on its publicly traded bonds in September 1997, and several Japanese banks followed suit in subsequent months. These defaults called into question the guarantees that trustees had implicitly provided in the past for yen corporate bonds (Hattori et al (2001)). Consequently, Japanese investors began to pay greater attention to the credit quality of issuers. In the US dollar market, the Treasury's announcement in February 2000 that it would auction fewer 30-year bonds and concentrate buybacks at the long end of the curve seemed to catch market participants by surprise, inducing some market stress. Episodes of this sort accelerated the substitution of private instruments for government instruments as hedging vehicles and pricing benchmarks in bond markets.Even while traumatic events have discredited some once-routine investment strategies, others have gained in popularity. Index tracking is one example. Equity, bond and other financial market indices were originally intended to summarise price changes for a broad basket of securities, ie to measure the "mood" of the market. Increasingly, indices are being used as performance benchmarks. Some portfolio managers deliberately attempt to replicate an index in its entirety. Other managers have their performance measured against an index, and so have an incentive to minimise deviations when constructing their portfolios. In their contribution to this volume, Clerc, Drumetz and Haas outline how widespread adherence to such a strategy could distort the price discovery process.

Shifts in supply

A final development of note in financial markets is shifts in the supply of available instruments. These have been especially important in fixed income markets and related segments (BIS (2001b)). Outside Japan, where it actually accelerated, net issuance of government securities slowed to its lowest level in decades by 2000. At the same time, issuance by corporations, financial institutions and other non-government borrowers soared (Graph 1). As a result, between 1995 and 2000 the outstanding stock of debt securities issued by industrial country governments fell from 45% of all debt securities issued worldwide to 35%. The types of instruments issued have also changed. US Treasury-like issues from big non-government borrowers, new securitisation vehicles such as asset-backed commercial paper, and various credit derivatives have all gained broad market acceptance.

The shift in the supply of government debt has reflected widespread fiscal consolidation, breaking a previous long-standing trend. Beginning in the 1970s, government securities markets in many industrial countries had experienced a long period of expansion. Fiscal deficits had led to the large-scale issuance of treasury bills and bonds, and government debt managers and market participants alike had grown accustomed to ever increasing supplies of government debt. In the late 1990s, government securities markets contracted fastest in Australia, Canada, Sweden, the United Kingdom, the United States and other industrial countries with fiscal surpluses. Fiscal deficits in France, Spain and other euro area countries served to maintain the size of the euro-denominated market. At the other end of the spectrum, large deficits in Japan produced the world's biggest government bond market. The global economic slowdown in 2001 undermined the fiscal position of many governments, but they remain committed to keeping their deficits low.

In contrast to government issuance, bond issuance by non-government entities rose to record levels. The non-US Treasury segment of the US dollar market nearly doubled in size between 1995 and 2000, to $13.2 trillion. Euro-denominated issuance by non-government entities rose noticeably following the introduction of the euro. Even the outstanding stock of yen-denominated non-government securities expanded modestly in the late 1990s.

To the extent that government borrowing "crowds out" private borrowing, the falling supply of government bonds may have contributed to the strong growth of non-government markets. This seems to have been the case at least in the United States (BIS (2001b)) and, as noted in the accompanying paper by Edey and Ellis, in Australia. Indeed, in the US dollar and euro markets, big European, US and supranational borrowers have competed to provide liquid assets that could play some of the roles traditionally performed by government securities, notably as hedging instruments and pricing benchmarks. A key question going forward is how smoothly private debt markets will take over the broad set of functions previously performed by government securities, including that of safe haven at times of stress.

The growth of non-government markets may also have been assisted by the development of markets for transferring credit risk, in particular the credit derivatives market. Credit derivatives allow credit risk to be unbundled from other risks, traded in standardised markets and rebundled into new products that better meet the needs of investors (Rule (2001)). The credit derivatives market, which only came into existence in the early 1990s, had expanded to $694 billion in terms of notional principal by end-June 2001 (BIS (2001b)). It remains much smaller than other derivatives markets: for example, the over-the-counter market for interest rate derivatives stood at $76 trillion in notional terms at end-June 2001. Nevertheless, credit derivatives have the potential to become a benchmark for pure credit risk and as such are increasingly driving the pricing of credit risk in financial markets. In turn, their growth has been part of the broader trend towards heightened awareness of credit risk in the emerging environment as well as reflecting efforts to economise on regulatory capital.

4. Implications for market liquidity

Against the background of the structural changes just outlined, two questions loom large. First, how have these changes affected market liquidity in various market segments? Second, if liquidity has been shifting, can we draw lessons about its robustness? In particular, could liquidity be adequate in good times but have become more vulnerable under stress (the so-called "fair-weather hypothesis")?

How has liquidity been shifting?

For the reasons explained in Section 3, measuring liquidity is not straightforward. Even so, an examination of various indicators would suggest that, *at least as measured in tranquil times*, since the Asian and LTCM crises, liquidity has indeed been evolving in various market segments. In particular, with the exception of some emerging market currencies (Galati (2000)), liquidity does not appear to have changed much in foreign exchange markets. By contrast, it seems to have declined in the US government bond market and, on balance, to have risen in segments of the euro government bond market. Generally, swap markets appear to have gained in liquidity.

For foreign exchange markets, indirect measures of liquidity provide mixed evidence. The latest triennial survey of foreign exchange and derivatives market activity shows that global turnover declined markedly between 1998 and 2001 (Table 2). This is the first time that trading volumes have fallen since the first comprehensive survey was conducted in 1989. In addition, in their contribution to this volume, Chaboud and Weinberg present evidence that exchange rate volatility measured at very high frequency has increased in recent years. At first glance, these developments might imply that markets have become less liquid. However, according to market commentary, bid-ask spreads in foreign exchange markets have remained tight over the last few years, suggesting no change in liquidity (Galati (2001)).

Table 2

Global foreign exchange market turnover[1]

Daily averages in April, in billions of US dollars

Instrument	1989	1992	1995	1998	2001
Spot transactions	317	394	494	568	387
Outright forwards	27	58	97	128	131
Foreign exchange swaps	190	324	546	734	656
Estimated gaps in reporting	56	44	53	60	36
Total "traditional" turnover	**590**	**820**	**1,190**	**1,490**	**1,210**
Memo: Turnover at April 2001 exchange rates[2]	570	750	990	1,400	1,200

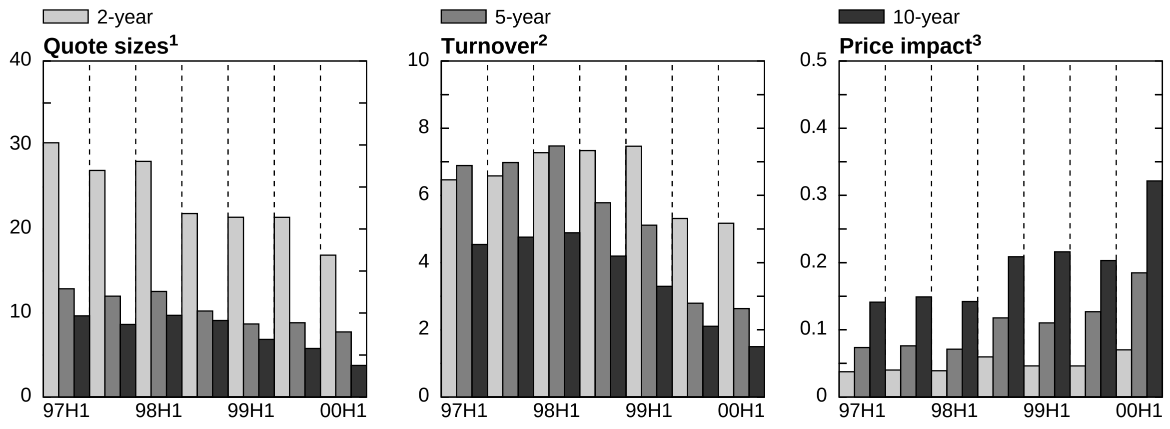
[1] Adjusted for local and cross-border double-counting. [2] Non-US dollar legs of foreign currency transactions were converted into original currency amounts at average exchange rates for April of each survey year and then reconverted into US dollar amounts at average April 2001 exchange rates.

Source: BIS (2002).

Among fixed income markets, there is evidence of a decline in liquidity in the US Treasury market. In particular, Fleming (2001) shows that in the inter-dealer segment of the US Treasury market quote sizes for two-year, five-year and 10-year notes began to decline in the second half of 1998 (Graph 3). Turnover in the cash market also slowed down. More importantly, the impact of a given trade on prices became stronger. Similar trends are present in the Treasury futures market. The picture in Australia is more mixed. In their accompanying paper, Edey and Ellis find that liquidity in the cash market has deteriorated, but liquidity in the futures market has improved, so overall liquidity in the Australian government securities market is more or less unchanged. In Japan, liquidity in the JGB market appears to have remained essentially unchanged too (BIS (2001b)).

Graph 3

Liquidity of US Treasury securities



[1] Average quantity of securities bid or offered during the period, in millions of US dollars. [2] Average daily turnover, in billions of US dollars. [3] Basis points per trade.

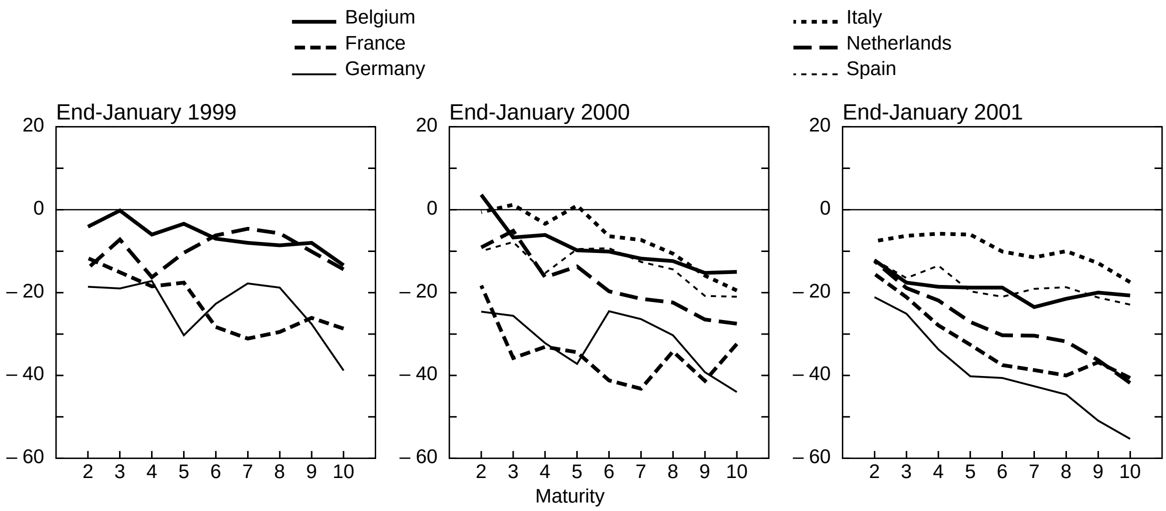
Source: Fleming (2001), based on GovPX data.

By contrast, in the euro area the evidence points to a rise in liquidity in certain segments. In an apparent anticipation of the single currency in Europe, turnover on German bund futures began to surge before 1999 and, as discussed in the paper by Schulte and Violi, the contract has since become the most actively traded derivative in the world. Likewise, yield curves for government bonds have become smoother over time. In 1999, these yield curves tended to be jagged in shape and should have invited arbitrage activity between maturities had there been enough liquidity (Graph 4). By January 2001, most of these curves were smooth so as to suggest that there was enough liquidity to allow the trading that would eliminate arbitrage opportunities. In his contribution to the volume, Blanco finds that among euro area government securities markets, the German market has benefited the most from the improvements in liquidity brought about by the euro. French government bonds were more liquid at maturities of less than 10 years in the months following monetary union, but by 2001 German bonds had established themselves as the most liquid in all maturity ranges.

Graph 4

Euro area government bond yields

Spreads over swap rates, in basis points



Sources: Bloomberg; Datastream; BIS calculations.

What determines market liquidity in normal times?

What factors may account for the observed changes in liquidity patterns? Consider in turn changes in relative supplies, changes in risk management, shifts in the population of market participants, notably through financial consolidation, and the spread of electronic trading platforms.

The previous picture is generally consistent with the view that, ceteris paribus, size, and hence *changes in relative supplies*, matters (McCauley and Remolona (2000)).[8] Developments in the United States and the euro area support this conclusion. Likewise, while so far liquidity in the Australian market does not appear to have declined overall, Edey and Ellis note that the government is committed to maintaining a critical amount of debt outstanding, regardless of the fiscal position. At the same time, the stable liquidity conditions in the Japanese market are a reminder that other structural factors are important too. Moreover, even in the US Treasury market, trading activity seems to have picked up, and liquidity indicators to have improved, during 2001 as the size of the market continued to contract.

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[8] Like liquidity, market size has several dimensions. McCauley and Remolona (2000) discuss the relevance of various measures of size for liquidity.

Changes in risk management practices have been highlighted as a potentially important factor leading to a reduction in liquidity. In particular, institutions appear to have withdrawn some of the capital devoted to market-making and own trading activities (CGFS (2001b)). This in turn seems to have reflected several factors, including a keener appreciation of risk/return trade-offs, shareholders' distaste for the high volatility of the earnings associated with these activities, and the traumatic experience of the market turbulence of 1998. In addition, the introduction of electronic trading platforms may also have played a role (see below). At the same time, the absence of a *generalised* evidence of a decline in liquidity points to two considerations. First, the withdrawal of market-making capacity has probably been uneven. Independent evidence, for instance, suggests that it may have been more significant in the US Treasury market, as indicated by the withdrawal of a large market-maker in the first half of 1998. Second, and more importantly, the implications of withdrawal of market-making capacity may become more apparent under stress, when prices move outside normal ranges.

Changes in the constellation of market participants may also have contributed to a reduction in liquidity, as already anticipated in Section 3. For one, the changing characteristics of the surviving hedge fund population have arguably reduced the amount of quasi-liquidity services that these players supply, at least in tranquil conditions, by standing prepared to take the other side of transactions through their own trading.[9] In addition, financial consolidation may have led to a further withdrawal of liquidity services. Consolidation has reduced the number of independent market-makers, reportedly contributing to the withdrawal of risk capital from market-making and trading, and led to a reduction of aggregate counterparty credit limits. Indeed, as highlighted by D'Souza and Lai in their analytical contribution, there are good reasons to believe that bank consolidation could lead to such a withdrawal of capital, although this result is by no means necessary. Here again, however, the impact of consolidation may be more apparent under stress conditions.

The effect of *new electronic trading platforms* on liquidity is an unresolved question. On the one hand, through their greater efficiency and cost-effectiveness, these platforms can increase participation in markets and reduce transaction costs. This could help to improve market liquidity, especially market tightness. On the other hand, by reducing the informational advantage traditionally enjoyed by dealers, these systems could reduce their incentive to make markets. In particular, in over-the-counter markets, dealers were traditionally better informed than customers, and so price discovery took place in the inter-dealer segment. The spreading of electronic broking systems in these markets can enable a broader set of participants to know instantly the best prices available at any point in time. As a result, market-making could become less profitable and attractive. Market depth could suffer even as tightness improved. The effects of these changes, however, might become visible only under stress.

How does market liquidity behave under stress?

As the previous discussion suggests, the concerns expressed in recent years that changes in financial markets may have made liquidity adequate in good times but more vulnerable in bad times have largely been based on two arguments. The first has stressed the shift from quote-driven to order-driven markets and, in addition, the potential decline in the profits of dealers which have gone hand in hand with the spreading of electronic trading platforms. The second has stressed a broader constellation of factors, with particular emphasis on risk management practices.

The first argument notes that market depth is likely to be greater in quote-driven markets because of the presence of market-makers whose role is precisely to quote two-way prices and iron out order imbalances. By contrast, in order-driven markets liquidity provision is more diffused, deriving from the limit orders entered into a centralised system. In systems where no participant has either an obligation or an incentive to make markets, the availability of liquidity will then depend on whether well informed and well capitalised investors can be expected to take the other side in an incipiently one-sided market. Moreover, to the extent that the introduction of electronic platforms undermines, directly and indirectly, the returns from market-making, it could reduce the incentive to provide liquidity services, especially under stress.

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9 Such quasi-liquidity services could be provided either as part of their "contrarian" position-taking or, more specifically, through systematic "liquidity" arbitrage, taking offsetting positions in securities of similar characteristics except for their liquidity. Note, in addition, that in foreign exchange markets, carry trades were very common in the run-up to the Asian crisis. In this case, of course, liquidity was ultimately provided by the monetary authorities' defence of the peg.

It is still unclear, however, how far these concerns are justified. The accompanying paper by Jiang, Tang and Law examines trading activity on the Hong Kong Futures Exchange before and after the migration to an electronic order matching system. They find that the electronic system has provided better liquidity during normal times, but that, at least relative to floor trading, the performance of the system has deteriorated during periods of high volatility or large volumes. More generally, analysis of the experience during the 1987 stock market crash proved inconclusive on this issue (OECD (1989)). One reason for this is that it is unreasonable to expect market-makers to continue to maintain market depth even in the presence of major imbalances, when their capital would be most at risk. Similarly, a recent CGFS study on electronic trading concluded that, while deserving close monitoring as they continue to evolve, electronic platforms had successfully coped with a number episodes of sharp price adjustments (CGFS (2001a)). Finally, it could also be argued that in quote-driven decentralised markets liquidity may in fact be *more* vulnerable, to the extent that it depends crucially on the financial strength of the main liquidity providers (Borio (2000)). Other things equal, this vulnerability is more of a concern if market-making is highly concentrated. In 1990, the consequences of the demise of Drexel Burnham Lambert, the key market-maker in the high-yield segment, illustrated most vividly the risks of concentration.

The second argument emphasises that the determinants of liquidity under stress are rather different from those in normal times (Borio (2000)). In particular, at times of stress concerns with counterparty risk and funding liquidity constraints, including those arising from the management of collateral, become much more binding than in tranquil times. Likewise, other risk management limits, such as value-at-risk constraints and stop-loss mechanisms, bite more strongly. The mutually reinforcing nature of these factors can, in extreme circumstances, lead to the complete evaporation of liquidity, as trading grinds to a halt amid higher volatility (Breedon (2001)). As in traditional bank liquidity crises, actions that may appear reasonable from the viewpoint of individual institutions exacerbate the perverse price and liquidity dynamics. According to this view, the state of liquidity in good times carries little information about its behaviour under duress. Indeed, ample market liquidity in a tranquil period may actually signal heightened vulnerabilities. This is so if it is accompanied by overextension in balance sheets. In this case, abundant liquidity would be a form of liquidity illusion, ie a symptom of market participants' excessive appetite for risk and of their underestimation of the build-up of risk in the system. It is precisely this overextension that provides the necessary wood for the fire.

Experience with episodes of market stress confirms the relevance of these factors. They were in evidence during the 1987 stock market crash and again during the 1994 bond market crash (Borio and McCauley (1996)). More recently, they were clearly at play during the 1998 market turbulence, which affected especially US fixed income markets (CGFS (1999b, 2001c)). So far, however, rigorous econometric analysis of the recent episode has been very limited. And most of it has been carried out by researchers in the central banking community, not least since the academic literature has only begun to come to grips with the analysis of perverse market dynamics under stress (Genotte and Leland (1990), Morris and Shin (2000), Danielsson et al (2001)). Data limitations have been a severe constraint.

On the basis of this recent work, some of the features of the 1998 turbulence are becoming clearer. In their contribution to this volume, Upper and Werner conclude that during the October 1998 crisis the German bund futures market on Eurex proved rather robust to extreme volatility.[10] Trading costs did rise, but the pricing relationship between the futures and spot market remained comparatively stable, at least with respect to the underlying that was cheapest to deliver. The relationship did break down, however, with other bonds, including the on-the-run issue. The accompanying paper by Cohen and Shin finds that during the 1998 market turbulence positive-feedback trading in the US Treasury market became more pronounced. Moreover, Furfine and Remolona (2002) show that dealers scaled back their quote sizes asymmetrically, with ask sizes being reduced more than bid sizes, and that they relied more on negotiated trade sizes (“work-ups”) (Table 3). As trade frequency increased, overall volumes actually rose, a sign that the market did not freeze altogether.

[10] See also Upper (2001).

Table 3

Liquidity under stress

Daily market averages for the 5-year on-the-run US Treasury note

	May-Dec full sample	Stress days I[3]	Stress days II[3]	Stress days III[3]	Stress days IV[3]
Number of transactions	662	786	887	745	738
Number of hit transactions	342	406	462	379	370
Number of take transactions	320	380	425	366	368
Dollar volume[1]	6,740	8,283	9,399	7,241	7,484
Hit volume[1]	3,374	4,142	4,697	3,619	3,765
Take volume[1]	3,366	4,141	4,701	3,623	3,719
Inter transaction times[2]	56.8	51.2	38.6	47.8	47.9
Ask depth[1]	9.84	9.20	9.22	7.55	8.07
Bid depth[1]	9.53	8.66	8.22	7.49	7.77

[1] In millions of US dollars. [2] Measured in seconds between transactions. [3] Stress days I are based on the Johnson-Lowenstein events, stress days II on the Kho-Lee-Stulz exposed bank stock returns, stress days III on the Reinhart-Sack credit spreads, and stress days IV on increases in swap yields.

Sources: Furfine and Remolona (2002), based on GovPX data.

Some changes in risk management practices since the market turbulence of the autumn 1998 suggest that national authorities and market participants are beginning to address a number of the shortcomings that exacerbated the stress. Examples include improved counterparty risk assessment as well as collateral and liquidity management, including through greater reliance on stress testing (CRMPG (1999)). Moreover, there is some evidence that institutions have become more aware of the risks of automatic reliance on limits that arise from the interdependence among market participants (CGFS (2001d)). Even so, the ultimate causes of the evaporation of liquidity under stress are exceedingly hard to address (see below).

Looking forward, a related and yet unanswered question concerns the characteristics of a flight to quality under stress in a world in which government securities could become scarce (BIS (2001b), Schinasi et al (2001)). The question is pertinent given the declining supplies of some government securities. The dynamics of the flight to quality would be likely to depend on the particular assets that investors choose to move into. These dynamics would also be likely to change if collateral no longer took the form of a default-free asset. At the same time, Wojnilower (2000) suggests that the absence of such an asset would reduce the willingness of investors to bear risk even during normal times.

5. Implications for asset pricing

Three questions concerning the implications of recent changes in market functioning for asset pricing merit particular attention. First, what has been the impact of changes in market segmentation and integration? The effects brought about by the creation of the euro are especially important. Second, how has the information about fundamentals reflected in asset prices changed? Of particular interest here is how well yield curves in various fixed income markets reflect expectations about macroeconomic fundamentals, notably facilitating the identification of the evolution of expected future rates and estimates of the default-risk free rate. Finally, given the new prominence of credit risk, which markets are best informed about this risk? The consistency of the information derived from different prices is especially relevant.

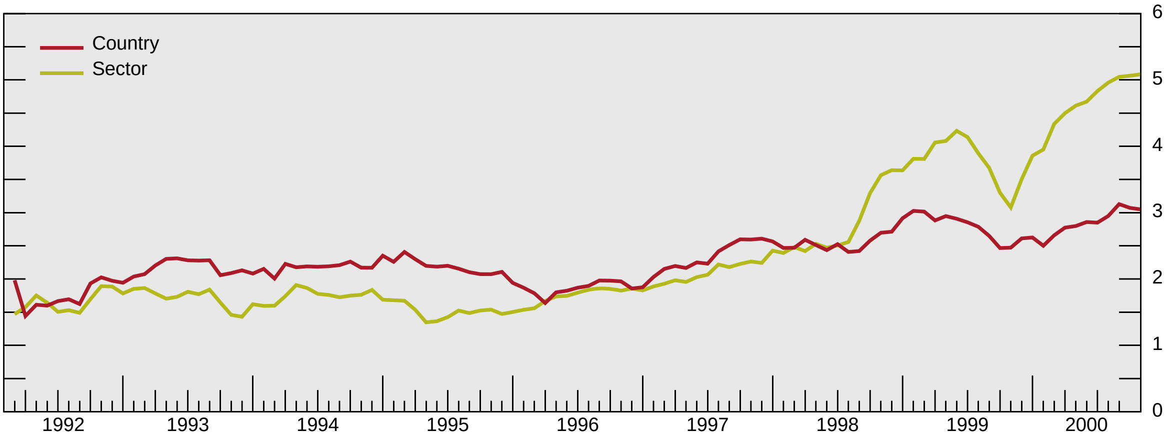
What can prices tell us about market integration and segmentation?

A key question since the establishment of the euro has been to what extent the introduction of the new currency has promoted the integration of different market segments. Pricing relationships can be used to cast light on this issue. In a fully integrated market, instruments with the same characteristics should command the same price.

As regards the equity market, the accompanying paper by Emiris finds that the degree of integration had already been increasing before the introduction of the single currency. Tsatsaronis (2001) and Galati and Tsatsaronis (2001) show that the process accelerated measurably following the advent of the euro, with sectoral factors superseding country factors in determining pricing (Graph 5). At the same time, there is evidence that, at least qualitatively, this trend has affected equity markets more globally in recent years.

Graph 5

Changes in the relative importance of country and sector factors in the determination of equity prices



Source: Tsatsaronis (2001).

The impact of the creation of the euro on fixed income markets has been more profound. Even so, a number of papers stress that the integration of fixed income markets in the government segment has been less than complete. In fact, since the introduction of the new currency, spreads across bonds issued in different countries have actually widened. While credit factors may still play a role, differences in liquidity appear to be more important, as indicated most clearly by the fact that the yields cross at different maturities (Galati and Tsatsaronis (2001)). As a result, a fully reliable government yield curve has not as yet taken shape. Blanco as well as Schulte and Violi examine these issues in detail in their contributions to this volume, looking also at the various factors that may impede full integration, and considering both cash and futures markets. An additional unsatisfactory aspect stressed in both contributions is the comparatively high potential for squeezes, not least owing to the large size of the futures relative to the cash market. This is still an unresolved issue.

How well do various yield curves reflect macroeconomic expectations?

Traditionally, government bond markets have reflected mainly public information, especially about macroeconomic developments and monetary policy actions. In contrast, equity markets have been more indicative of the earnings prospects of individual companies. Hence, government bond markets have had a comparative advantage in revealing expectations about macroeconomic fundamentals, while equity markets have had such an advantage in providing information about individual companies. In recent years, shifts in liquidity and changes in the mix of asset supplies may have altered the process by which these markets impound information and the way markets respond to price signals from other markets.

One way of identifying what information is reflected in asset prices is to examine how they respond to news. Other things equal, the stronger and more consistent the response to a particular type of information, the more likely it is that that information is reflected in the price.

In the past few decades, yield curves based on government securities were widely recognised as the pre-eminent benchmark for the cost of funds at different borrowing horizons. In industrial countries, price discovery about macroeconomic prospects occurred mainly in government securities markets rather than in equity markets. Thus, Fleming and Remolona (1999a, b)) show that prices in the US Treasury market were largely driven by macroeconomic announcements and monetary policy actions.[11] Fair (2001) found that only a small fraction of the large changes in US stock prices were due to such macroeconomic announcements. As a result of the information reflected in the yield curve, Estrella and Mishkin (1998) were able to conclude that for predicting US recessions over horizons beyond one quarter, the slope of the US yield curve was the clear choice over other variables, including stock prices. Similar evidence was found for other countries too (Bernard and Gerlach (1996)). The existence of such a yield curve made it convenient to compare yields on instruments with different credit risks at a given maturity, and hence bonds issued by corporations, financial institutions and other non-government borrowers tended to be priced against this curve.

Admittedly, the usefulness of the yield curve has varied from one government bond market to another. The Swedish market, for example, seems to have behaved in a similar way to the US market. The accompanying paper by Andersson, Dillén and Sellin finds that in the Swedish market monetary policy signals play a key role along the yield curve. The Swiss market may have been different. In his contribution to this volume, Büttler fits a three-factor model of the term structure to yields in the Swiss government bond market and finds that the implied term structures for real short rates and inflation rates are hard to explain. But overall, the key role played by government yield curves in providing information about macroeconomic fundamentals was not generally challenged.

In recent years, however, some of the largest government securities markets have begun to lose their pre-eminence as the centres for price discovery about macroeconomic fundamentals. In particular, owing to the deterioration in liquidity in the US Treasury market, changes in issuance or buyback plans and unexpected safe haven flows have introduced idiosyncratic shocks. Because of the interference of these shocks, Reinhart and Sack find that yields in this market have become less informative about the risk-free rate. As a consequence, a search for alternative benchmarks is under way, with a range of non-government instruments being considered as potential candidates (Wooldridge (2001)).

In the search for alternative benchmarks, attention has been focused on the debt instruments of government-sponsored enterprises (GSEs) and on interest rate swaps. The bonds of GSEs such as Fannie Mae and Freddie Mac in the United States, or of similar institutions elsewhere, such as Kreditanstalt für Wiederaufbau in Germany, have high credit ratings and are relatively liquid. Some GSEs have seized the opportunity to provide benchmarks by issuing large amounts of debt at regular intervals across a range of maturities. Interest rate swaps are another possible alternative, especially with the decline in concerns about the credit risk of the dealers. Nonetheless, neither agencies nor swaps have so far been as successful as the government bond markets had been in providing meaningful yield curves. For example, in their contribution Reinhart and Sack also note that the information about fundamentals contained in agency and swap yields remains difficult to interpret, owing to the combined effect of different influences. They also suggest that information can best be gleaned if the movements of different yields are assessed jointly, by imposing identifying restrictions on the factors that they are supposed to reflect.

Looking forward, McCauley (2001) points to certain factors that would help swaps become the new pricing benchmark. First, new swaps of a given maturity are traded every day, so their maturity is constant from day to day, unlike the yield on an on-the-run agency bond. Second, new swap rates are quoted at par and are therefore not affected by the tax and accounting effects that influence secondary market prices for bonds. Admittedly, since they are unsecured interbank rates, swap rates

[11] For an update of this study, see Furfine (2001).

remain susceptible to changes in the credit quality of banks. Nevertheless, it appears that the use of swap rates as a pricing benchmark will probably continue to grow over time. This process appears to be furthest advanced in the euro market, where the interest rate swap curve has already emerged as the benchmark yield curve (BIS (2001b)). Even so, in his contribution Blanco suggests that in Europe the government yield curve might still continue to be more reliable as a source of information for macroeconomic fundamentals.

Which markets are best informed about credit risk?

The remarkable shift in the issuance of debt securities from government to private sector borrowers has gone hand in hand with greater attention being paid to the pricing of credit risk. The two most significant developments in this regard have been the growth of credit derivatives and the use of an approach to measuring credit risk that relies on information from stock prices. At the same time, credit derivatives, corporate bonds and stock prices do not seem to provide entirely consistent signals. The issue this raises in the short term is which market provides the most reliable signals. The longer-term issue is how price formation about credit risk is likely to evolve.

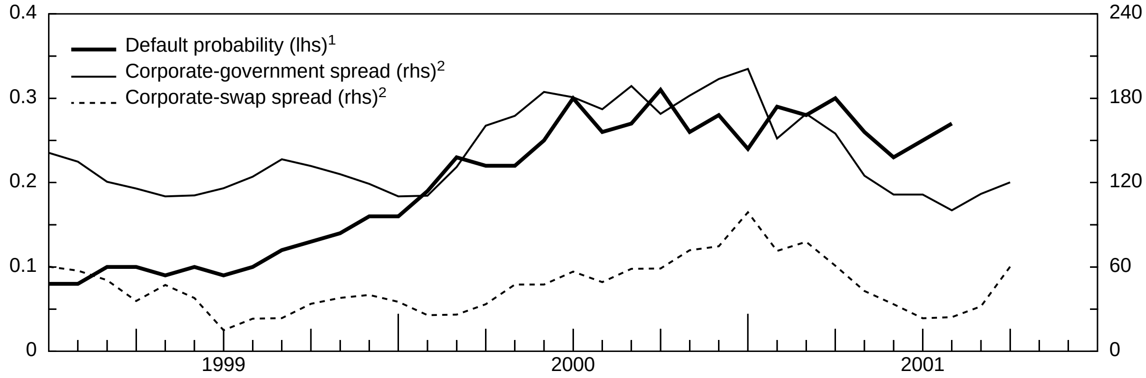
Before the introduction of credit derivatives, it was difficult to isolate credit risk from other factors, in particular from liquidity risk. In principle, credit derivatives facilitate the decomposition of corporate spreads into their various risks and give concrete form to the term structure of credit risk. They thereby allow price differences among similar securities to be exploited more efficiently. While credit derivatives themselves may have credit or liquidity premia, they have the potential to become a benchmark for pure credit risk. As such, they may increasingly drive the pricing of this risk. The accompanying paper by Marsh compares the default probabilities implied by spreads on corporate bonds with those implied by default swaps and finds significant differences. He attributes the differences partly to liquidity factors. In their contribution, Boss and Scheicher find that credit spreads in the euro area are driven by idiosyncratic factors as well as by macroeconomic factors that are reflected in German government bonds.

One of the notable developments in fixed income markets in 1999 and 2000 was the apparent emergence of a new link between credit and equity markets (BIS (2000), Cohen (2000)). In particular, credit spreads tended to widen in the wake of price declines and increases in volatility in equity markets. This phenomenon seems to have stemmed at least in part from an increasingly widespread use by fixed income dealers and institutional investors of an option-based approach to the estimation of credit risk. The approach, first proposed by Robert Merton in 1973 but only widely applied in recent years, derives a firm’s default likelihood from the market value and volatility of its equity and its leverage. The approach relies on the idea that information about a firm’s prospects would be reflected first in the stock market. Trends in 2000 and early 2001 in stock and corporate bond markets were roughly consistent with such an approach.

At the same time, whatever the influence of the new methods, the estimates of credit risk gleaned from movements in equity prices and credit spreads have not always been consistent. This was clearly evident, for instance, as 2001 progressed (BIS (2001a) and Graph 6). While equity prices fell markedly, credit spreads narrowed, resulting in divergent movements in the implied estimates of probabilities of default. As various methods for measuring credit risk become increasingly widespread and are incorporated into prudential standards, notably minimum capital requirements, differences in the messages derived from various market instruments will no doubt deserve greater attention.

Graph 6

Implied probability of default and corporate bond spreads
A-rated US companies



[1] In percentages; derived from a Merton-type methodology (KMV). [2] In basis points.
Sources: Bloomberg; Merrill Lynch; KMV.

6. Implications for central bank policies

The changes in market functioning analysed in the previous sections raise a number of issues for central bank policies. One set of issues relates to the appropriate role that central banks should play in fostering well functioning markets, in particular in promoting robust *market liquidity*. Questions arise regarding both the prevention of market liquidity breakdowns and the response to episodes of stress. A second set of issues includes strategic and tactical aspects of monetary policy setting, such as the implications for the *transmission mechanism*, for the use of the *information* contained in asset prices as a guide to policy and for central banks' *communication* with the markets. A third set concerns central bank market *operations*, including domestic liquidity management operations, FX reserves management and foreign exchange intervention.

Market liquidity

Central banks have traditionally had a keen interest in promoting *robust* liquidity in financial markets. This has been predicated on the belief that liquid markets can facilitate their operations, improve the transmission mechanism of monetary policy impulses, make it easier to read market participants' expectations and contribute to financial stability. The range of instruments employed is very broad. It includes, inter alia, furthering the understanding of the determinants of market liquidity, encouraging or adopting improvements in financial infrastructure (eg trading platforms, clearing and settlement arrangements), advising or managing the government's debt management operations, and the choice of operating procedures (eg eligible collateral, choice of counterparties). This has largely been done at the national level but, increasingly, at the international level too. In this regard, the activities of the Committee on the Global Financial System are noteworthy (eg CGFS (1999c)).[12]

The contribution from Marès considers in more detail public policy towards market liquidity and the role of central banks. Marès stresses, in particular, the need for a comprehensive cost-benefit analysis. In addition, the analysis of liquidity under stress in the previous section suggests that ensuring robust liquidity is an exceedingly difficult task. Moreover, it requires the activation of instruments well beyond

12 An additional channel through which central banks can promote liquidity is through their influence on debt management operations by the government. However, in recent years there has been a tendency for this influence to become weaker, as responsibilities in this area have increasingly shifted to governments.

the control of central banks. Given the importance of risk management practices, prudential authorities have a key role to play too. Two major, interrelated difficulties deserve attention (Borio (2000), Crockett (2001)). The first, as highlighted by Marès too, is that market liquidity tends to be procyclical with respect to financial market conditions. Its price is low in good times and can rise dramatically under stress. This tends to reinforce, rather than dampen, cycles in liquidity conditions. The second is that actions that may appear reasonable from the perspective of individual institutions may actually exacerbate the vulnerability of liquidity conditions. Generalised retrenchment at times of stress is an obvious case in point. This problem is entirely analogous to the broader one of the procyclicality of the financial system and prudential regulation generally (Borio et al (2001), Crockett (2000)). Addressing it involves better information, in the form of leading indicators of financial market stress, and better safeguards, in the form of safety cushions that can be built up in good times to be run down in bad times. These problems have only begun to be tackled.[13]

A separate, but just as difficult, question concerns the appropriate role of central banks in responding to episodes of stress in market liquidity, which would normally be associated with broader stress in markets. There is of course a consensus that central banks should facilitate the smooth functioning of markets. This is especially uncontroversial when the origin of the disturbances is clearly exogenous to the behaviour of participants, such as in the case of Y2K or of the terrorist attacks of 11 September 2001, which heavily disrupted normal market functioning. At the same time, in intervening central banks need to be quite conscious of the potential “collateral damage” in terms of moral hazard that may be associated with their actions (Crockett (2001)). Damage may arise not only, or indeed primarily, from the provision of emergency liquidity assistance but, more insidiously perhaps, from reductions in interest rates aimed at relieving pressure on markets. Making such a decision implicitly involves a judgment about the damage for the “real” economy inflicted by market malfunctioning.[14] Central banks may position themselves differently along the spectrum of possible policy responses.

One factor influencing this choice will no doubt be which market is affected by the evaporation of liquidity. In general, central banks would care strongly about those markets that are critical for the implementation of policy; their paralysis could cripple the central bank’s armoury. The interbank market for bank reserves is a clear case in point. Markets whose functioning is critical for the economy would also rank high. Their identity, however, would depend on the characteristics of a country’s financial structure, including its connecting tissue with the rest of the world, and may even vary with circumstances. For example, the size and functions of the swaps market differ considerably across countries. Likewise, developments in the equity market may be relatively unimportant against the background of robust economic conditions, but could become pivotal if the economy was already fragile.

The transmission mechanism

The significance of the changes in market functioning for the transmission mechanism is not straightforward to identify or quantify. There is indeed some general evidence that the transmission mechanism may have been changing. For the United States, for instance, this has recently been documented by Barth and Ramey (2001) and Hanson (2000). Likewise, following the creation of the euro area, a network of central bank economists was formed to coordinate research on the transmission mechanism in the new currency area, culminating in a conference at the ECB in December 2001. Moreover, previous work has shown how financial structure can have significant implications for how monetary impulses are transmitted to the real economy (BIS (1995)). Even so, the marginal contribution of the changes in market functioning discussed above remains an open issue.

Kuttner and Mosser partly fill this gap. In their accompanying review of research concerning the impact of financial innovation on the monetary transmission mechanism, they conclude that financial

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13 Indicators of financial market stress would most likely have to be based on the aggregation of risk management information from individual firms’ risk management systems. A first step to consider this question has been taken by the CGFS, with reference to the possible aggregation of stress tests (CGFS (2000, 2001d)).

14 Other factors would be relevant too. One issue, for instance, is the risk of misinterpretation of the authorities' intention. For instance, even if exclusively interested in the consequences for the real economy, the central bank may be perceived to react to market illiquidity per se. The economic background against which the action is taken, such as whether the economy is already deteriorating for other, more fundamental reasons, could affect the choice.

innovation has left the transmission mechanism unchanged in certain areas, even while the overall impact remains uncertain. Looking to the future, Clerc, Drumetz and Haas provocatively ask whether by improving hedging possibilities, the development of credit derivatives might not help insulate the economy from changes in policy interest rates, dampening their effect. This general issue, in fact, is not new. It was already raised in the past with respect to the development of instruments for the hedging of interest rate and exchange rate risks (Euro-currency Standing Committee (1994)) and has been subject to some empirical analysis (Fender (2000a, b)). But the answer still remains unclear.

Economic developments in Japan, however, remind us that some "old" questions related to the transmission of monetary policy remain. Namely, how does a central bank which uses an interest rate as a policy tool conduct policy when interest rates reach their zero lower bound, and how can a central bank most efficiently increase economy-wide liquidity when banks stop lending? In March 2001, the Bank of Japan switched its operating target from an overnight interbank interest rate to the average outstanding balance of current accounts at the Bank of Japan. The new policy seems to have had a more pervasive effect across the JGB term structure, while the narrowing of credit spreads as bond yields decline may be indicative of a search for higher returns induced by the more expansionary stance (Marumo et al (2002)).

Indeed, one might well ask whether this latter effect might not in fact be a distinguishing feature of the new landscape more generally. Specifically, in the new environment financial institutions have become much more conscious about the management of risk, notably credit risk, and default-free government debt may be losing its pricing benchmark role. If so, perceptions of risk, attitudes towards risk and the ability to take on risk may have become more important in driving economic activity (Borio et al (2001)). Consequently, measuring these factors and the impact of monetary policy actions on their evolution should receive more attention.[15] Arguably, for instance, the link was evident in the swift response of financial markets to the reduction in interest rates by the US Federal Reserve following the financial turmoil associated with the difficulties at LTCM. Likewise, while the Fed's monetary easing in 2001 may have failed to boost equities, lower the dollar or ease Treasury yields much, it did appear to encourage demand for high-yield bonds, tightening spreads and unlocking issuance (BIS (2001a)).

Information from and to markets

In contrast to the implications for the transmission mechanism, those for the information content of asset prices are much more apparent. At least two of these implications can be highlighted. First, the development of new markets, such as those for credit derivatives, and the broadening and deepening of existing ones, such as those for corporate debt, have increased the range of possible sources of information. This has been further facilitated by the spreading of new methodologies for the assessment of risk, such as Merton-type methodologies to derive estimates of default probabilities from equity prices. Second, several developments have actually clouded the information content of traditional indicators, such as term structures of interest rates based on government debt instruments. Changes in relative supplies, shifting liquidity patterns, and the initial difficulties in forming an integrated bond market in the euro area have all contributed here. Moreover, the increased range of information per se at times appears to result in conflicting signals.

This has put central banks in a rather paradoxical situation: they have a broader spectrum of potential information from which to draw but face greater difficulties in interpreting it. A symptom of these difficulties is that two papers in the volume - Reinhart and Sack and Clerc, Drumetz and Haas - reach different conclusions regarding whether government bonds or swaps may now be more reliable indicators of expectations about the future course of risk free rates. A key issue is whether the difficulties faced are just transitional or whether they are likely to persist for the foreseeable future. Looking forward, the most promising area for further development arguably relates to the leading indicator properties of credit risk signals. If the previous argument about the role of risk perceptions in driving economic fluctuations is correct, then the value of the information contained in these signals is likely to increase. Empirical evidence from the United States appears to be consistent with this

15 See, for instance, BIS (1999) and Tsatsaronis (2000b) for an attempt to measure risk appetite and a possible link with monetary conditions.

proposition (Gertler and Lown (2000)).[16] Such indicators are also potentially very useful for central banks in terms of their responsibilities for financial stability.

Regardless of the information that central banks can *receive* from the markets, there seems to be a broad consensus that the greater role that financial markets now play in influencing economic activity puts a premium on the information that central banks should *provide* to them. In recent years, central banks have become increasingly transparent. For instance, inflation targeting regimes make very high demands on transparency, as discussed in the contribution by Bogdanski, de Freitas, Goldfajn and Tombini. Even so, articulating an appropriate communication policy is not straightforward. The accompanying paper by Andersson, Dillén and Sellin notes that speeches and releases of minutes can have a considerable impact on markets' future expectations about policy. Calibrating the information released and avoiding confusion may be difficult. Moreover, circumstances can arise in which central banks may wish to surprise markets, so as to magnify the psychological effect of their actions. Differences of views on these tactical questions, partly shaped by the constraints under which policies are formed, do appear to exist within the central banking community. Against this background, in their contribution to the volume Gaspar, Perez-Quirós and Sicilia examine the predictability of ECB policy moves.

Domestic operations

Turning next to the implications of changes in market functioning for domestic monetary operations, one issue that has come to the forefront is that of the range of eligible collateral. For structural reasons, scarcity of collateral is in fact a rather familiar issue for many emerging market countries, where the lack of an established securities market inhibits the use of repurchase-type operations in liquidity management. But it has also become a potential constraint in some of the industrial countries where the adjustment of structural deficits has led to a decline in sovereign debt issues, threatening the disappearance of the primary source of collateral. This is especially relevant for those countries without a (recent) tradition of relying also on private sector instruments as collateral, such as the United States and Australia, and which may also rely on the use of sovereign debt securities for permanent injections of liquidity, through outright purchases (Borio (1997)).

In turning away from domestic sovereign debt for their operations, central banks must confront at least two questions.[17] The first, not faced by other market participants, is how to conduct operations without distorting market prices. Eligibility as collateral, by enhancing the liquidity of the corresponding instrument, in effect subsidises its issuer. In the extreme, the choice of securities used in operations may afford the issuer an undesirable advantage. These concerns have been particularly prominent in the United States, where government-sponsored enterprises have aggressively positioned their debt issues as alternatives to Treasury securities as risk-free instruments. Debates have ensued regarding the status of the GSEs' implied government guarantee and whether or not that implied guarantee amounts to an unfair subsidy. The second question, shared with other market participants, is how to address the default risk associated with non-government debt instruments. This requires setting up the infrastructure to measure and manage the corresponding credit risk.

In the event, the central banks faced with these questions have broadened the set of eligible collateral, by extending it either to additional domestic currency instruments (the United States and Australia) or to foreign currency ones (the euro in the United Kingdom). In some instances, they took advantage of the broadening of eligible collateral that had taken place at the time of the Y2K operations, turning it from temporary to permanent (Borio (2001)). In addition, some central banks have also relied more heavily on foreign exchange swaps. Edey and Ellis discuss in detail in their contribution how the Reserve Bank of Australia has addressed these issues.

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[16] In addition, Lown et al (2000) show that information gleaned from surveys of banks' perceptions of risk as reflected in non-price terms of the loans helps to predict economic activity.

[17] From a historical perspective, the use of government securities as collateral for central bank operations is actually of relatively recent vintage. In the early days of central banking, private sector instruments were the rule. This was dictated by the orthodoxy of the day, not least concerns with the financing of government deficits. It was only with the relaxation of this doctrine and the growth of the stock of public sector debt in the wake of government deficits that sovereign claims came to prevail in, and in some cases monopolise, operations.

The increasing consolidation of the financial services industry also presents a problem for the conduct of domestic monetary policy operations (and external operations as well). The increased consolidation may lead to market pricing power, or even collusion, in the markets in which central banks conduct their operations. The Swiss National Bank, for instance, was forced to switch its policy target to an offshore interest rate, specifically Swiss franc Libor, once two large banks came to dominate the domestic market following a merger. The Bank of England, too, has had difficulties with non-competitive behaviour of securities firms in money markets. The accompanying paper by Allen discusses some of the resulting changes in interest rate volatility and the Bank of England's response.

External operations

External operations are affected by some of the same developments impinging on domestic operations. In particular, the falling stock of US Treasury securities presents a problem for central banks holding them as foreign reserves. There is some evidence that central banks have begun to diversify their dollar reserves into other instruments (Fung and McCauley (2000)). Between 1995 and 2000, US dollar reserves held as GSE securities more than doubled to 5%, while reserves invested in Treasuries fell to 59% (Table 4). Other alternatives to Treasury securities include the dollar-denominated obligations of other sovereigns, corporate issues (including equity), asset-backed securities, interest rate swaps, credit derivatives and purchases of non-US sovereign debt combined with forward sales vis-à-vis dollars. In choosing among these alternatives, central banks face many of the risks mentioned previously. More generally, the shift away from default-free sovereign issues is itself part of a broader trend reflecting central banks' increasing attention to yield in the management of reserve assets, bringing them closer to strategies followed by private sector agents. The implications of this trend for market functioning have arguably not yet received the attention that they deserve. In his contribution to this volume, Visser examines how the Netherlands Bank has adjusted its reserve management practices to the challenges raised by the new environment.

Table 4

Composition of US dollar reserves

As a percentage of identified dollar reserves[1]

	1995	1998	June 2000
US Treasury securities	63	62	59
Treasury bills	23	15	16
Treasury notes and bonds	40	47	43
Other short-term instruments	29	27	29
Onshore deposits	4	4	4
Offshore deposits	14	13	15
US money market paper	10	10	10
Other long-term instruments	3	4	6
US GSE securities	2	3	5
US corporate bonds	0	1	1
Equity	5	7	7
Memorandum items (in billions of US$):			
Identified US dollar reserves[1]	740	916	1,014
Total US dollar reserves	835	1,082	1,451[2]
Total foreign exchange reserves	1,347	1,640	1,909[2]

[1] Identified US dollar reserves exclude US dollar-denominated securities held outside the United States, such as international dollar bonds. [2] December 2000.

Sources: Fung and McCauley (2000); US Treasury; BIS calculations.

Another external operational issue is foreign exchange intervention. Market commentary suggests that since the mid-1990s, central banks have increasingly used electronic brokers to intervene in the major foreign exchange markets. The growing role of electronic trading in foreign exchange markets presents several strategic questions for intervening central banks. On the one hand, the transparency of prices in a screen-based currency dealing system may make it increasingly difficult for central banks to intervene in secret. On the other hand, central banks may find electronic broking systems a good tool to use when they need to be seen to be intervening.

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Implications of declining government debt for financial markets and monetary operations in Australia

Malcolm Edey and Luci Ellis,[1]
Reserve Bank of Australia

1. Introduction

Like a number of countries, Australia has undergone a substantial fiscal consolidation in recent years and a consequent reduction in government debt. On a cash basis, the Commonwealth government moved into surplus in the 1997/98 fiscal year, and has since run an average surplus of around 1% of GDP. Official projections over the next three years are for surpluses of similar magnitude to be maintained, resulting in substantial further reductions in the government's net debt.

A declining level of government debt has a number of potential implications for financial markets and for monetary operations, which are the subject of this paper. Three areas in particular are explored:

- The size and liquidity of the government bond market;
- Growth and development of private sector bond markets;
- Implications for Reserve Bank of Australia monetary operations.

The paper argues that markets in Australia have so far coped smoothly with the reduced supply of government debt, although a further substantial reduction in gross debt would have implications for the viability of the government bond market and for the conduct of monetary operations.

2. Developments in government debt

Key indicators of the Commonwealth government's fiscal position are presented in Figure 1. The government's "underlying" budget balance (ie excluding the proceeds of asset sales) shifted substantially into surplus in the second half of the 1990s and has remained in surplus notwithstanding an expansionary package of tax reforms implemented last year. The move into surplus reflected both a structural fiscal consolidation and the cyclical effects of strong economic growth in the second half of the 1990s. At the same time, a continued programme of asset sales has added to the average surplus on a cash basis, and hence increased the rate at which government debt has been reduced.[2]

The net debt of the Commonwealth government peaked at 19.1% of GDP in 1997/98 and has since declined to stand at 5.8% of GDP in 2000/01. The debt position of Australian state governments has been much more stable than that of the Commonwealth, and hence the developments at the Commonwealth level have been the main driver of trends in the aggregate debt of the government sector as a whole.

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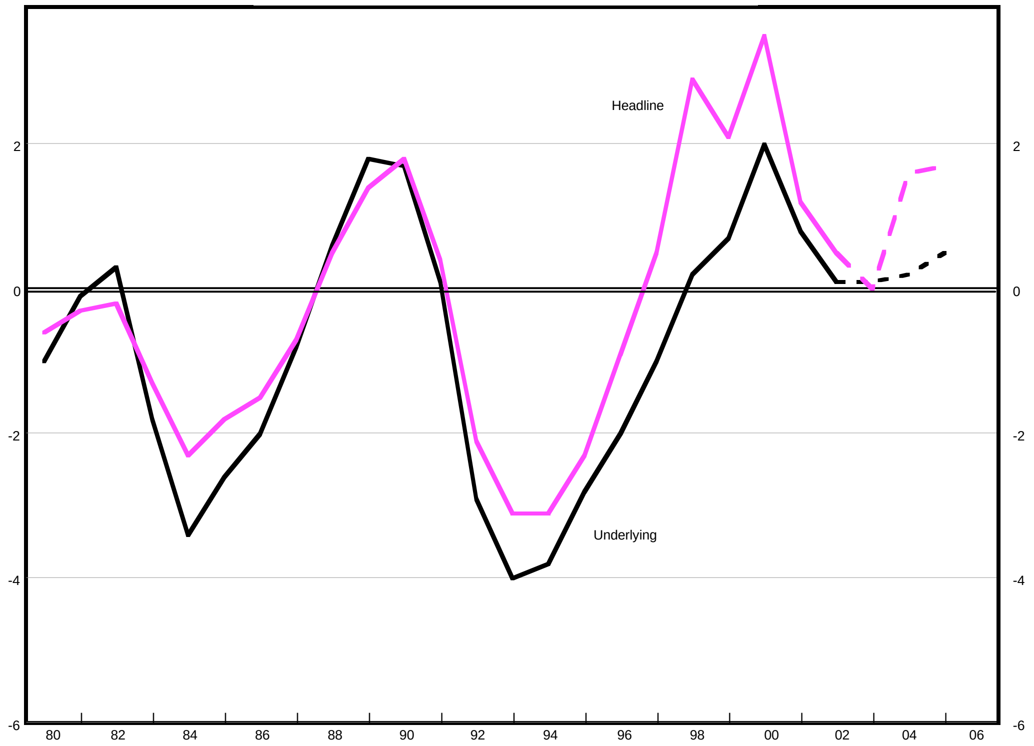
[1] This paper has benefited from helpful discussions with Marion Kohler and Marianne Gizycki. The authors would like to thank Keith Drayton and Kristy Clancy for assistance with data. Any remaining errors are the responsibility of the authors, not of the Reserve Bank. The views expressed in this paper are those of the authors and do not necessarily reflect those of the Reserve Bank of Australia.

[2] Net debt in this context is defined as gross debt less the financial assets of the government, where the latter excludes ownership of public corporations. Hence, on this definition, government asset sales reduce debt on both a gross and a net basis.

Figure1

Commonwealth budget surplus

% to GDP



The latest official projections, made at the time of the May 2001 budget, are for further substantial reductions in net debt, to the point where the Commonwealth government's net debt is projected to decline to –0.6% of GDP by 2004/05. This projection is of course subject to a number of uncertainties. First, it is based on a technical assumption of no changes to expenditure programmes or tax rates. Second, it is subject to the usual uncertainties concerning the economic cycle, a point which may be particularly important at a time when expectations of growth in the global economy are being revised downwards. And third, the projections incorporate the sale of the final tranche of Telstra (the formerly publicly owned telephone utility), which has not yet been passed by the parliament; this is projected to contribute just under 3 percentage points of GDP to the reduction in debt over the period. But notwithstanding these uncertainties, the trend in net government indebtedness at present is clearly downward.

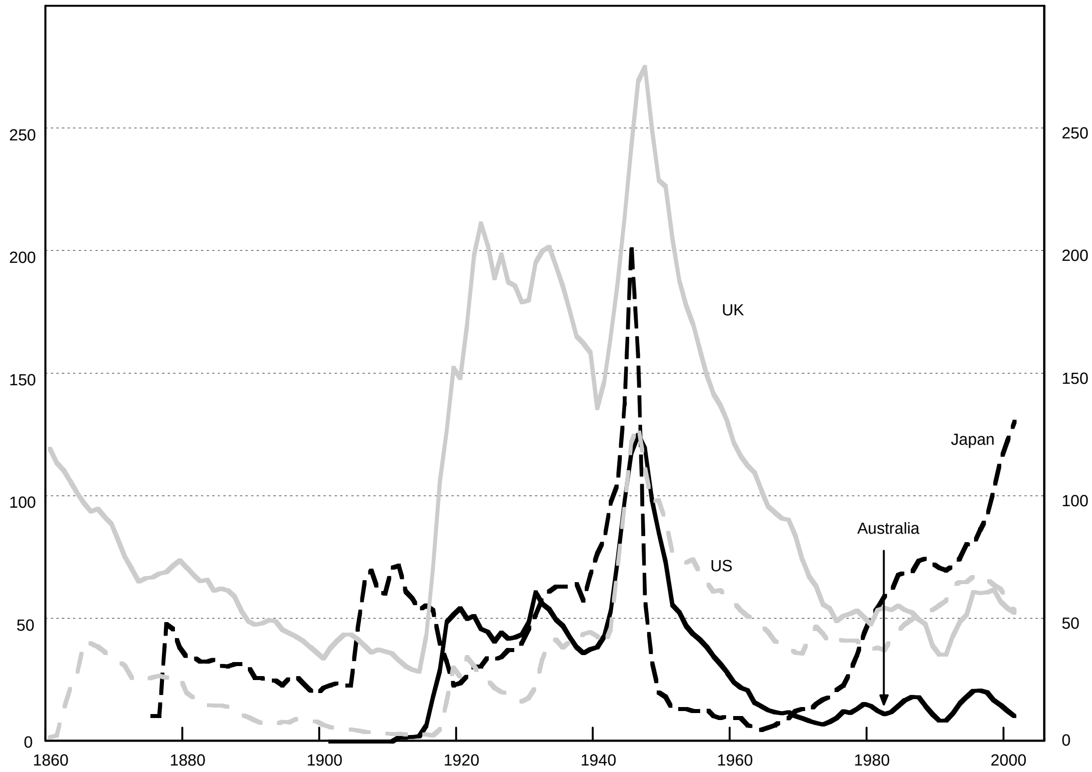
In international terms, Australia's level of central government debt is relatively low (Figure 2). It has been lower than in most major economies throughout the past decade and is also declining more quickly than elsewhere, including in the United States, where falling levels of government debt have similarly sparked debate on possible implications for financial markets and monetary operations (Reinhart and Sack 2000, Broaddus and Goodfriend 2001, Greenspan 2001).

Gross debt of the Commonwealth government has declined more slowly than net debt, reflecting a significant accumulation of financial assets by the government in recent years. The government has stated that it aims to maintain a sufficient stock of bonds on issue to support the liquidity and efficiency of the market, although it has not publicly endorsed a particular estimate of the amount required. At this stage, the financial assets accumulated by the government have been short-term deposits with the RBA, which have increased from virtually zero in 1997/98 to between AUD 10 billion and AUD 15 billion at present. The counterpart to this growth in deposits on the RBA balance sheet has been a build-up in RBA repos and foreign exchange swaps.

Figure 2

Central government debt

% to GDP



The government debt ratio can decline even when the government is not deliberately reducing debt. Any government that keeps its budget in balance on average over the course of the business cycle will eventually eliminate its debt, if only during the stronger phases of the business cycle. Provided growth in nominal GDP is positive in the long run, the long-run average government debt ratio will asymptote to zero from whatever is its starting point. It will then oscillate around zero. Therefore, a government that tries to maintain fiscal balance on a cyclically adjusted basis will eventually find itself accumulating net assets during cyclical upturns, but seeking to issue debt during downturns. Unless some efforts are made to sustain a continued positive gross debt position, such a government would be forced to re-establish a market for government debt in every cyclical downturn. This is likely to be difficult at the very time investor confidence is weak.

The time it takes for the stock of government debt to hit zero depends on the initial level of debt, the average rate of growth in nominal GDP and the amplitude of the deficit cycle, that is, the size of the peak deficits and surpluses relative to GDP. The larger these cycles in the fiscal position are, the earlier peak surpluses will cause the (temporary) elimination of government debt. However, it should be noted that this is a very long-term phenomenon. If the business cycle has a period of, say, 10 years, then even with peak annual surpluses of 5% of GDP, it will take 30 years to eliminate a government debt stock of 40% of GDP, given an average nominal GDP growth rate of 6%, and nearly 20 years to eliminate a stock equal to 15% of initial GDP. Sustained periods of positive net government assets would only occur after 40 years, given a starting point for debt of 40% of GDP.[3]

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[3] These time periods can be a little shorter if the deficit cycle is asymmetric, with deficits large but brief while surpluses are smaller but occur for more sustained periods. See Ramsey and Rothman (1996) for examples of functions that generate asymmetric cycles.

3. Liquidity of government bond markets

Liquidity is usually defined as the ability of participants in the market to trade significant volumes of a security without generating substantial adverse price movements by doing so. Gravelle (1999) defines a liquid market as one "…in which trading is immediate, and where large trades have little impact on current and subsequent prices or bid-ask spreads". Pagano (1989) links liquidity more closely to trading volume, defining it as the ability of the market to absorb large trades.

Given this, Gravelle (1999) presents a number of separate indicators of the liquidity and functioning of the market. These are related to the four dimensions of liquidity listed in that paper: immediacy (time taken to complete large trades), width (largest trade possible for a given bid-ask spread), depth (bid-ask spread) and resilience (price response to large trades).

The following sections examine the available evidence on these aspects of liquidity for both the physical bond market and the bond futures contracts traded on the Sydney Futures Exchange.

3.1 Physical bond market

The bottom panel of Figure 3 shows that trading activity in Australia's physical bond market has declined noticeably in recent years, even as derivatives associated with the bond market have experienced increasing activity.[4] In principle, this might be expected to indicate declining liquidity and to result in increased price volatility. However, the picture is complicated by changes in the liquidity of specific security issues. Figure 3 does not cover a fixed set of securities. Turnover and liquidity of individual issues decline markedly in the year prior to their maturity date (Figure 4). At this short end of the yield curve, the bulk of trading activity is focused on the markets for bank-accepted bills and other types of high-quality commercial paper. These markets are deep and liquid, and are generally seen as the main locus of price discovery for short-dated securities in Australia, rather than the market for longer-term government securities that happen to be close to maturity.

Although both the stock of government bonds outstanding and turnover have declined in recent years, turnover has fallen to a greater extent than the stock. Therefore, the *turnover ratio* declined a little over the 1990s (Figure 5). Once the trading of futures contracts is factored in, however, it appears that the total turnover ratio began to recover in the late 1990s. This is consistent with the idea that the futures market has been replacing liquidity that has disappeared from the physical market.

Gravelle (1999) argues that fragmentation, that is, low *average issue sizes*, can interfere with the ability of market-makers to maintain a sufficient inventory to offer their market-making service. Benchmark (on-the-run) issues are usually larger in size. In Australia, the Commonwealth government has concentrated debt buybacks on illiquid stocks and consolidated new issues into a limited number of benchmark stocks, in order to enhance the liquidity of markets in the remaining securities. Since 1996, the average size of each benchmark issue has increased from AUD 4 billion to AUD 4.7 billion.

Bid-ask spreads are an important indicator of liquidity in many markets, and have been used to assess variations in bond market liquidity by a number of authors (Gravelle 1999). However, the physical bond market in Australia uses a fixed bid-ask spread of 2 basis points, by convention (note that this spread is based on the yield, not the price). The spread is unfortunately therefore not an indicator of the liquidity of this market, either through time or in comparison with other securities markets such as corporate bond, foreign bond or bond futures markets. The bid-ask spread on bond futures contracts is lower than the underlying physicals, as would be expected for this more liquid market, but beyond this, there is little we can say about movements in the liquidity of these markets relative to each other.

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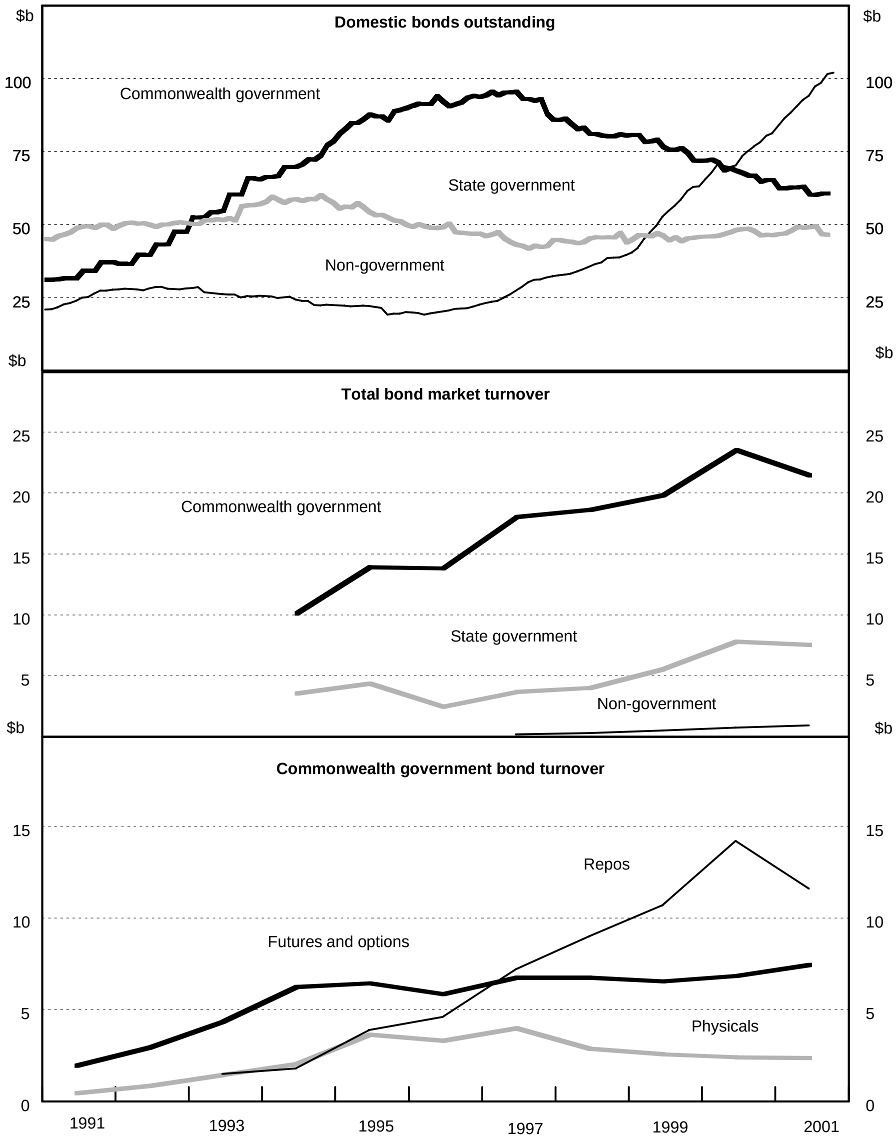
[4] The annual turnover data presented in Figures 3 and 5, and Table 3 in Section 4, are compiled by AFMA. Like the higher-frequency turnover data, they do not suffer from double-counting of turnover, unlike the results presented in Inoue (1999). However, the annual AFMA data exclude repos, whereas the higher-frequency data include them.

Figure 3

Bond market indicators

Outstandings and daily turnover



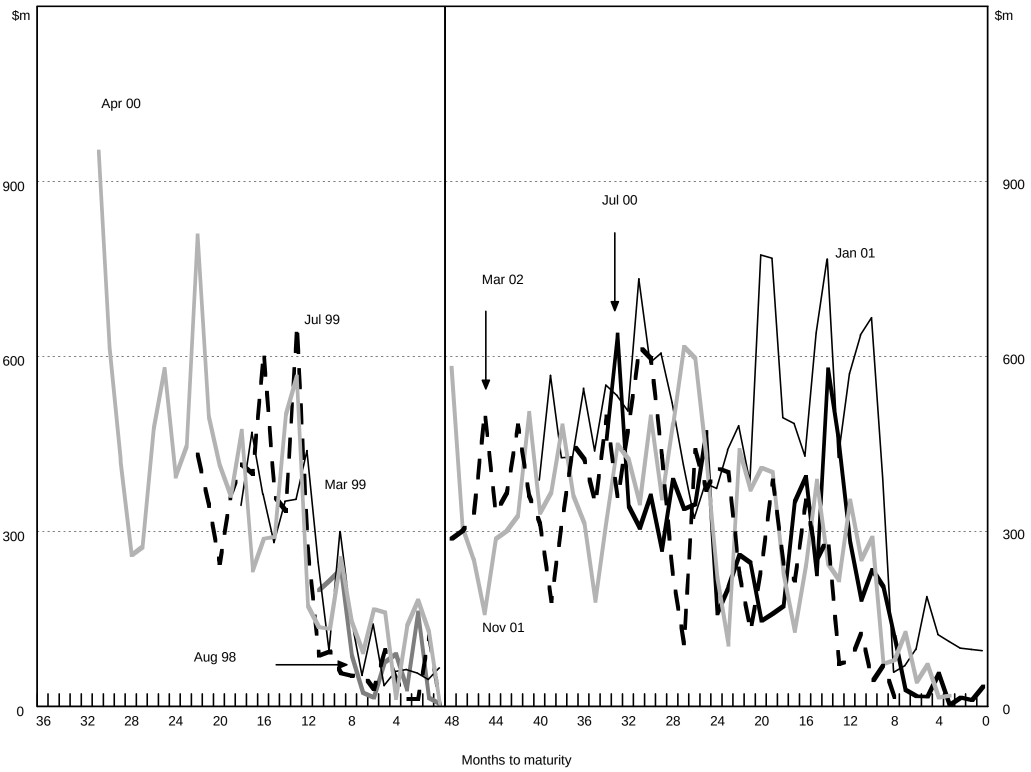
Sources: AFMA; SFE; RBA.

The *resilience* of the market depends on the relationship between trade size and price movements. Past theoretical and empirical work using a range of plausible models suggests that we should expect a positive relationship between trading volume or turnover, and the magnitude of price volatility in the market, for a given level of market liquidity. Copeland (1976) presented a model where trading volume had a positive relationship with the magnitude of price changes due to sequential arrival of information. The mixture of distributions model developed in Clark (1973), Tauchen and Pitts (1983) and related papers explains persistence in price volatility via the joint determination of price movements and trading volume; see Lamoureux and Lastrapes (1990) for an empirical application of this model using stock price indices and Watanabe (1996) for an investigation using Japanese government bonds. Karpoff (1986, 1987) provides surveys of this earlier literature. Dupont (1997) presents a theoretical result showing that price volatility and absolute movements in price are necessarily positively correlated if traders' demands are symmetric.[5] If liquidity were falling, we would expect that a given level of turnover would be associated with greater price volatility than had been the case previously.

Figure 4

Turnover of government bonds by issue

Monthly average of daily turnover



Institutional factors make it difficult to assess the resilience of the market, that is, the extent to which the market can absorb a large transaction or large volume of trades without prices moving precipitously. The physical bond market frequently does not trade for periods within a trading day. At those times, the quoted price for physical bonds is generally derived in a mechanical way from the activity in the futures market, which is much more liquid than the underlying physical market. Therefore, the quoted prices will give misleading signals about the ability of the market to absorb a large trade.

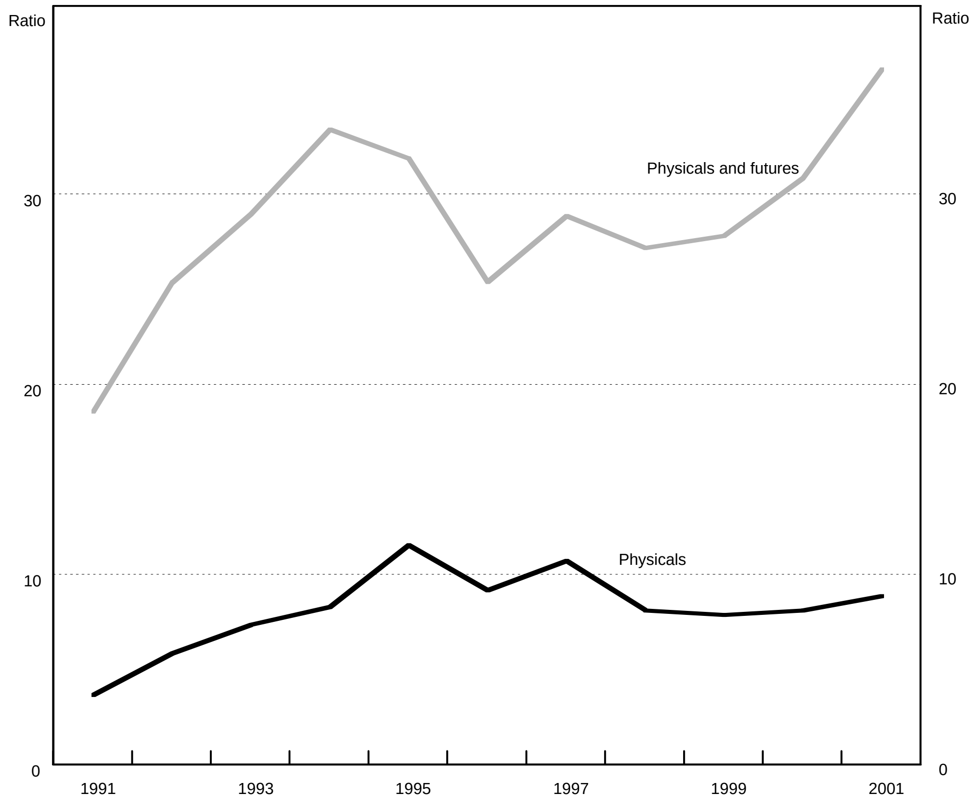
Another way of looking at the resilience of the market is to examine the response of prices in one market to an event relative to the price response in another market. In an illiquid market, we would expect the absolute change in price in response to a particular event to be greater than the price response in a related, more liquid market. Therefore, we could compare price changes across markets to obtain a sense of relative liquidity. Again, however, the quoting practices mentioned above prevent us from comparing the activity of the two markets; the quotes and yields recorded for the physical market will not differ from yields in the futures market, and it would be impossible to use price information to determine relative liquidity at those times.

5 Dupont's theoretical results also require that changes in prices be jointly normally distributed with traders' demands, but her simulation results indicate that the volatility-volume relationship also appears to be robust to more general, non-normal specifications.

Figure 5

Liquidity of Commonwealth government bonds

Ratio of turnover to bonds outstanding



Source: AFMA; SFE.

The difficulties of attributing price developments in the physical bond market to liquidity considerations are exemplified by the lack of connection between price volatility and trading volume across different government bond issues. Ordinarily, we would expect to see a positive relationship between price volatility and trading volume in a given securities market. As shown in the next section, this is clearly true for bond futures. However, the relationship between price changes and trading volume in the physical bond market is very weak for most issues, indicating that pricing in the bond market is not closely related to the flow of orders in that market. Table 1 shows that regressions of trading volume for bonds of different maturities have little relationship with volatility in their own yield. Although there is almost certainly some simultaneity bias in regressions of this kind, the results presented here are at least indicative of a pricing process that bears little relation to turnover in that market.[6] There is, however, some noise in these data; daily volumes data for the physical market are somewhat distorted by the difficulty of separating repurchase agreements from outright sales, since these are generally entered through the same trading systems. This does not apply to the annual turnover data compiled by AFMA and presented in Figures 3 and 5.

6 The regressions presented in Table 1 differ from the results presented for bond futures in the next section on a number of counts, due to limitations in the available data. First, the estimation period is much shorter - around half the length of the data available for futures. Second, we were constrained by data limitations to using the (absolute) difference between consecutive closes as our measure of price volatility for the physicals data, compared with intraday (close-open) variation used for the futures data. Third, these data are for specific bond issues, rather than being benchmark contracts for debt of a specific maturity. Finally, the turnover data are measured in millions of AUD for the physicals data, whereas the futures trading volume data presented below are measured as the number of contracts traded.

Table 1

Government securities (physicals) turnover and volatility

Regressions of daily data

Maturity date	Average daily turnover ($ million)	Own turnover			Total turnover		
		Coefficient on yield volatility	Coefficient on time trend	Adjusted R^2	Coefficient on yield volatility	Coefficient on time trend	Adjusted R^2
Apr 2000	353.0	135.7 (0.598)	– 0.244 (0.001)	0.344	2,622.6 (0.204)	– 0.288 (0.502)	0.271
Jul 2000	280.7	125.1 (0.533)	– 0.129 (0.007)	0.349	2,911.2 (0.132)	– 0.448 (0.254)	0.300
Jan 2001	440.6	234.6 (0.298)	– 0.142 (0.003)	0.298	1,552.5 (0.355)	– 0.514 (0.089)	0.286
Nov 2001	306.0	73.7 0.632)	– 0.069 (0.005)	0.315	2,523.9 (0.073)	– 0.318 (0.139)	0.278
Mar 2002	457.6	48.0 (0.807)	– 0.003 (0.936)	0.108	2,309.6 (0.096)	– 0.336 (0.116)	0.277
Oct 2002	359.1	– 2.4 (0.990)	0.035 (0.243)	0.140	2,405.5 (0.727)	– 0.342 (0.107)	0.278
Aug 2003	549.9	– 55.0 (0.810)	0.068 (0.049)	0.158	1,977.5 (0.126)	– 0.356 (0.091)	0.277
Sep 2004	455.2	451.8 (0.016)	0.100 (0.009)	0.175	2,218.5 (0.077)	– 0.353 (0.092)	0.277
Jul 2005	446.9	247.5 (0.195)	0.061 (0.052)	0.143	1,731.4 (0.181)	– 0.356 (0.090)	0.276
Feb 2006	311.0	– 35.5 (0.822)	– 0.101 (0.000)	0.348	1,114.6 (0.385)	– 0.359 (0.088)	0.275
Nov 2006	462.9	298.2 (0.291)	– 0.002 (0.949)	0.189	984.1 (0.454)	– 0.358 (0.089)	0.275
Oct 2007	448.3	– 221.5 (0.219)	– 0.132 (0.000)	0.153	609.1 (0.645)	– 0.362 (0.086)	0.275
Aug 2008	606.7	– 317.1 (0.318)	– 0.052 (0.159)	0.262	483.3 (0.719)	– 0.363 (0.085)	0.275
Sep 2009	635.8	508.8 (0.067)	0.109 (0.002)	0.180	301.8 (0.820)	– 0.365 (0.083)	0.275
Jun 2011	483.6	296.1 (0.257)	0.333 (0.000)	0.280	– 345.1 (0.000)	– 0.181 (0.546)	0.231

Notes: Average daily turnover excludes final month before maturity, when issues trade infrequently. Estimation period is from the beginning of September 1997 to the end of August 2001 (910 observations after excluding lags and holidays), except where the security had already matured. Figures in parentheses are *p*-values. Regressions also include a constant, a time trend and eight lags of the dependent variable, accounting for the equations' explanatory power and eliminating serial correlation in the residuals that would otherwise be present. The time trend is scaled as one unit per day.

The two exceptions to this seem to be the issues with September 2004 and September 2009 maturity dates. While this could simply be coincidence, these issues would have been the physical bonds closest to the benchmark three- and 10-year maturities for most of the estimation period. Therefore, the prices and yields recorded for these securities may reflect the greater interest and liquidity for benchmark maturities, partly associated with activity in the futures market, than applies for bonds with maturities that are not associated with the main futures contracts.

There seems to be a closer relationship between the turnover of government bonds at *all* maturities (shown in the fourth to sixth data columns of Table 2) and yield volatility for each of the securities than there is between the turnover of a given security and its own yield volatility. This is particularly true for securities currently around the middle of the yield curve. One possible interpretation of this is that activity in the bond market generally is related to yield or price volatility generally, but that the relationship is less strong at the level of the individual security. The statistically significant relationship between yield volatility and total turnover occurs because movements in yields are highly correlated across the yield curve. Still, the explanatory power of this equation is largely unrelated to the volatility term, indicating that other forces drive both turnover and pricing in this market.

A final consideration in assessing the liquidity of the market for a particular security is the concentration of the market. If there are only a few active players in the market, participants may find it difficult to find a counterparty that wishes to trade at the same time as they do. The number of market-makers actively trading Commonwealth government securities has declined in recent years, due to mergers between some investment banks.

3.2 Futures market

The preceding discussion shows that, although there are good reasons to suspect that liquidity has declined in the Australian bond market, institutional factors make it very difficult to find definitive evidence of this decline. What does seem apparent, however, is that liquidity in the bond futures market increased through the 1990s. Figure 6 shows that volume increased noticeably in the three-year market, while for the 10-year market, it was in most periods about 50% higher after 1994 than in the late 1980s and early 1990s. We focus on the contract for next delivery, since this is the contract accounting for almost all bond futures trading activity. Contracts expire around 15 March, June, September and December.

At the same time, price volatility (equivalently, yield volatility) declined noticeably, as shown in Figure 7. In particular, intraday volatility declined relative to the fairly small decline in volatility as measured by the change between consecutive market closes. Since it is the price movements within the trading session that indicate the market's ability to withstand large trades, we interpret this development as indicating increased liquidity in the market, at the same time as responses to overnight developments became more important, particularly movements in the US Treasury market.[7]

Table 2

Daily bond futures trading volume

Dependent variable	Constant	Yield volatility	Lagged yield volatility	Time trend	Adjusted R^2 and SIC
10-year	270.1 (0.674)	32,978.2 (10.633)	49,453.0 (11.216)	1.681 (9.910)	0.40892 0.425
3-year	2,347.0 (2.32)	138,172.2 (13.84)	–	5.917 (12.23)	0.4058 21.839

Notes: Sample size is 2,910 for 10-year contract regression (January 1988 to end-August 2001) and 2,450 for three-year contract regression (January 1992 to end-August 2001). Figures in parentheses are t-statistics, showing that all estimated coefficients shown other than constants are significant at the 1% level. Standard errors calculated using the Newey-West heteroskedasticity consistent covariance matrix. Coefficients on lags of the dependent variable are not shown; the first and some later lags were generally statistically significant at the 1% level.

Table 2 shows the results from regressions of volume on intraday yield volatility for the three- and 10-year benchmark bond futures contracts, similar to those in Gravelle (1999). We focus on intraday volatility on the grounds that it is the intraday price movements that would be affected by any lack of liquidity to enable transactions; differences between opening price and the previous close can occur almost regardless of liquidity during the day trading session, as quoted prices adjust to overnight

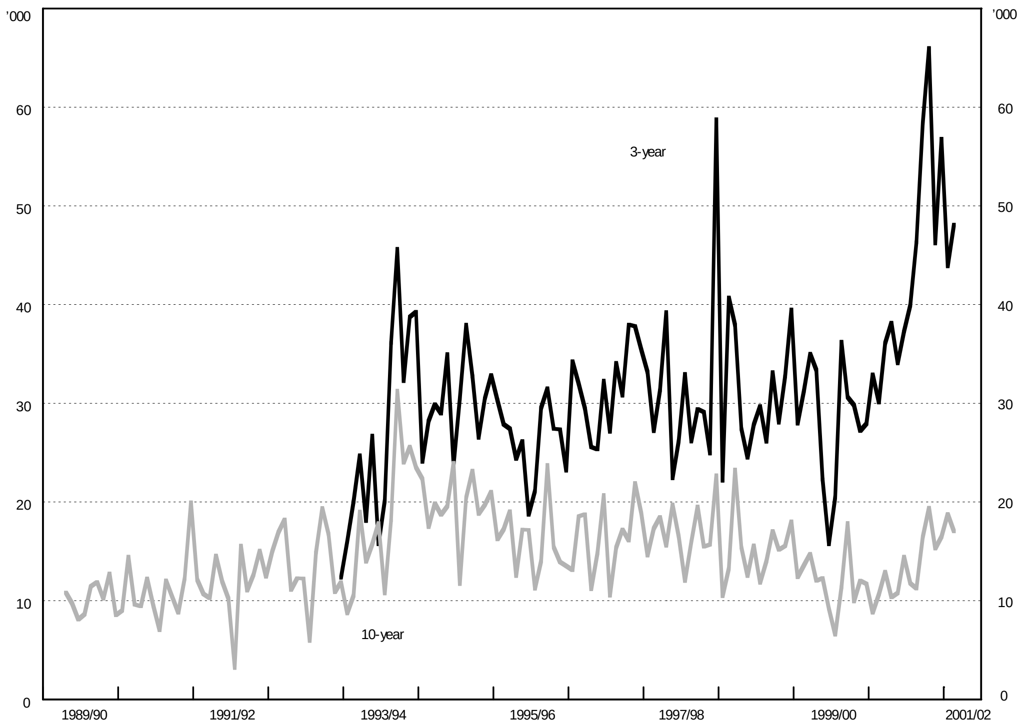
[7] Ellis and Lewis (2001) presented evidence that overnight developments in the US Treasury market accounted for an increasing fraction of the volatility in yields on Australian and New Zealand bond futures during the late 1990s.

movements in offshore markets. We obtained similar results for alternative regressions using absolute yield changes between consecutive closes rather than between the open and close on the same day. We also allowed for an asymmetric effect of volatility on volume by including the yield change as well as the absolute yield change, as suggested by Karpoff (1987). The sign on the estimated coefficient was not statistically significant and therefore the results in Table 2 do not include this term.

Figure 6

Bond futures trading volume

Monthly average of number of contracts traded daily



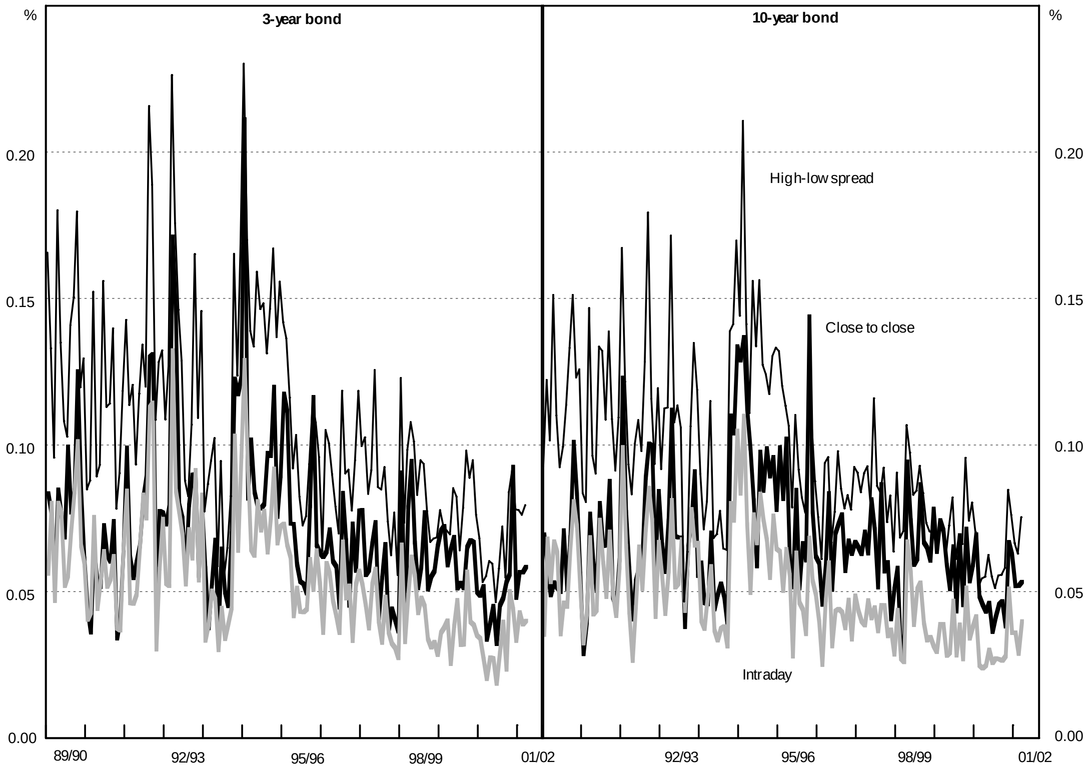
The regression results show that price volatility clearly results in increased trading volume. Since bond futures in the Australian market are priced as 100 minus the yield, we can interpret these coefficients as indicating that a 1 basis point movement in interest rates requires an additional 330 10-year contracts to be traded on the day (824 over two days), or 1,381 three-year contracts. Of greater interest is the significant positive time trend identified in these results. This implies that in the 10-year contract market, the mean number of contracts exchanged when yields did not move increased by around 5,000 contracts from 1988 to the end of August 2001. The surge in trading volume in 2001 has resulted in an even higher estimate for the time trend in the three-year contract regression, suggesting that base daily trading volume - the trading volume that should be expected when yields are constant - has increased markedly over the past eight years.

These estimates should be treated with some caution. Our approach of fitting a simple time trend to the available data points implies that days that are missing due to gaps in the data, public holidays or other reasons do not contribute to the rising trend. Given Sarig and Warga's (1989) finding that errors in recorded bond prices were more prevalent for illiquid securities, data issues may have non-trivial effects on our results. Our data on price volatility are not adjusted for the small price movements that occur when futures contracts expire and trading activity switches to the next contract, but this is unlikely to affect our results much. Volume also tends to increase a little in these changeover periods. On the other hand, there is no evidence of non-stationarity in the data; standard augmented Dickey-Fuller tests strongly reject the null of a unit root.

Figure 7

Bond futures volatility

Monthly average of daily absolute change in yield



The 10-year contract regression included six lags of the dependent variable, while the three-year contract regression included seven lags of the dependent variable. This minimised the Schwartz information criterion as well as eliminating serial correlation. Elimination of serial correlation in the 10-year regression also required the inclusion of the lag of the price volatility variable. Some ARCH characteristics remain in the residuals, but estimation of a standard GARCH model does not seem to make much difference to the estimated coefficients or the qualitative conclusions to be drawn from the results.

4. Implications for financial markets

4.1 Functioning of the debt market

The effect of declining supply on government bond yields is ambiguous in principle. If one market were to become less liquid relative to another, we might expect it to start displaying a *scarcity premium* relative to the other market. That is, its price would rise (yield fall) relative to the other security. This seems to have explained the falls in US bond yields in early 2000 when expectations of continued fiscal surpluses generated an expectation that the supply of US Treasury securities would become constrained (Reinhart and Sack 2000).

On the other hand, declining supply may imply a declining *liquidity premium*; investors will accept a lower return on liquid securities because of the confidence that liquidity brings, that future trades can occur without engendering adverse price movements. That is, highly liquid securities trade at a premium to less liquid alternative securities, so as supply declines we would expect yields to increase relative to other markets where supply and liquidity are not falling. The net effect of declining supply on yields may therefore be ambiguous and hard to discern. We would expect that the liquidity premium is more important for corporate bonds. However, if there are institutional factors generating underlying or exogenous demand for a particular security, the scarcity premium may be relatively more important. This seems to be an important consideration for benchmark securities such as government bonds, which are more likely to be affected by regulatory requirements inducing market participants to hold these securities rather than alternatives. Examples of these requirements include the past restrictions that required Australian banks to hold a certain percentage of their assets in liquid and government securities, and the choices made by central banks about the securities they will trade in as part of their liquidity management operations.

Whatever the direction of the net effect of declining supply on government bond yields, these premia imply a possible change in the spread between interest rates on government bonds and interest rates on other fixed interest securities such as corporate bonds. However, measuring the effect of declining liquidity on spreads is difficult because risk spreads change for other reasons, unrelated to the supply of government debt.

Similarly, it is not obvious that there should be a sustained liquidity premium between a less liquid physicals market and a highly liquid futures market. A premium for scarcity or illiquidity in the physical market would presumably be arbitraged away. We would nonetheless expect that the short-run effects of yield-moving events could be different, or the effect on trading volume could be different, were the Australian market's convention of quoting prices for physicals based on futures trading outcomes not distorting that signal.

If a declining volume of bonds outstanding ultimately results in a highly illiquid bond market, its importance to markets for other securities would diminish. The physical bond market would cease to be the locus of price discovery and be replaced by the futures market; this transition is essentially already complete in Australia. This is essentially the result of the very high transactional efficiency of the futures market rather than any shortage of supply of physical bonds. Similarly, the yields paid on longer-term government bonds would become less representative of overall financial conditions, and thus less relevant for pricing other forms of debt, whether in securities or retail lending markets.

We should expect the consequences of illiquidity to be most acute at times when news events such as monetary policy changes occur. Chen et al (1999) found that equity markets experienced excess volatility and trading volume on the days when unexpected changes in the discount rate occurred. If this follows through to the bond market, then any problems of illiquidity would be particularly acute on those days. However, there is no evidence of this occurring in Australia.

4.2 Effect on private bond markets

Shrinkage of the government bond market might be conjectured to affect private bond markets in two opposing ways. First, to the extent that government borrowing crowds out borrowing by the private sector, reduced levels of government debt could be expected to "make room" for growth of the private bond market. On the other hand, the existence of a viable market for government bonds could be expected to provide valuable benchmarks for highly liquid and essentially risk-free securities from which private sector bonds can be priced. Hence, a significant loss of liquidity in government bond markets might make it more difficult for markets in private debt securities to grow and develop.

At this stage, there is no evidence of this latter effect occurring in Australia, and it is the first effect that seems to have predominated. Markets for private sector debt securities have grown strongly in recent years, and particularly in the period since around 1996 (see Figure 3 above). As in other countries, the largest segment of the market is in asset-backed securities, mainly securitised mortgages. However, the other segments of the market have been faster growing in recent years, with the outstanding stock of corporate bonds, for example, increasing by a factor of about four since 1996. Security issuance by the financial sector and by non-residents into the Australian market has also been expanding rapidly. In part, the growth of these markets has been a reflection of a global trend, but it also appears to have been hastened in Australia by strong demand for fixed income securities from an expanding funds management industry, as well as the falling supply of government bonds.

Another development that has assisted the growth of these markets has been the increasing use of credit enhancements ("credit wrapping") provided by highly rated financial institutions. While demand for fixed interest securities has been mainly concentrated in highly rated paper (A or better), the use of credit wrapping has enabled a number of less highly rated borrowers to gain access to the market in recent years, particularly in the corporate sector.

Notwithstanding their rapid growth in recent years, these markets remain less liquid than those for government bonds, as indicated by the comparisons in Table 3. There are nonetheless now a number of market-makers in this sector, and prices have provided a useful source of additional information on financial conditions. In general, the yield spread between corporate and government bonds has tended to follow the movements in the corresponding spreads in the United States (Figure 8). On occasions, there have been quite sharp increases in these spreads in response to shocks that diminished the market's appetite for risk (for example the Russian debt default in 1998). However, the two markets have not invariably moved together. For example, in early 2000 Australian corporate bonds began to trade at consistently narrower spreads to government paper than their counterparts in the United States. This appeared consistent with other indicators of relatively robust conditions in the Australian corporate sector, and helped support assessments at the time that credit conditions were less likely to constrain activity in Australia than seemed the case in the United States.

Table 3

Bond market liquidity

Ratio of turnover to stock outstanding, 1999/2000

Sector	Turnover ratio
Commonwealth	8.2
State	7.4
Corporate (corporate, financial, non-resident)	3.6
Asset-backed	2.1

Figure 8

Spread between yields on corporate and government debt

Falling government debt may not only have an effect on interest rates via liquidity or scarcity premia on government securities. The effect of the underlying fiscal policy stance responsible for the reduction in debt may also be important, influencing interest rates other than those in the government bond market. Expanding government deficits in the United States in the 1980s were thought potentially contractionary. Because higher deficits in the near future meant higher taxes later, the long-run interest rates would rise now, before the spending had even taken place. By the same argument, increasing surpluses would be expansionary because of the downward pressure they would put on (long) interest rates, even if the fiscal tightening were common across the world and therefore there was no exchange rate channel. Reinhart and Sack (2000) show that a permanent tightening in fiscal policy should lead to lower real interest rates. Therefore, although the quantity of private sector debt could rise as government debt falls - the effect mentioned earlier - this adjustment might be less than one for one, abstracting from other effects such as economic growth and increasing financial sophistication. Lower interest rates in the long run will also reduce total demand for debt securities, so the size of the net effect on issuance of private sector debt depends on the elasticities of supply of and demand for these securities with respect to the interest rate.

As mentioned earlier, the government debt market may become less important as a benchmark for pricing other types of debt if the stock on issue continues to diminish. However, since long-term fixed rate loans are uncommon in Australia, this would be of less importance to the retail market than is likely in the United States. Most corporate debt securities are at the shorter end of the maturity spectrum, which remains very liquid, and there is relatively little consumer or mortgage debt with fixed interest rates. Most mortgages in Australia are floating rate, and those with fixed interest rates are usually only fixed for one to three years. Unlike the United States, where there is a large retail market for loans with fixed rates for very long periods, there is little retail demand in Australia for the pricing benchmarks provided by long-term government securities, though with markets increasing in diversity and sophistication, the demand for such benchmarks may increase in the future.

4.3 Portfolio choice without government debt

The qualitative effects of the complete elimination of the government bond market are likely to be quite different to the effects of a declining stock of debt in a market that still exists. The elimination of this market would effectively remove the risk-free asset from the spectrum of available assets. Although the literature on incomplete markets is extensive (see Laffont (1989) and Saito (1999) for surveys), there has been surprisingly little theoretical work on the consequences for markets of this particular kind of incompleteness. Most academic studies of incomplete markets still assume that a riskless asset is available (Telmer 1993; Heaton and Lucas 1996), or that sovereign bonds are the only asset that is traded (Devereux and Saito 1996; Kim et al 2001).

In principle, the absence of government bonds may not have much effect on the workings of the economy. We know from the theory of the second best that adding a new asset into an incomplete market is not necessarily welfare-improving (Laffont 1989). By the same logic, removing an asset might not be welfare-reducing. Indeed, in some models, opening a new market in an incomplete markets setting can make all agents worse off (Hart 1975; Newbery and Stiglitz 1984). On the other hand, government securities are the closest available proxy to a risk-free asset in developed country financial markets, other than currency, so their absence may have non-trivial implications that do not apply for other securities.

Heaton and Lucas (1996) showed that the presence of an outside supply of government bonds dampened the effect of transactions costs in preventing consumption smoothing and generating a large equity premium. On the basis of this argument, elimination of the supply of government bonds would tend to increase the equity premium and reduce the rate on remaining risk-free bonds. Borrowing constraints would become more binding, because of the requirement that private sector bonds be in zero net supply. However, this result assumes that there is still a risk-free bond available, issued by a private sector entity. Although highly rated institutions such as large international banks and supranational institutions do issue securities into the Australian market, it is usually the case that only sovereign debt is considered close enough to being risk-free.

Nielsen (1990) developed a model where, without a riskless asset, investors could become satiated; more of the remaining assets is not better because the additional income cannot compensate them for the additional risk. The result is a potential for non-existence of general equilibrium in financial markets, negative prices for some assets and other degenerate outcomes. However, this is probably not an issue in practice. There are empirical precedents of markets lacking government debt; many emerging markets have never had well developed domestic government bond markets. Although financial market instability occurs on occasion in these markets and those in developed countries, satiation of demand for certain types of asset does not appear to be the cause of this instability.

In summary, theory has to date contributed little to our understanding of the workings of an economy without sovereign debt or some other proxy for a risk-free asset. Moreover, given that governments in modern economies have generally retained a continuous presence in the bond market, it is difficult to assess how markets would function in a world where that was no longer the case.

5. Developments in monetary policy operations

A declining stock of government securities also raises issues for the conduct of monetary policy operations. Domestic monetary operations in Australia were, until 1997, conducted only in Commonwealth government securities (CGS), bought and sold either on an outright basis or through repurchase agreements (repos). It has been evident for some time, however, that the declining stock of CGS would make it increasingly difficult to confine operations to these securities, and this has prompted a number of decisions to expand the range of eligible securities for RBA operations. Key decisions to accept additional securities have been:

- securities of Australian state and territory central borrowing authorities ("semi-government securities", or "semis"), June 1997;
- Australian dollar securities of supranational organisations of which Australia is a member, October 2000 (this was extended to a broader range of AAA-rated supranationals in June 2001); and
- Australian semi-government securities lodged offshore and traded in Australia in a form known as euroentitlements, June 2001.

Of these decisions, much the most important in quantitative terms was the first. It added around $40 billion to the pool of eligible securities (on a stock of $110 billion in CGS at that time). The other elements have so far had a relatively minor impact. The available stock of supranational securities issued in Australia is small, although this market can be expected to develop over time. Euroentitlements potentially add a significant volume to the available stock, amounting to $15 billion on issue in June 2001, though at this stage there has been little activity in these instruments as they are relatively expensive to trade (Table 4).

Table 4

Domestic securities outstanding

as at 30 June 2001 ($ billion)

	RBA holdings (outright or under repo)	Total outstandings
CGS	11.8	65.4
State authorities	5.9	52.8
Supranationals	0.4	3.5
Euroentitlements	0.4	15.0

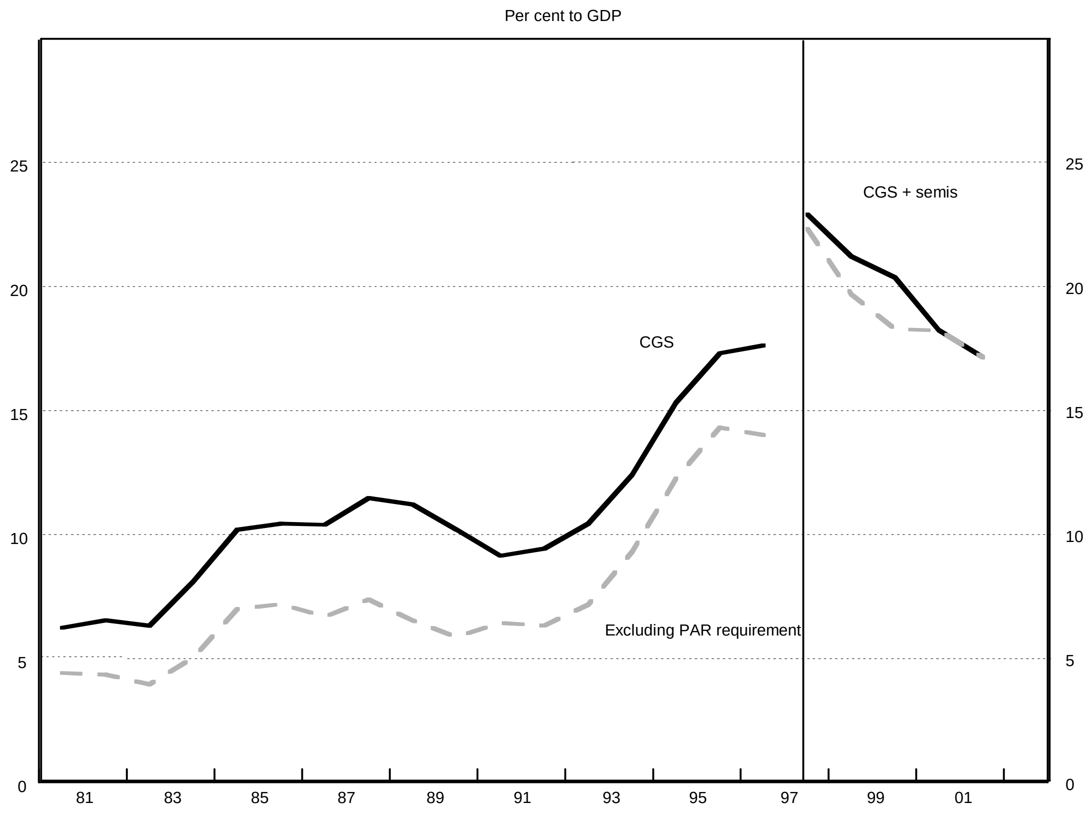
A further decision that had an important bearing in this area was the removal of the prime assets ratio (PAR), which had required banks to hold a minimum percentage of assets in the form of government securities. This was reduced from 6 to 3% in June 1997 and removed in June 1999.[8] The combined

[8] Previously, the ratio had been reduced from 12 to 6% in the late 1980s, a time of similar concerns about the consequences of a reduced stock of government securities.

effects of the removal of PAR and the decision to accept semis in RBA operations are illustrated in Figure 9. It can be seen that, despite recent declines, the stock of eligible securities available to be traded remains well above the average of the past two decades in relation to GDP. On the other hand, with the financial system continuing to expand more rapidly than GDP, the demand for these securities has also been increasing.

While the decisions outlined above have helped to alleviate pressure on the supply of eligible securities, the RBA has also responded by adjusting the structure of its monetary operations in recent years. The most important change has been an increasing use of foreign exchange swaps to supplement operations in domestic securities. Average annual turnover in foreign exchange swaps now stands at around a quarter of the volume of operations in domestic securities. The average stock of foreign exchange swaps outstanding has also increased substantially, to a level currently equivalent to around 40% of the stock of Commonwealth and state government bonds on issue. Clearly, if these operations had had to be replaced by domestic repos this would have represented a major source of additional pressure on the stock of available securities.

Figure 9
Government securities on issue
% to GDP



6. Conclusions

While issues associated with declining public debt have been raised in a number of countries, the process is more advanced in Australia than elsewhere. This paper has argued that financial markets and policy operations in Australia have so far coped smoothly with this process.

In terms of the impact on RBA monetary operations, the pressures that might have been expected to arise from a diminishing stock of government debt have been alleviated by policy decisions in three main areas; a run-up in government financial assets, which has absorbed part of the decline in net debt; an expansion of the range of eligible securities for RBA operations; and increased use of foreign exchange swaps for domestic liquidity management.

In terms of the impact on financial markets, there is little evidence at this stage of declining overall liquidity in government bond markets, although it does appear that liquidity has shifted from the physical to the futures markets in recent years. Nonetheless, this shift has had little effect on market-determined interest rates, and there is as yet little evidence of declining trading volume resulting in significant market disruption. Were the stock of government bonds to decline substantially further, this would clearly raise issues as to the viability of the domestic bond market and would require further changes in the composition of RBA operations. However, existing literature does not give much guidance as to how important the wider consequences for financial markets might be. In any case, the government remains committed to maintaining a viable stock of gross debt on issue even as its net debt declines.

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The influence of structural changes on market functioning and its implications for monetary policy: a focus on the euro area

Laurent Clerc, Françoise Drumetz and François Haas,[1]
Bank of France

1. Introduction

The last decade has been characterised by dramatic changes on financial markets: the development of electronic trading on foreign exchange markets or the introduction of the euro, for example, have had a significant impact on euro money, bond and equity markets. These changes have also been fostered by technical and financial innovations.

Amongst these changes, the paper focuses on three major themes:

(i) The change in the relative supply of private debt securities, and the growing importance of credit markets.

(ii) The spread of electronic trading and of distribution platforms.

(iii) Factors which could amplify market dynamics.

Section 2 of the paper tries to assess whether and how these changes have impacted on euro area capital markets. In this fact-finding exercise, we gather some of the stylised facts that have emerged over the last decade and compare them with what has been evidenced for the United States or the United Kingdom.

Section 3 concentrates on some of the possible consequences of these recent changes for central banks' policies, with a particular focus on monetary policy. More specifically, we try to analyse their plausible impact on the choice of relevant indicators used for the setting of monetary policy, but also on the transmission mechanism through the growing role of financial markets, and ultimately on the implementation of monetary policy.

2. Structural developments affecting market functioning

2.1 Changes in the relative supply of government and private debt securities

Whereas in a period of rising public deficits such as the 1980s the policy debate focused on the negative externalities of government debt (eg "crowding-out" effects), recently the implications of fiscal consolidation for financial markets have highlighted the positive externalities of government securities eg as providers of benchmark interest rates and the difficulty of finding satisfying substitutes (IMF (2001)).

While the declining stock of US Treasury securities has already had significant implications for market participants and US policymakers, fiscal developments in the euro area have had much less of an impact on the bond market. However, other factors, triggered by the introduction of the euro, have also contributed to a structural evolution of the euro area bond market.

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[1] Bank of France. The views expressed in this paper are those of the authors and do not necessarily reflect the opinion of the Bank of France.

The launch of the EMU process has had far-reaching implications for euro bond markets:

– The implementation of the Stability and Growth Pact has involved a gradual strengthening of member countries' public finances, therefore reducing the net borrowing requirements of governments.

– The introduction of the euro in 1999 has accelerated the integration of bond markets across the euro area, intensified competition amongst issuers, particularly sovereign issuers, and boosted euro-denominated bond issuance by private sector borrowers both within and outside the euro area.

As a result, the euro area's bond market structure has shifted. The outstanding stock of government bonds fell from 55% of the total bond stock before the introduction of the euro to 50%.

Table 1

Outstanding long-term euro-denominated securities other than shares by sector of issuer

(as a percentage of total)

	Banks	Non-monetary financial corporations	Non-financial corporations	Government (central and other general)	International organisations
End-1998	35.5	3.1	4.4	54.8	2.2
End-1999	35.2	4.5	5.1	53.0	2.0
End-2000	36.1	5.3	6.8	50.0	1.8

Source: *ECB Monthly Bulletin*, Table 3.6.

2.1.1 *Implications of the levelling-off of the euro government bond market and of remaining barriers to integration*

Medium-term budgetary consolidation in the major industrialised countries, except Japan, has resulted in a decline in government debt-to-GDP ratios. However, whereas the launch of EMU has involved a generalised improvement of member states' public finances, this decline has been less significant in the euro area than in the United States or in the United Kingdom and has, in addition, affected the euro area member countries unevenly.

Table 2

Government debt

(as a percentage of GDP)

	1996	1997	1998	1999	2000	2001 f	2002 f	2003 f	2004 f
Euro area	**75.4**	**74.8**	**73.0**	**72.0**	**69.6**	**67.9**	**66.0**	**63.8**	**61.8**
Italy	122.1	120.1	116.2	114.5	110.2	106.6	103.5	99.6	94.9
Germany	59.8	60.9	60.7	61.1	60.2	58.0	57.5	56.5	54.5
France	57.0	59.3	59.7	58.7	58.0	56.9	55.2	54.0	52.3
Spain	68.1	66.7	64.7	63.4	60.6	58.9	56.6	52.8	49.6
Belgium	130.5	125.3	119.8	116.4	110.9	105.8	101.4	97.2	92.9
Netherlands	75.2	70.0	66.8	63.2	56.3	52.3	50.2	48.7	46.7
United States	**73.9**	**71.4**	**68.3**	**65.2**	**58.8**	**55.0**	**51.7**	**–**	**–**
Japan	**86.5**	**92.0**	**103.0**	**115.3**	**122.9**	**130.5**	**138.3**	**–**	**–**

f: forecast.

Sources: Euro area and member countries: *ECB Monthly Bulletin* (1996-2000), stability and convergence programmes (2001-2004); United States and Japan: OECD.

The government debt-to-GDP ratio in the euro area declined for the fourth consecutive year in 2000 to 69.6% and is expected, according to the stability and convergence programmes of the member countries, to fall further to 61.8% in 2004.

Under these assumptions, the growth of the six largest national government debt compartments in terms of outstanding stocks (Italy, Germany, France - these three countries representing about three-quarters of the total stock - followed by Spain, Belgium and the Netherlands, in that order) and, more generally, of the euro area government bond market can be expected to level off during the period 2001-04, whereas the absolute size of government securities markets in countries with fiscal surpluses such as the US Treasury debt market has been declining sharply since 1998.

Consequently, government securities markets in the euro area are set to surpass the US Treasury market in terms of amount outstanding.

Table 3

Size of government bond markets

(outstanding stock in billions of US dollars)

	Face value		**Market value**
	2000	**2002**	**2000**
Euro area	2,834	2,900	2,430
United States	2,993	2,438	1,740
Japan	3,626	4,115	1,733

Source: Galati and Tsatsaronis (2001).

However, the euro area government bond market is not a fully integrated market yet as, despite progress achieved, some barriers to full integration persist, notably in the fields of market infrastructure, tax treatment and legal harmonisation.

Moreover, the multiplicity of sovereign issuers in the euro market and differences, albeit small, in their credit standing continue to distinguish the euro market from its US counterpart.

Member states with limited issuing volumes offer a spread over benchmark greater than that justified by differences in credit ratings (Deutsche Bank Research (2001)). Owing to this liquidity premium, spreads between government bonds of smaller and larger member countries have tended to widen marginally in the third stage of EMU despite the elimination of exchange rate risks and an upgrading of some countries, thus preventing the emergence of a single benchmark curve. In addition to market size as measured by outstanding stocks, these developments are also influenced by the existence (or not) of liquid futures markets that offer investors adequate hedging possibilities.

Intensified competition for the same pool of funds, fostered by the relatively high level of homogeneity between government bonds, has resulted in national treasuries implementing a number of measures aimed at attaining benchmark status by improving the liquidity of the secondary market:

– Buybacks and bond exchanges have been implemented to retrieve illiquid debt instruments.

– Over the past few years, sovereign issuance has concentrated on the 10-year segment of the yield curve to boost the liquidity of these “benchmark” bonds; moreover, the average size of individual public issues has increased, bringing outstanding amounts of individual 10-year bond issues of the largest euro area issuers to figures comparable to US Treasury benchmarks.

– For maturities other than 10 years, sovereign issuers, particularly smaller issuers, have tended to concentrate on strategic “niches” at different points along the yield curve.

As a result, no individual government securities market can offer the depth[2] and spread of issuance and, consequently, provide the range of services associated with a benchmark status across the entire yield curve (pricing of private fixed income instruments, management of liquidity and trading positions in securities markets, hedging of risks, etc). However, since corporate financing in the euro area does not yet rely to a great extent on securities markets (see 2.1.2), this drawback should be mitigated.

The implications for the liquidity of the euro area government bond market and, more generally, for the functioning of the financial system as a whole of the trend towards a sustained budgetary consolidation, which could, however, be threatened in a medium- to long-term perspective by the consequences of the ageing of populations (BIS (2001)) and of a still imperfect integration, have been addressed in the technical field, for example by an enhanced harmonisation of technical standards regarding public bond issuance in euros between sovereign issuers (eg similar coupon calculation conventions). More radical responses, such as fully coordinated debt issuance by the member countries of the euro area in order to foster a broader and deeper market for government securities (eg creation of a multilateral agency), are problematic, both technically and institutionally: the market is probably not yet ready to accept instruments with mixed credit ratings; moreover, cross-government guarantees are not consistent with the Maastricht Treaty.

Table 4

Euro area government long-term debt by sector of holder

(as a percentage of total)

	Domestic creditors[1]				**Other creditors**[2]
	Total	**MFIs**	**Other financial corporations**	**Other sectors**	
1997	76.4	38.8	19.3	18.3	23.6
1998	73.4	37.0	22.2	14.2	26.7
1999	69.8	35.2	20.5	14.0	30.2
2000	66.9	33.8	19.5	13.6	33.1

[1] Holders resident in the country whose government has issued the debt. [2] Includes residents of euro area countries other than the country whose government has issued the debt.

Sources: IMF (2001) and *ECB Monthly Bulletin*, Table 7.2 for the year 2000.

While still imperfect, integration has nevertheless improved on the secondary market with the removal of some obstacles to geographical diversification within the euro area brought about by the introduction of the euro, such as regulations restricting currency mismatches on institutional investors' balance sheets or by an increased integration of securities settlement systems. The share of government debt securities held by "domestic" investors (ie holders resident in the country whose government has issued the debt) has decreased from 73.4% in 1998 to 66.9% in 2000. "Non-domestic" (ie euro area residents and foreign investors) creditors' holdings account currently for one third of the total stock of euro area government debt securities, reflecting a lesser "national bias" of euro area investors and, more generally, an increasing internationalisation of the euro bond market.

[2] For example, the single largest borrower, the Italian Treasury, accounts for no more than 30% of the outstanding stock of euro-denominated government securities.

2.1.2 *Implications of the increasing importance of the private euro bond market*

Liquidity is rising in the private segment of the euro area bond market, with issuance having accelerated sharply since the beginning of 1999. The overall outstanding amount of private bonds increased by 16% in 1999 and by 12% in 2000. Non-euro area issuers are particularly active in the market: their share of the total outstanding amount rose from 13% at the end of 1998 to 18% in 2000. Private issuance in general has been stimulated by the introduction of the euro, which has brought about a widening of the investor base and reduced government issuance, and by other structural factors such as the funding requirements associated with large mergers and acquisitions or related to the deregulation of telecommunications companies and to changing technologies such as the sales of UMTS licences.

Bonds issued by financial institutions still dominate the market, reflecting the importance of bank finance in continental Europe (eg “Pfandbrief-style” mortgage bonds), banks being the main channel of financing for euro area corporates and partly relying on capital markets for their own financing. Financial institutions seem to have benefited the most from a “crowding-in” effect since their issuance, generally at initial maturities of 10 years or above, ie in the maturity range most particularly affected by the retrenchment of the public sector, has increased in nominal terms. However, the corporate segment of the market, which remains concentrated in the shorter segment of the yield curve, has been very dynamic, particularly the non-resident segment.

Table 5

Outstanding long-term euro-denominated long-term private securities

(as a percentage of total)

	Euro area residents			**Non-residents**			
	Banks	**Non-monetary financial corporations**	**Non-financial corporations**	**Banks**	**Non-monetary financial corporations**	**Non-financial corporations**	**International organisations**
End-1998	73.9	4.9	7.6	4.6	1.9	2.2	4.9
End-1999	69.5	6.8	6.9	5.6	2.9	3.9	4.4
End-2000	65.6	7.6	8.8	6.6	3.1	4.8	3.5

Source: *ECB Monthly Bulletin*, Table 3.6.

The lag in the response of euro area corporations can be related to the fact that relatively few firms in the euro area (less than a third) had credit ratings at the time of the introduction of the euro since bank finance is predominant.

Consequently, whereas the euro government bond market is comparable in size to the US Treasury market, the euro area non-government securities market represents less than one third of the US dollar market, which is characterised by more active markets for corporate financing and for mortgage-backed securities.

However, non-government issuance is generally expected to remain relatively buoyant in the medium-term as non-bank finance grows further. As euro area private markets grow in importance, especially the corporate market, so will the need for reliable benchmarks for pricing private bonds and managing liquidity and trading positions in securities markets. The growth in the issuance of corporate bonds together with the lack of a single, clearly defined benchmark sovereign yield curve has already enhanced the depth of the euro swap market.

Moreover, the expansion of the corporate bond market has encouraged diversification of bond portfolios into “credits” and will stimulate the development of new segments of the market such as credit derivatives.

Table 6
Size of non-government bond markets in 2000

	Outstanding stock (billions of US dollars)	Sector of issuer (percentages of total non-government debt outstanding)		
		Financial institutions	Corporates	Government sponsored enterprises
Euro area	3,964	73.2	17.7	6.3
United States	13,222	41.2	24.8	14.4
Japan	2,577	39.8	34.0	25.0

Source: BIS (2001).

2.2 Electronic trading systems: from theory to reality

Among the numerous structural changes that have taken place on financial markets during the last decade, the sudden emergence of the "new technologies" is one of the most striking, as it, potentially at least, affects the infrastructures of the markets in their entirety, from the trading desks of wholesale market participants and brokers to the settlement and clearing processes, from the institutional investor to the retail participant. In Europe, organised markets (for instance stock exchanges and futures markets) have led this move towards electronic devices, rapidly followed by the forex market and, at a later stage (in the wake of the monetary unification process), by bond and interest rate markets.

Basically, one can distinguish three groups of electronic platforms that cover the whole range of market activities:

– *Transaction platforms*, which match reciprocal interests from market participants, and allow transactions to be completed electronically; due to safety considerations, these platforms tend to use secured/proprietary telephone lines.

– *Distribution systems*, which are customer-oriented and allow a participant to centralise order flows from his clients and help secure his customer relationship. For cost considerations, these systems usually rely on internet-based technologies. While the initial approach was a bilateral one (between one market participant and his clients), the second generation of these platforms took a different approach, allowing a client to simultaneously access offers and services from a range of participants.

– *Issuance/initial offering platforms*, allowing issuers to reach more directly a wider range of final investors. These platforms are still at a very preliminary stage of development.

The following developments will mostly concentrate on the impact of these changes on wholesale over-the-counter markets (foreign exchange and interest rate markets).

When considering the changes that are being brought about by the spread of electronic systems, a crucial aspect is to assess whether these changes translate into a better functioning of financial markets, on an ongoing basis, and increase their stability and resilience in periods of stress. While, theoretically, the electronic revolution has the potential to deeply transform the functioning of financial markets, the magnitude of its impact up to now has been limited.

2.2.1 A better functioning of financial markets?

In theory, various characteristics of electronic markets can be considered as leading to an overall improvement in the functioning of financial markets.

A wide dissemination of accurate information, a large base of participants and investors and a liquid secondary market are among the key requirements for an efficient functioning of financial markets. Potentially, the technical changes brought about by the dissemination of new technologies are susceptible to improving the functioning of financial markets on these three scores, ultimately leading to lower costs (as the marketplace becomes more competitive and technology more affordable) and allowing for increasing volumes.

2.2.1.1 Brokerage activities

The spread of electronic devices fundamentally alters the way brokerage has been traditionally conducted on OTC markets. Voice brokers are facing increasing difficulties to remain competitive when confronted with electronic platforms that offer automation possibilities (for instance, automated links with futures markets, allowing for immediate hedging, constant updating of prices and spread relations, etc), real-time execution and increased reliability at low unit costs. Indeed, on the forex market, electronic systems such as EBS or Reuters Dealing already capture most of the professional flows on the major pairs of currencies. The move towards electronic devices is also rapidly gaining momentum on bond markets, as traditional brokers turn electronic (Cantor's E speed) and new platforms develop (BrokerTec, the MTS family).

2.2.1.2 Market-making and market liquidity

Aside from pure brokerage systems, some bond market platforms impose market-making obligations on their participants, in order to guarantee a certain level of liquidity in the system. Such liquidity risk sharing agreements between participants are not new in essence (primary dealership frameworks often implicitly rely on a similar approach), but their implementation through electronic systems allows for a more systematic enforcement.

These market-making commitments are also expected to revive trading activity on "off-the-run" securities, which traditionally suffer from a lack of interest from market participants, due to a greater degree of illiquidity, translating into wider bid-offer spreads: once market-makers feel more comfortable with the structural liquidity of these securities, they will show more willingness to post their interests.

Electronic platforms on the bond market are more and more systematically offering connection functionalities with netting/clearing systems, a move that also has to be seen as positive in terms of market liquidity as it decreases bilateral counterparty risks for participants and thus frees up resources.

2.2.1.3 Transparency and price discovery

The development of electronic platforms allows for a wider and more rapid spread of information among the community of market participants, thus translating into a faster integration of new pieces of information into prices, a higher level of transparency in the price formation mechanism, and ultimately leading to more homogeneous pricing patterns (curve arbitrage). An illustration of this can be found in the ability of some platforms to give their participants a detailed picture of the pending interests in the marketplace, and a sense of the depth of the market.

This increased transparency is expected to benefit not only market professionals, but also, ultimately, final investors, who can take advantage of this improved dissemination of information on prices and volumes.

2.2.2 The full effect of the electronic revolution remains to be seen[3]

A preliminary appraisal of the move to electronic markets leads to mixed conclusions: while electronic platforms have been able to gain market shares in the most widely traded market segments, their impact on the functioning of these markets remains limited.

2.2.2.1 A quantitative assessment of European interest rate markets

Bond markets: a mixed picture

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[3] Coverage of the following developments relies extensively on information provided by S Lange and C Stevant (from the Bank of France Front Office Division).

– *Inter-dealer markets:* electronic systems are seen nowadays as capturing more than 50% of market-makers' cash volumes, with the MTS platforms being considered the main beneficiaries of this trend. However, it is worth noting that the average size of trades remains small (€10 million) and that trading is still concentrated on a limited set of benchmark bonds.

– *Dealer-to-customer markets:* the use of ET systems is significantly less pronounced than on the inter-dealer market, and is estimated to represent about 5% of the total business.

Money market cash transactions**:** a high level of concentration

– The leading European electronic platform is e-MID, which has an average daily turnover of €15 billion, a significant volume compared to the declared EONIA volumes (€40 billion). Liquidity appears highly concentrated both in terms of maturity (an overwhelming share of the business is done on the O/N and T/N segment of the market) and as regards the participants.

Repo markets: a rapid development

– Electronic platforms represent about 8% of the global market activity. However, it is widely considered that this segment (for GC transactions, especially on short maturities) is potentially among the fastest growing ones as ET capabilities could significantly reduce back office costs. The market appears spread between two major platforms.

Derivatives and corporate markets: still marginal

– Electronic trading in derivatives has remained quite limited up to now.

– Various platforms (notably the MTS family) now offer a "credit segment" (Pfandbrief-type bonds, supranational and agency bonds) as a complement to the initial government bond segment. However, activity remains largely concentrated on the latter. A reason for this lack of activity, despite the introduction of market-making commitments and strict listing requirements, might be that activity on the corporate market is mostly driven by final investors' demand, and thus follows a much less active pattern than government bonds.

2.2.2.2 Limited impacts on the functioning of financial markets

As mentioned above, electronic markets can be expected to lead to more transparency in the price discovery mechanism and to more liquid markets. However, observation of day-to-day market functioning, during quiet periods as well as under stress conditions, leads to mixed conclusions.

Transparency remains limited

– While transparency is a plus for the market community as a whole, it does not necessarily serve the interests of each and every participant systematically. More specifically, major participants in a market segment can prove reluctant to "publicise" their trading interests (even anonymously) through electronic platforms for fear that it could alter their execution conditions. Hence, big size trades are often executed outside these platforms, or spread between different devices. Consequently, the market picture given by the electronic systems can easily prove incomplete and biased.

– It remains to be seen if the development of electronic systems has narrowed the existing gap between the major market participants that are able to participate in the different existing systems, and thus have a "global picture" of the marketplace, and a "second tier" group of market participants that gravitate around the former and are not in a position to fully benefit from the capabilities offered by the new information technologies.

Liquidity lacks resilience

– Contrary to initial expectations, the development of electronic platforms, especially when supplemented with market-making commitments, does not automatically lead to an improvement in market liquidity. Market-making has for years been affected by decreasing margins and low returns on capital. This trend has indeed been reinforced in recent years as new information technologies have strengthened the position of the "buyer's side" (investors) at the expense of the "seller's side" (market intermediaries). Hence, the business of making prices for the market community appears less and less affordable to the vast number of market participants, and more and more concentrated among a small group of major market participants. Consequently, there is the fear that liquidity, an ill-compensated risk, will prove even more fragile, because increasingly dependent on a small number of global players, as electronic platforms gain market share.

– While this might not be a major problem in quiet times, it could prove detrimental to the market's functioning in periods of stress, when the number of market-makers willing and able to provide liquidity might shrink. Such episodes of liquidity gaps have been experienced during recent years on the forex market. An illustration of the difficulty encountered by market-makers can be found in the behaviour of the euro bond markets following the events of 11 September 2001 in the United States: the sudden deterioration of market conditions translated into a widening of bid-offer spreads that made market-making commitments on the platforms unrealistic to fulfil. Participants on the MTS and Eurex platforms decided to stop carrying out their market-making obligations and returned to the "old-fashioned" but more flexible way of trading.

2.3 Some potential sources of amplification of market dynamics[4]

We will focus here on some factors that can be seen as prone to amplifying market dynamics but that are not specific to the euro area. While different in nature, what these factors have in common is to focus on the behaviour of market participants. The analysis of the financial market events of 1998 has clearly shown that, in times of market stress, the combination of short-termism, herding behaviour and a generalised use of similar risk management techniques could amplify the homogeneity of behaviours and contribute to market disruption and the spread of difficulties from one market segment to another. It should be noted that, up to now, markets have shown a higher degree of resilience than might have been feared in the aftermath of the tragic events of September 2001.

2.3.1 Imitation in behaviours: can they be rational attitudes?

Numerous research projects have been devoted to studying the role of imitation, among market participants, in the dynamics of asset prices, and the development of asset bubbles and their subsequent collapse. Departing from the theoretical approach that considers the "standard" investor a rational person deciding on an investment strategy on the basis of an objective and up-to-date set of information, these approaches insist on the importance of interactions between market participants in their decision-taking process, and more specifically in the way they treat information. Such interactions help explain why contagion phenomena can take place, translating into excess volatility and leading ultimately to the development of asset bubbles: in a simplistic way, an irrational (valuation) situation can be defined as a situation where decisions based on expectations regarding other participants' behaviour spread among participants and take the lead over decisions based on a fundamental analysis.

However, as shown by Kindleberger (1978), concluding that the global outcome (the situation prevailing on the market at some point in time) is irrational does not necessary mean that market participants individually have behaved irrationally in the first place.

Indeed, imitation, when considered from the individual's point of view, can be seen as a rational behaviour. Orléan (2001), for instance, offers an interesting classification of rational imitation patterns, distinguishing three different sorts of behaviours:

– *Informational imitation*, as it may be more judicious for a participant to herd with better informed participants than to acquire the needed information. As long as market prices can be considered as reflecting fundamental values, less well informed participants will be better off using these prices than conducting their own costly research and analysis. However, as shown by Grossman (1975 and 1976), as the incentive to collect information diminishes, so does the content of fundamental information encapsulated in the price. Unfortunately, the moment when a collection of individual rational imitation behaviours turns into a collective irrational pattern cannot be determined ex ante. A distinction is traditionally drawn between

[4] An in-depth analysis of factors amplifying the financial cycle will appear in the Bank of France's November 2001 monthly bulletin.

"insider" and "outsider" investors, the former category encompassing well informed market professionals, having direct access to the market (fund managers, for instance), and the latter represented (mostly) by individual investors that do not benefit from the same tools, background and experience. Such a switchover from rationality to irrationality is all the more likely to happen as the number of "outsiders" grows. However, it would be too simplistic to infer that professionals are not prone to such behaviours.

– Even when (and if) participants realise that the market is moving away from what fundamentals would justify, it can still make sense for them individually to ignore such signals and feed the momentum. Once the existence of an asset bubble is recognised, the behaviour of the participants will depend on their estimation of when it will burst, ie on the probability that it will do so before the participants exit the market. As long as the potential rewards of investing in the bubble are seen as exceeding the rewards of retreating on a non-inflated asset, rationality commends feeding the bubble. In such circumstances, markets can be prone to *self-fulfilling imitation.* The analysis of informational cascades (Lee (1998)) shows how participants can chose to do so and deliberately ignore their own negative signals.

– Such situations are especially liable to happen as market participants, like any human group, have an inclination to generate a common set of rules and beliefs that will drive their behaviour and understanding of events, leading to a tendency to conformism. Once established, this consensus will not easily be challenged, translating into some sort of *conventional imitation.* Such a set of common beliefs does not need to emerge *ex ante*, and help trigger the movement. It can indeed materialise ex post, once the bubble has already inflated, and help justify its development. For instance, the virtues of the "new economy paradigm" and the idea that traditional valuation tools were inadequate to appreciate the movements in internet stocks to a large extent appeared after the stock market had already made most of its upward move.

– As mentioned above, it would be oversimplistic to consider, based on a rigid distinction between "insider" and "outsider" investors, or "informed" and "uninformed" investors, that only the outsiders/uninformed participants can succumb to such behaviours. On the contrary, there are reasons to believe that all kinds of market participants can be "victims" of these imitation biases and participate in herding. Institutional fund managers, for instance, because of the way their performance is measured, can be inclined to follow such imitative patterns. As the industry of fund management makes intensive use of benchmarking to judge the performance of its members, there is a natural tendency to appreciate one's performance on a relative basis (compared to one's peers) rather than on an absolute basis. This is all the more true when fund managers are compensated according to their market share: the risk of underperforming the "average" manager seems to be given more weight than the potential reward of outperforming. In the same vein, herding has been evidenced among stock analysts and investment newsletters (see, for instance, Jondeau (2001) for a survey of herding behaviour in financial markets).

– "Large players: are they destabilising?" Herd behaviour can be observed on markets whose agents are small and atomistic. However, a strand of the literature has investigated both theoretically and empirically the role of large players, ie agents with market power on market dynamics, in particular in currency crises. The main finding can be summarised as follows (Corsetti et al (2000)): the presence of a large player injects a degree of strategic fragility into the market. The influence of large players is not mechanically related to size, as measured by the value of asset holdings or market share (Corsetti et al (2001)). It depends also on the fact that they are better informed (or perceived to be better informed[5]), able to build sizeable short positions via leverage and prompt to react to a change in fundamentals. Consequently, their strategies provide a "focal point" for speculative behaviour, in particular for smaller investors prone to herd on their positions. Therefore, the presence of a large player makes

[5] Analysing the results of a survey of US-based foreign exchange traders, Cheung and Chin (2001) find that some smaller segments of the market are believed to be dominated by a few big players. Large players are perceived to have a better customer and market network and, consequently, to have better information.

other investors more aggressive. Globalisation might incite smaller players to herd. Calvo and Mendoza (1996) show that the increasing number of countries available for international investment reduces the incentive of individual investors to acquire costly country-specific information, especially for highly diversified investors. Accordingly, investigating international US bank lending, Barron and Valev (2000) find that small US banks follow the behaviour of large banks: private lending by small banks responds primarily to private lending by large banks with regard to which countries to lend to. Moreover, they follow large banks to a greater extent in countries where there is more persistence in economic conditions (ie where prior investment behaviour provides valuable information about the current state of the economy).

2.3.2 Index management: is it neutral on market dynamics?

Index management began developing dramatically during the 1970s, in parallel with the modern portfolio theory by Markowitz (1959) and works on market efficiency by Fama (1970). Modern portfolio theory states that, in an "efficient" market, a diversified portfolio guarantees an optimal performance: in such a market, where every piece of new information is immediately and fully reflected in the price of financial assets, an investor cannot systematically beat the market as a whole (the market is considered here as a proxy for the optimal market portfolio). Hence, it is wiser, and less costly, to mimic the market, through a diversified portfolio that replicates its global performance, than to actively trade the market (stock picking/stock selection).

The idea of efficiency, which constitutes the ground on which the index investment approach is built, is a complex notion, still under discussion among academics. This issue will not be discussed here.

By definition, index management offers a performance close to that of the reference index, at a low cost. As the turnover of the portfolio is limited, transaction costs, as well as research costs, are reduced. As a matter of fact, management fees associated with index funds are in general below 0.5%, against 0.8 to 1.2% for actively managed funds. Indeed, competition among index funds tends to concentrate on management fees, as performances appear, by construction, very similar. In addition, the tax treatment is usually also more favourable than on an actively traded portfolio.

However, some issues arise when considering index management:

2.3.2.1 From the theoretical framework to the practical approach

– The theoretical approach to index management implicitly considers that stock returns are distributed according to a normal distribution, which means that, among the shares that constitute the index (the portfolio), none contributes to the global performance for a proportion significantly different from the average contribution. If so, the index can be considered as the "average" stock. On the other hand, if the distribution of returns is not normal, then the contribution of each and every stock is meaningful, and "stock picking" and the skills of the fund managers become significant contributors to the global performance. The portfolio is then seen as a collection of particular stocks. Whether or not stock returns are distributed according to a normal distribution appears to be increasingly discussed in the literature. This question is of special interest when markets deviate from their "normal" pace and show either very high or very low levels of activity: in both cases, the performance of a portfolio compared to its benchmark index will crucially depend on the ability of the manager to pick up the right mix of assets.

– The above developments regarding imitation in behaviours have shown that the Efficient Market Hypothesis can be called into question: according to Grossman and Stiglitz (1980), under costly information, no equilibrium-efficient markets can exist. Similarly, one has to recognise that the very restrictive assumption of the CAPM (identical investment horizons, and homogeneous beliefs regarding asset returns and covariances among investors, unlimited access to short selling/borrowing) is hardly met in reality.

– Strictly speaking, a true index management approach should not be limited to an asset class (shares, bonds), as each of these classes represents only a fraction of the global universe of tradable assets, but should encompass all the categories of risky assets available on the market. Limited to a sole asset class, this approach ends up favouring an asset category to the detriment of the other ones, and thus risks distorting their relative prices. The same remark holds within an asset class when index management is excessively focused on a specific index or family of indices (the major stock indices, for instance: in the United States, some 75% of index funds replicate the S&P 500 index). Interestingly, while active fund managers regularly underperform the major stock indices, they keep on overperforming the less widely known indices and the specialised ones. As regards index management on the stock markets, the question arises whether the inability of active fund managers to beat the S&P 500, for instance, is due to the intrinsic superiority of index management or to the excessive weight of the indexed management approach on the market for the shares that compose this index. Additionally, it would be worth examining which part of the overperformance of index funds comes from the tax effect.

While active fund managers are usually less diversified within a single asset class (an active stock manager generally does not own all the S&P 500 components), they are indeed usually more diversified among various asset classes, owning, as a complement to the core investments, cash/money market products and/or bonds. This diversification can act as a cushion in adverse market conditions, a comfort that does not benefit "pure" index funds. Indeed, it is interesting to note that new types of funds have been attracting renewed attention recently, following the stock market correction: "all-in-one" funds, which pool stocks, bonds and cash, either through a mix of actively traded funds or through index funds. As of 20 June 2001, the three-year annualised return on some of the largest of these "all-in-one" funds was ranked from 10.9% to 3.1%, depending on the mix of assets of each of these funds, compared with +4.9% for the S&P 500 index over the same period.

2.3.2.2 On the dynamics of market prices: is there a risk of an "index bubble" as the growth of indexation interferes with market pricing efficiency?

What is at stake is the question of whether or not index management introduces a bias in the dynamics of prices. Three aspects of this general question are worth mentioning:

– The development of index management means that there are more "passive price follower" investors and market participants and fewer active ones. As such, one can ask whether this phenomenon impacts on the quality of the price discovery mechanism: not only are asset prices being determined by a decreasing group of market participants, but at the same time these prices are undisputed, and, to some extent, "ratified" as a whole by the community of passive investors. In essence, passive management looks like a "free rider strategy" that by definition cannot be generalised: in a world where passive management would dominate, relative prices of assets would stop carrying any information about the underlying issuers (but indexers by definition are insensitive to relative value), while absolute prices would only reflect the magnitude of the global flow of funds.

– Everything else being equal, index replication tends to amplify short-term market movements. Faced with a rise (a drop) in the price of a particular stock that will change its weight in the index, the index manager will be mechanically led to increase (decrease) its position on this specific share, thus amplifying the initial price movement (see, for instance, Artus and Orsatelli (2001)). This can act as a strong disincentive for active managers to trade on fundamental views, as there is less guarantee that mispricing will soon be corrected. On the other hand, one can consider that active managers will be tempted to "front run" passive managers and implement strategies based on index additions and deletions.

– The increasing demand for indices (for replication purposes as well as for performance measurement) raises the question of the influence of the "index industry" as a whole on the behaviour of markets, as indices are not neutral as regards market price dynamics. The decision to include a specific share in an index is likely to lead to the appearance of a "price bias" (whether this bias is a permanent or only a temporary phenomenon remains open among academics). While such a (upward) bias appears justified to some extent as it reflects the liquidity premium attached to the said stock, it might be magnified through the amplification mechanism of the "passive" imitation attached to index managing. This might be even more the case when the weight of a specific stock in an index does not adequately reflect its actual "tradable/investable" quantities, ie when its weight is based on its total capitalisation instead of being derived from its "free float". In this respect, it is welcomed that the major index providers have now embarked on a process of adjusting their index building methodology to reflect the "true" market capitalisation of their index components (ie free float). More generally, these potential problems clearly show the crucial importance of securing well designed/objective (ie representative) index constitution processes.

The use of capitalisation-weighted indices can lead to disturbing, or even aberrant situations. Such phenomena have been well publicised on equity markets, especially in continental Europe as former state-owned companies were progressively brought to the market. But they can also appear on fixed income markets: for instance, the sheer increase in Japanese government bonds in recent years, while the relative supply of bonds in some other government markets was declining (in the United States and the United Kingdom notably), has translated into a growing weight of JGBs in bond indicies, leaving indexers with no choice but to increase their allocation of Japanese bonds, at a time when these bonds not only offer historically low yields but are also subject to rating downgrades.

Lastly, the distortion that indices can contribute to creating between stocks when one is included in the index and not the other is not neutral for the firms themselves as it translates into distortions in their respective cost of capital.

Ultimately, what is questionable is not the idea of passive management through the replication of an index, but the extensive use of standard indices that are supposed to represent “the market” as a whole. For an investor, defining a theoretical portfolio that matches his investment goals (in terms of duration, risk profile, sector allocation, etc) and replicating this portfolio or its profile is obviously the sensible approach. But the replication of a standard “market portfolio” implicitly leads to the puzzling idea that in the world of investment “one size can fit all”. Indeed, tailor-made benchmarks and indices entail more costs than using standard indices, and thus reduce the traditional cost advantage that is supposed to be enshrined in index management.

In this respect, the development of “all-in-one funds” as well as the move towards a “core/satellite” portfolio approach (the combination of a core, passively managed portfolio and aggressively managed satellite portfolios) can be seen as potentially significant improvements on the traditional indexing approach, as they imply a higher degree of diversification and give increased weight to the manager’s judgment. However, it is clear that the border between a “traditional” active management and the “core/satellite” approach is difficult to draw precisely.

2.3.3 The use of value-at-risk (VAR) techniques

VAR/DEAR (daily earnings at risk) calculations have become the standard approach implemented by market participants to assess the risks deriving from their financial market activities, whether they act as market-makers or investors. These approaches have also been encouraged by supervisors who have promoted market-sensitive risk management systems over recent years. Both the 1996 amendment of the Basel Accord on regulatory capital for market risk and the new capital adequacy framework are illustrative of this new climate. Position limits are frequently defined, and consequently stop-losses triggered, according to this risk management framework. As such, VAR calculations obviously represent useful tools for market participants as they help them quantify and monitor more precisely the risks inherent in their market activities.

However, it is legitimate to ask if what can be rightly regarded as beneficial at the level of each firm remains positive when considering the community of market participants as a whole: can an attitude that may be considered rational at the level of the firm become counterproductive when simultaneously adopted by numerous participants?

A series of weaknesses in the VAR approach have been identified, and feed these concerns:

– By construction, VAR models fail to take into account the feedback effects on market conditions that result from the implementation of decisions based on their signals. As stated by Shin et al (2001), “by their nature [these] systems treat the uncertainty governing asset returns as being exogenous” and “fail to take into account [...] the fact that the behaviour of market participants is affected by the adoption of these techniques, creating a feedback effect on the whole financial system”. It is quite surprising to see that while the day-to-day observation of market participants’ behaviour shows that they treat market risk (defined here as the impact on market behaviour of their own decisions and the decisions of their peers) as endogenous, the risk management systems they use do not.

– Models developed by Shin et al (2001), but also by Artus (2001), show puzzling consequences of the widespread use of these risk management techniques: a general tendency for prices of risky assets to be undervalued, a greater instability of their equilibrium prices, and a global decline in market liquidity. Somehow, the use of VAR techniques translates into a permanent increase in the market’s level of risk aversion. However, this level of risk aversion keeps on fluctuating with the current market situation, and becomes especially constraining in periods of stress, thus amplifying market disruptions and contagion phenomena at the worst time.

If a greater focus on risk management techniques and on internal models and ratings might contribute to financial stability in general, the combination of market participants' behaviours, prone to herding, index management and the spread of identical tools for the analysis of risks might deliver the opposite result in periods of market stress. In such periods, the lack of diversity amongst behaviours and techniques might result in the disappearance of market counterparties, or market-makers, and quite sharply reduce market liquidity. Besides these financial stability issues, recent changes have also impacted on the way central banks operate.

3. Impact on central banks' policies

The deep changes recently observed on financial markets have directly impacted on the transmission mechanism of monetary policy: for example, technical changes are likely to have improved financial markets' efficiency, from which one might expect a greater responsiveness of both prices and real activity to monetary policy impulses.

As a consequence, both the tactics and the implementation of monetary policy have to deal with and adapt to this new environment.

3.1 Should monetary policy react to asset prices?

The greater role played by financial markets and their potential effects on the real economy have recently raised the issue of whether monetary policy should react to financial prices, and more generally to asset prices. Not only could the large swings observed on asset prices endanger price stability, which is the primary objective of most central banks, but also they could impinge upon financial stability.

Recent papers addressing this issue are far from having reached a consensus: in their seminal paper, Bernanke et al (1999) advocate that central banks should ignore movements in asset prices that do not appear to generate inflationary or deflationary pressures. Conversely, elaborating on the same model, Cecchetti et al (2000) conclude that central banks should react systematically to asset price bubbles in many cases.

In order to assess these conclusions, we slightly modify the framework of Bernanke et al (1999) by introducing various monetary policy rules, depending or not on asset prices. Then, we try to analyse the welfare implications of these rules by assuming the central bank is seeking to minimise a loss function à la Rudebusch and Svensson (1999):

$$L = \lambda_{\pi} \mathrm{Var}(4 \times \pi_t) + \lambda_y \mathrm{Var}(y_t) + \lambda_r \mathrm{Var}(r_t) \qquad (1)$$

where $(4 \times \pi_t)$ stands for the annualised inflation rate, y_t is the output, r_t the nominal interest rate and λ_{π}, λ_y and λ_r the weights assigned to these variables by the monetary authority. All the objective variables are expressed in deviations from their steady state levels. Var(x) stands for the unconditional variance of x. The weights respectively take the values of 1, 1 and 0.5 as in Rudebusch and Svensson (1999). Since these weights are not uncontroversial, Table 7 below provides an estimation of each component of the loss function.

We consider three different kinds of policy rules: (1) "accommodative", for which the central bank moves its key policy rate according to the changes in expected inflation so as to keep the real interest rate unchanged; (2) "aggressive", for which the central bank overreacts to the changes in expected inflation so as to modify the real interest rate; and (3) a Taylor-like rule, which depends on the output gap, the deviation of the inflation rate from the target (here set equal to zero for convenience) and the lagged nominal interest rate to account for financial stability purposes (interest rate smoothing). Each of these rules is considered in two versions, one of which incorporates the central bank's response to asset prices, with a 10% weight.

Whereas Cecchetti et al (2000) only consider a single scenario of a bubble in asset prices lasting exactly five periods, we try to account for the probabilistic nature of the bubble, and consider the entire probability distribution of this shock. For each of the envisaged monetary policy rules, we compute out the second moments of the variables by taking averages across 500 stochastic simulations of the model.[6] Four different shocks are embedded in this model: a technological shock, a demand shock, a monetary policy shock and an asset price bubble. As in Bernanke and Gertler (1999), we make the termination point of the asset price bubble probabilistic and assume that the probability of the bubble lasting another period is 0.5. Following Battini and Nelson (2000), we divide our 500 simulations into nine unequal amounts, each associated with the bubble ending after 1, 2, … 9 periods.[7] The results are provided in Table 7.

Table 7

Welfare implications of alternative monetary policy rules

Forward-looking policy rules	**Standard deviations**			**Loss**
	$\sigma(4\times\pi)$	$\sigma(y)$	$\sigma(r)$	
$r_t^n = 1.01 \cdot E_t \pi_{t+1}$	41.10	13.71	10.23	1,929.91
$r_t^n = 1.01 \cdot E_t \pi_{t+1} + 0.1 \cdot s_t$	26.02	1.14	6.57	700.12
$r_t^n = 2.0 \cdot E_t \pi_{t+1}$	0.22	1.29	0.95	2.17
$r_t^n = 2.0 \cdot E_t \pi_{t+1} + 0.1 \cdot s_t$	0.43	1.19	0.85	1.96
$r_n^t = 0.765 \cdot r_{t-1}^n + (1 - 0.765) \cdot [1.26 \cdot E_t \pi_{t+1} + 0.63 y_t]$	7.26	1.87	1.76	57.68
$r_n^t = 0.765 \cdot r_{t-1}^n + (1 - 0.765) \cdot [1.26 \cdot E_t \pi_{t+1} + 0.63 y_t + 0.42 s_t]$	8.73	1.56	2.07	80.86

Note: S_t stands for the market asset price.

As shown in the table, responding to asset prices generally reduces the loss incurred by the monetary authorities (comparing (2) to (1), and (4) to (3)). But this is not systematic since, when incorporated in a Taylor-like rule,[8] it may then generate higher losses. Conversely to Cecchetti et al (2000), our results are not sensitive to the parameters of the Phillips curve, which has the features of the New Phillips Curve, described in Gali et al (2000), and is calibrated according to their econometric estimations.

As in Bernanke and Gertler (1999), we find that what is most important to limiting asset price bubble casualties is to implement an aggressive monetary policy since, according to our results, the greater the responsiveness of nominal interest rates to changes in inflation expectations, the lower the loss.

To conclude, even if financial prices provide central banks with useful information about both future activity and prices, they should not directly enter the central bank's reaction function. Furthermore, on practical grounds, it may be very difficult to detect with certainty whether asset price changes reflect the dynamics of fundamentals or rather are due to a bubble.

Needless to say, financial prices must be part of the information set the central bank mobilises when setting its monetary policy. But the recent changes observed on financial markets may also have impacted on their information content.

[6] See Clerc (2001) for details.

[7] Because the probability of a bubble lasting nine periods is the smallest, the number of simulations considering this case is the lowest: out of 500 simulations, only one is dedicated to a bubble lasting nine periods ($500*0.5^9 \approx 1$).

[8] The Taylor rule has been estimated on euro area data using GMM. See Verdelhan (1999) for details.

3.2 A need for new indicators for monetary policy

Amongst the most important changes observed these last few years, Section 2 of the paper has pointed out some issues raised by the changes in the relative supply of government and private debt securities. The introduction of the euro, the emergence of a euro bond market supported by technical changes, and potentially increased competition amongst European issuers may have impacted on the informational content of government bond yields for the conduct of monetary policy.

Government bonds constitute a traditional indicator for monetary policy. Using the standard Fisherian approach, according to which the nominal interest rate can be explained as the sum of the real rate, expected inflation and a risk premium term, they provide monetary authorities with some information on future economic activity, since the real rate is generally considered as reflecting long-term growth prospects, future inflation and to some extent the uncertainty associated with these expectations, via the risk premium term. Furthermore, when assuming a constant risk premium and a steady real rate, changes in nominal bond yields reflect changes in inflation expectations and, as such, provide central banks with a measure of their credibility.

Since the seminal papers by Harvey (1988) and Stock and Watson (1989), the slope of the yield curve has been considered a useful indicator for monetary policymakers: the performance of this slope, generally measured as the difference between a 10-year government bond's rate and a short-term rate, as a leading indicator of future economic growth has been well established. Estrella and Hardouvellis (1991) for the United States, Estrella and Hardouvellis (1997) for some European countries, Ricart et al (1997) as well as Sédillot (1999) for France, and more recently Hamilton and Kim (2000) have evidenced such a performance. For instance, Hamilton and Kim (2000) compare the slope of the yield curve, computed as the difference between the 10-year Treasury bond and the three-month Treasury bill, to the annualised growth rate of US real GDP and show that the yield curve has flattened or become inverted prior to all seven recessions identified by the NBER.

Recent patterns observed on financial markets may have diminished this information content of government bond yields:

– first, medium-term budgetary consolidation in the major industrialised countries evidenced in Section 2, accompanied by debt buyback programmes in the United States, the United Kingdom and some European countries, provoked an inversion or a flattening of the yield curve in these countries, unrelated to any expectation of a forthcoming recession. Moreover, volatility in government bond yields may have increased due to discrepancies between demand and supply of bonds, therefore reducing their usefulness as leading indicators;

– second, EMU has accelerated the process of integration of financial markets in Europe and created a wide euro-denominated market for government securities. However, as pointed out by the IMF (2001), this market remains segmented. As a consequence, different maturities are characterised by different degrees of liquidity and therefore are not traded in a homogeneous manner across the euro area. In such a context, it is likely that the slope of the yield curve does not convey accurate information about future growth prospects but rather embeds variable liquidity premia;

– third, recent papers by Gertler and Lown (2000) and Dotsey (1998) also show that some standard indicators such as the term spread, which performed well through the 1980s, have lost considerable forecasting power in the last few years. One explanation, provided by Gertler and Lown (2000), relates this reduction in explanatory power to recent changes in the role monetary policy plays in the business cycle.

As a consequence, new indicators, which convey similar information to government bond yields, are needed. Some alternatives have already emerged.

Swap yield curves, for example, may better reflect market interest rate expectations than government bond yields. As noted above, government bond markets, or segments of the market, may be relatively illiquid, whereas swap markets are generally liquid and the contracts standardised across currencies, as far as credit, taxes and structure are concerned. The only caveat in using swaps rather than government bond yields is the credit risk they entail.

Focusing on the role financial factors may play in the business cycle, Gertler and Lown (2000) consider the market for high-yield corporate bonds as another possible alternative. According to the literature dedicated to the "financial accelerator mechanism", imperfect credit markets give birth to the so-called external finance premium, by which financial factors amplify and propagate business cycles.

In their analysis, they consider the information content of the spread between the high-yield bond rate and the corresponding safe rate, which may approximate the external finance premium. According to their results, such a spread outperforms other leading indicators, including the traditional term spread. As far as the euro area is concerned, the issuance of corporate bonds has accelerated dramatically over the recent period. However, the market for corporates in the euro area is far from being as important and as liquid as in the United States. Indicators of this kind should also be considered by policymakers although they are currently probably less relevant for the euro area.

3.3 New issues related to the transmission mechanism of monetary policy

The growing role of financial markets for the financing of the economy and evidence gathered over the recent period on the key role financial factors may play in shaping and amplifying business cycles have both emphasised the importance of the "broad credit channel" in the transmission mechanism of monetary policy. Moreover, recent fluctuations on stock markets have also drawn attention towards the relative importance of wealth effects on the real economy.

Although wealth effects are still likely to be limited in the euro area, when compared with the United States, the empirical literature has already underlined the relevance of the financial accelerator mechanism for European countries such as France (Rosenwald (1995), Chatelain and Teurlai (2000)), Germany, Italy and Spain (Vermeulen (2000)). However, the emergence of new instruments aimed at hedging against credit risks, such as credit derivatives, may dampen the efficiency of this financial accelerator mechanism and finally affect the impact of monetary policy on the real economy.

The financial accelerator mechanism has its roots in imperfections on credit markets, such as information asymmetries between lenders and borrowers. As a consequence of imperfect credit markets, there exists a spread between the cost of external and that of internal finance, called the external finance premium, which decreases with the borrower's net worth relative to the amount of funds required. An adverse shock to the borrower's net wealth increases the cost of external finance, reduces his access to finance and may lead to a cutback in investment and employment spending, which in turn may result in a fall in aggregate supply.

To illustrate such a mechanism, we simulate a dynamic general stochastic equilibrium model directly inspired from Bernanke et al (1999), in which we introduce real rigidities via an increasing adjustment cost in the production of capital, and allow for a one-period delay in investment to account for time-to-plan/time-to-build in investment decisions. As above, the model is calibrated on euro area data. We assume that the central bank responds only to expected inflation, which is consistent with the ECB mandate. In the monetary policy rule, we also assume an interest rate smoothing parameter of around 0.8. Three different shocks are considered: a supply shock, which takes the form of a shift in total factor productivity; a demand shock, which works through unanticipated public expenses; and finally a monetary policy shock (Figures 1 to 4 below).

Figure 1

Supply shock

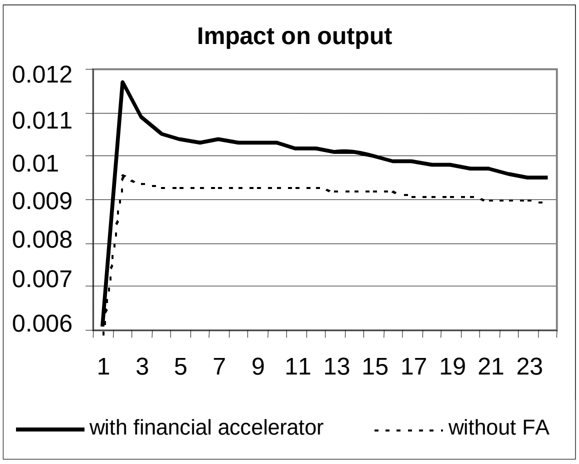
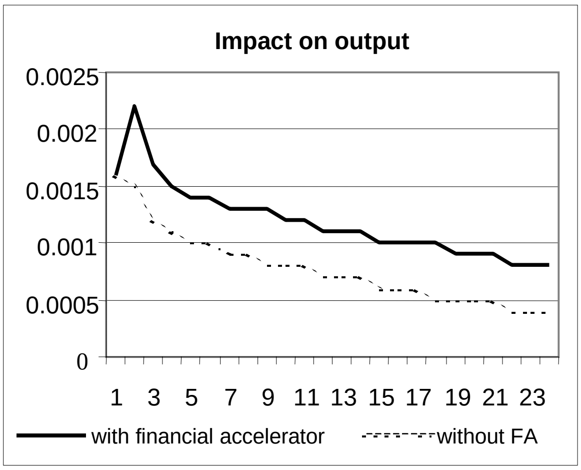


Figure 2

Demand shock



Monetary policy shock

Figure 3

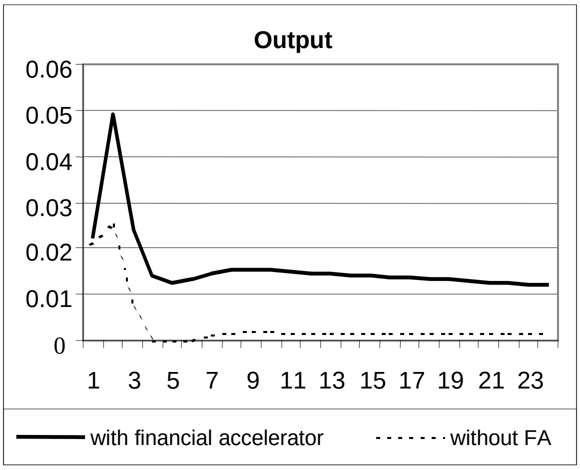
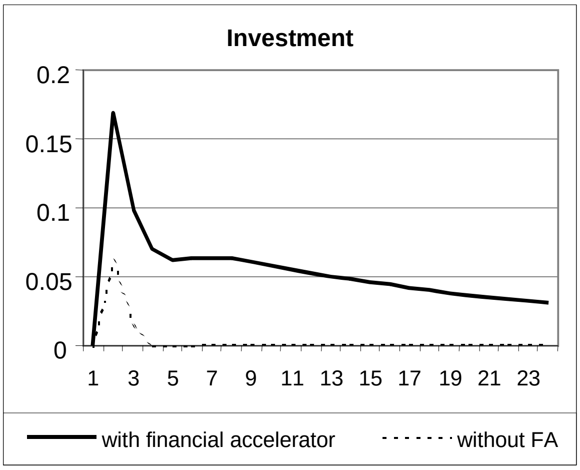


Figure 4



As illustrated in Figures 1 and 2, financial factors contribute to amplifying and to exacerbating the effects of exogenous shocks on the real economy via the financial accelerator mechanism. Such a mechanism also improves significantly the impact of monetary policy impulses on the economy. In this setting, an unanticipated monetary easing stimulates real activity through two different channels: first, the traditional interest rate channel, which activates the interest-rate-sensitive components of aggregate demand; and second, the decrease in nominal interest rates increases the discounted value of the collaterals, thus raising the borrower’s net worth and leading to a lower external finance premium. This, in turn, stimulates investment and finally aggregate supply (Figures 3 and 4).

However, corporate hedging or new financial products, such as credit derivatives, may hamper such a mechanism and reduce the efficacy of monetary policy. A rationale for corporate hedging is provided in a paper by Froot et al (1993). Building upon a simple setup, the authors show that, amongst the conditions that have to be satisfied for hedging to be beneficial, one is at the very heart of the financial accelerator literature, namely: that the level of internal wealth must have a positive impact on the optimal level of investment. As a consequence, hedging might help ensure that the firm will have sufficient internal funds to finance investment opportunities, and then reduce quite sharply the need for external finance. In such circumstances, the broad credit channel of monetary policy should be affected. The results obtained by Froot et al (1993) depend on the extreme assumption that all the fluctuations in internally collected funds are marketable, which has to be mitigated despite the huge increase in derivatives. However, the recent and very rapid growth of the credit derivatives market (see Rule (2001)) might also impact on this broad credit channel since it provides the lenders (banks) with an opportunity to reduce their credit exposure, and therefore the importance of information asymmetries on credit markets. Both sides of the financial accelerator mechanism, ie banks and firms, have increasing opportunities to hedge against credit risk and to transfer risks to other financial institutions. While such developments are likely to improve financial market efficiency and contribute to financial stability, they also reduce the power of monetary policy.

3.4 Operational issues

As far as the operational implementation of monetary policy is concerned, recent changes in financial markets have highlighted two important issues dealing with shrinking government bond supply and technological changes.

The first issue addresses the set of eligible collaterals for monetary policy operations. Because of their features (no credit risk, active trading, deep markets, etc), government bonds are widely accepted as collateral against the future delivery of cash and, as such, play a very important role in monetary policy operations. However, changes in the relative supply of government bonds have impacted on their relative prices, making them increasingly expensive for market participants. In turn, their role as collateral for transactions has diminished, to the extent that some central banks have expanded the set of eligible collaterals for monetary policy operations: as an illustration, both the Federal Reserve and the Bank of England expanded the menu of securities they use for the implementation of their monetary policy in 1999. However, such changes are irrelevant for the euro area: first, because government bond markets are deep and active, and fiscal consolidation in Europe has to date had a limited impact on the supply of government bonds, as illustrated in Section 2; and second, because the set of collaterals used by the ECB is already large enough to deal with such an issue.

Technical changes have also had an impact on the direct implementation of monetary policy. However, this impact has been limited on the money market relative to what has been observed on foreign exchange markets or euro bond markets (see Section 2). Greater efficiency might result from these technological changes, and this should also improve monetary policy efficacy. As far as the implementation of monetary policy is concerned, the most noticeable change might probably be related to the possibility of operating on a real-time basis. Such a change has many implications, both for financial stability, through the setting-up of a real-time payment system for instance, and for monetary policy. In the latter case, technological changes facilitate tenders not only by allowing the central bank's counterparties to participate in the tender directly, ie without any intermediary, but also by helping the central bank to monitor closely money market conditions (Pauly (2001)), ie in a "real-time" fashion. It should also help market participants to manage their resources more efficiently. However, while technological changes also favour market transparency, they have to be accompanied by appropriate communication.

3.5 A new role for central bank communication

Most major central banks have become independent over the last decade. As a consequence of and counterpart to independence, accountability and transparency have been considered one of the prime issues for central bankers. While theoretically they might contribute to reducing time inconsistency and inflation bias, they should also reduce financial market volatility and improve overall financial conditions. The forward-looking nature of monetary policy has also put greater emphasis on communication, which is sometimes considered a supplementary channel - if not "a hidden pillar", to quote Otmar Issing - of monetary policy. Moreover, transparency has been facilitated by modern communications over recent years.

The greater role played by financial markets has led central banks to operate in a more market-oriented way and, to that extent, to devote greater attention to the way they communicate their monetary policy decisions to market participants.

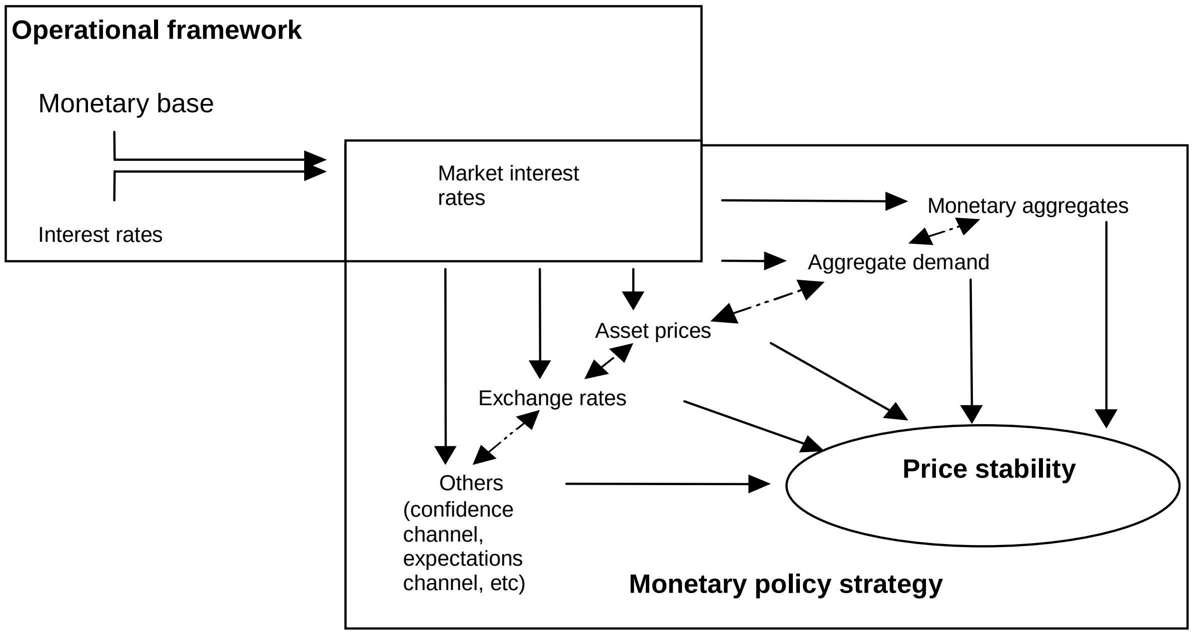
A simple description of the transmission mechanism of monetary policy helps explain why communication matters (see Figure 5).

As illustrated in Figure 5, markets play a central role in the monetary policy transmission mechanism as an interface between the operational framework and the strategic side. Monetary policy actually controls mainly the interbank overnight rate, which, as stressed by Blinder (1999), is not relevant for any important economic decisions. The only extent to which monetary policy affects significantly the real economy is when it moves relevant financial prices, ie when it impacts on the whole yield curve, but also on exchange rates or asset prices, besides other prices (eg wages). The common feature of all these financial prices is their dependency on agents' expectations. But to affect these expectations in an appropriate way, monetary policy decisions have to be clearly understood. This is why central banks have to communicate and why communication contributes to monetary policy effectiveness. As an illustration, Gaspar et al (2001) show in their in-depth analysis of the euro money market that markets have generally predicted the ECB's interest rate changes quite accurately.

To operate, the transmission mechanism requires market participants to understand each monetary policy decision as the "path of a logical chain of decisions leading to some objectives", as stated by Blinder et al (2001). For this reason, and according to our simplified version of the transmission mechanism, monetary authorities have to be clear about their instruments, their objectives and their horizon, which is generally longer than the markets' horizon, that is to say, their overall strategy, and also have to explain by which mechanisms their policy decisions will help to achieve in turn their objectives. Due to the forward-looking nature of monetary policy, such an explanation can be provided through an appropriate communication, an element of which might consist in the publication of projection exercises. Communication and transparency may finally result in greater efficiency of monetary policy and contribute to reducing financial market volatility.

Figure 5

Transmission mechanism of monetary policy



Source: Manna et al (2000).

Obviously, one has to keep in mind that market participants also have their own expectations and their own explanation of asset price dynamics, which may not be influenced solely by monetary policy decisions. Even if market volatility may be reduced by greater transparency and appropriate communication, this may be only to the extent that they reduce monetary policy uncertainties.

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Euro area government securities markets: recent developments and implications for market functioning

Roberto Blanco,[1] Bank of Spain

1. Introduction

Government securities markets have traditionally played an important role for both central banks and private agents. From the standpoint of central banks, certain indicators for assessing the inflation and output outlook have normally been derived from pricing data collected in these markets. From the point of view of private agents, these securities are used as a risk-free investment, as collateral, as a benchmark for pricing fixed income securities and for hedging interest rate risks. The important role played by government securities is the result of a number of characteristics that distinguish them from other securities. These include minimal credit risk, high market liquidity, a wide range of maturities and well developed market infrastructure.

In the euro area, recent developments in, and the functioning of, government securities markets have been affected by a number of factors, including the introduction of the euro and the reduction in the relative supply of government bonds. The removal of foreign exchange risk within the euro area since the start of monetary union has eliminated one of the elements that previously differentiated existing securities and, consequently, should have altered trading strategies and relative prices. The reduction in the relative supply of bonds as a consequence of the improvement of public finances raises the question of how the functions performed by these markets are going to change.

Against this background, the goal of this paper is to describe recent developments in euro area government bond markets and to discuss their implications for both the information content of prices and market functioning. It is found that the introduction of the euro has significantly affected the relative pricing of securities. In particular, 10-year spreads over German bonds for previous high-yield debt have narrowed whereas the spreads for all other euro area sovereign debt have widened. Market microstructure factors, such as relative market liquidity and the CTD status of bonds, are also found to play a part in determining relative prices, in addition to differences in credit risk. Finally, the reduction in the relative supply of government bonds is seen to have had a limited effect on the euro area hitherto, in contrast to the evidence in the US market.

The rest of this paper is structured as follows. Section 2 describes the main factors driving market developments and Section 3 discusses their impact on portfolio composition and trading activity. Section 4 is the core of the paper and analyses pricing developments and their implications. Section 5 discusses the outlook for euro area government bond markets and, finally, the last section concludes.

2. Main factors driving market developments

2.1 Introduction of the euro

The elimination of foreign exchange risk within the euro area since the start of monetary union has removed one of the elements that previously differentiated existing bonds. This has resulted in an

[1] I thank Francisco Alonso, Eva del Barrio and Alicia Sanchís for helpful research assistance. I also thank Juan Ayuso, Fernando Restoy, Javier Santillán and participants in the seminar held at the Bank of Spain and in the BIS meeting for helpful comments.

increase in the degree of substitutability among securities issued by different treasuries. At the same time, other elements such as credit risk and market liquidity may have gained in importance. These changes may have affected both pricing and trading activity. As regards pricing, the level and the dynamics of yield spreads between different national issuers will no longer reflect foreign exchange factors. The portfolio composition and trading strategies of investors have been affected through different channels. First, currency-driven strategies are no longer feasible. Second, the scope for risk diversification among national securities has been reduced. Finally, the introduction of the euro has removed certain legal barriers to cross-border investment such as currency matching rules, which traditionally limited the possibilities of certain investors - especially pension funds and insurance companies - to invest in foreign currency.

Besides the aforementioned effects, the introduction of the euro has had other more indirect effects. In particular, the search for market liquidity has fostered competition between issuers to attract investors and has prompted some reorganisation of market structure. On the side of the issuers, some significant changes have been observed since the start of monetary union. In this respect, mention may be made of the efforts by national treasuries to increase market transparency through different means such as the introduction of preannounced auction calendars. In addition, issue sizes have generally tended to increase. In some countries, the creation of large issues was facilitated by the introduction of programmes to exchange old illiquid bonds for new bonds and by the concentration of issuance activity in a smaller number of benchmark securities. Some of the smaller issuers, such as Austria, Belgium, the Netherlands and Portugal, have resorted to syndication procedures instead of traditional auctions with the aim of reaching a larger set of investors. Others, such as the French Treasury, have introduced new instruments such as constant maturity and inflation-indexed bonds to attract more investors. Other institutional changes were the harmonisation of market conventions such as the computation of yields, and the introduction of a single trading calendar.

As regards the organisation of markets, one notable development has been the creation of electronic pan-European exchanges for debt securities. So far, the most successful trading platform has been EuroMTS, a screen-based exchange owned by a number of the largest banks active in the European market. Currently, issues of the major euro area treasuries and some large highly rated private bonds are listed on this trading platform. Both spot and repo transactions are admitted. BrokerTec is another example of a recently created electronic trading platform. However, its market share is considerably lower. At the national level, there have been initiatives aimed at concentrating trading activity in a limited number of platforms.[2] In the futures markets, some small and medium-sized exchanges have established alliances to better cope with competition from the biggest exchanges.

In the case of settlement systems, there have been initiatives geared to achieving a higher degree of integration. In this regard, the introduction of links between national central securities depositories and the merger of the two international central securities depositories with existing national central depositories should be highlighted.[3]

To sum up, the introduction of the euro has increased the degree of substitutability of securities and has contributed to reducing fragmentation among euro area government bond markets. Advances in market integration are also explained by other factors, such as the implementation of the single market for financial services and technological changes. The euro area government bond markets are increasingly seen as one single market that is comparable in size to the US or Japanese markets (Table 1). However, the multiplicity of issuers and differences in credit rating distinguishes the euro area government market from its US and Japanese counterparts. In spite of the advances in integration, euro area government bond markets are currently far from being completely integrated. Some factors frequently mentioned as contributing to fragmentation are the lack of integration of the settlement system and the different tax regimes and market conventions.[4]

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2 See ECB (2001) for more details of recent changes in market infrastructure in the euro area bond markets.

3 Cedel merged with Deutsche Börse Clearing to form Clearstream International. Euroclear merged with CBISSO and Sicovam to form the Euroclear group.

4 See IMF(2001b), Santillán et al (2000) and ECB (2001).

Table 1

Size of government securities markets outstanding amounts, July 2001

(EUR billions)

Austria	106
Belgium	243
Germany	700
Spain	281
Finland	53
France	661
Ireland	22
Italy	1,102
Luxemburg	1
Netherlands	186

[1] December 2000.

Sources: ECB; BIS.

2.2 Reduction in the relative supply of government bonds

Over the last few years the share of the stock of government paper has trended downwards in the euro-denominated fixed income markets. More specifically, between end-1996 and mid-2001, the share of the stock of government paper decreased by more than 5 percentage points (Table 2). This process is the result of both a slowdown in government issuing activity, due to the reduction of fiscal deficits, and the surge in the stock of private paper.

Table 2

Stock of euro-denominated fixed income securities

(EUR billions)

End of period	1996	1997	1998	1999	2000	2001[1]
Euro area government	2,855	2,977	3,112	3,239	3,317	3,508
Other public debt	93	95	96	100	109	115
Financial institutions	1,836	1,975	2,146	2,467	2,680	2,825
Non-financial corporations	261	258	271	319	374	416
Non-residents	–	–	441	631	793	889
Total	–	–	**6,067**	**6,756**	**7,273**	**7,754**
Memorandum item:						
Euro area gov/total (%)	–	–	51.30	47.95	45.61	45.24
Euro area gov / resid sectors (%)	*56.58*	*56.12*	*55.32*	*52.89*	*51.19*	*51.10*

[1] To June.

Source: ECB.

The shrinking supply of government securities may have three different effects on their pricing. First, since lower debt obligations mean an improvement in the credit standing, the yield demanded by investors will be lower. Second, scarcity of risk-free securities may further reduce the yield demanded by investors in comparison with other securities. This effect, which is sometimes called the scarcity premium, might arise if there are no substitute securities with similar characteristics. Finally, the reduction in size may negatively affect market liquidity and, as a consequence, investors would demand an extra yield - liquidity premium - to compensate for the lower market liquidity. Thus, from a theoretical standpoint, the impact on the yield level of the reduction in the relative supply is ambiguous.

The existence of the aforementioned idiosyncratic elements in the prices of government securities may have some implications for the information content of interest rates and for market functioning. More specifically, certain indicators frequently used by central banks to extract information on the output and inflation outlook, such as the quality spread (the yield differential between corporate bonds and government bonds) and the term spread (the differential between long-term and short-term yields) might be distorted. Similarly, the usefulness of government securities as a benchmark for pricing other fixed income assets may also be affected. Finally, the presence of these idiosyncratic elements will reduce the effectiveness of hedging interest rate risk with government securities, provided that they are time-varying.

Another effect of the reduction in the supply of government securities is the lower availability of a risk-free asset for investment and for use as collateral in monetary policy operations, for intraday credit or in private transactions. For example, during the last quarter of 2000, these types of securities accounted for 56% of collateral used by Eurosystem counterparties for monetary policy and for intraday credit.

3. Developments in portfolio composition and trading activity

The information available clearly shows that the process of geographical diversification initiated in the mid-1990s in the euro area government debt markets has continued at a more rapid pace since the start of the monetary union. According to the figures of Table 3, the share of the stock of euro area government securities held by non-residents increased by 7 percentage points between 1998 and 2000. This suggests that the introduction of the euro has contributed to a geographical reallocation of portfolios. The removal of certain legal barriers, such as currency matching rules, and greater market integration after the introduction of the euro may have played a part in this process.

Table 3

Ownership of euro area government securities

(in %)

	Resident sector				
End of period	**Total**	**MFI**	**Other fin corporations**	**Other**	**Non-residents**
1991	83.8	43.0	12.5	28.2	16.0
1992	82.4	43.3	12.3	26.9	17.6
1993	78.1	41.1	12.6	24.3	22.0
1994	80.3	42.7	14.1	23.4	19.7
1995	79.0	41.1	14.7	23.0	21.0
1996	78.5	40.2	17.5	21.0	21.5
1997	76.5	38.9	19.3	18.3	23.7
1998	73.2	36.9	22.2	14.2	26.8
1999	69.5	35.1	20.7	13.7	30.5
2000	66.5	33.8	19.4	13.4	33.5

Source: ECB.

As regards trading activity, the most significant development has been in the bond futures markets. Since the last quarter of 1998, trading activity has increasingly been concentrated in the futures based on German bonds and traded on Eurex (Table 4). This process was driven by the high substitutability of existing contracts after the removal of foreign exchange risk within the euro area countries. Turnover in futures based on French, Italian and Spanish bonds decreased to very low historical levels and, as a consequence, their liquidity was seriously damaged. This situation changed slightly in 2000 when Euronext introduced a number of measures to improve the attractiveness of its contracts, including the extension of the list of deliverable bonds to include some other euro area bonds - German and Dutch bonds. Thereafter, turnover in bond futures traded on Matif recovered to pre-EMU levels, but continued to be relatively low when compared with contracts traded on Eurex.

Table 4

Ten-year euro area bond futures trading in selected markets

(monthly averages, EUR millions)

	1996	**1997**	**1998**	**1999**	**2000**	**2001**[1]
German bonds	596,390	827,981	1,211,089	1,402,122	1,323,842	1,639,148
Eurex[2]	172,424	341,019	1,055,158	1,402,122	1,323,842	1,639,148
LIFFE	423,967	486,962	155,931	0	0	0
French bonds						
Matif	224,366	214,397	145,910	51,092	360,975	301,000
Spanish bonds						
MEFF	93,337	104,848	78,386	29,810	9,121	3,772
Italian bonds	130,507	150,527	74,506	11,404	123	0
LIFFE	106,191	125,097	63,379	9,835	109	0
MIF	24,315	25,430	11,127	1,569	14	0
Total	**1,044,599**	**1,297,754**	**1,509,891**	**1,494,427**	**1,694,061**	**1,943,921**

[1] To June. [2] Formerly DTB.

Sources: FIBV; Bank of Italy; LIFFE; Eurex; MEFF; Euronext.

The increasing trading activity in the futures based on German bonds was also reflected in open interest in the contracts, to the point where it frequently exceeded the outstanding amount of deliverable bonds. This has sometimes favoured situations, known as squeezes, in which a small number of participants acquire a large proportion of the stock of deliverable bonds before the maturity of the contract with the aim of obtaining a profit. If the strategy succeeds, the short position holders in the futures contract are obliged to borrow deliverable bonds and lend money at below market rates in the repo market. The latest squeeze is reported to have involved the five-year contract maturing in March 2001. Other squeezes occurred in September 1998 and June 1999. The existence of squeezes may introduce potential efficiency-reducing distortions in the pricing of securities traded in the spot, derivatives and repo markets.[5]

Another relevant development recently observed on Eurex is the growing importance of contracts based on two- and five-year bonds. The cumulative trading volumes of these two contracts are currently similar to those observed with the ten-year contract. These movements probably reflect a change in investor trading strategies, which are more balanced along the yield curve.

In the spot markets, recent changes in trading patterns seem to have been less dramatic. In some small markets, such as the Irish market, a drop in trading figures has been observed. Similarly, trading with Italian government bonds in the MTS market has continued to decline since the start of monetary union, a trend initiated in 1998. However, this process seems to reflect, at least partially, a shift to the EuroMTS platform rather than a lower trading volume of Italian securities. In the Spanish market, trading has increased slightly since the introduction of the euro but the turnover ratio has dropped. By contrast, trading figures for French government bonds show a robust increase as compared with pre-EMU levels - the monthly average volume during 1999-2001 was 37% higher than that in 1996-98. Similarly, there is some evidence of growing trading activity in German government bonds.[6] However,

[5] The pricing effects due to the existence of the futures market are studied in Section 4.

[6] The BIS (2001b) reports a significant increase in trading volumes for German bonds using data on the most actively traded bonds settled through Euroclear.

the lack of more detailed data in some markets and the absence of information in others do not allow us to determine to what extent a process of concentration towards the most liquid markets has also occurred in this market segment.

Trading conducted through EuroMTS has risen significantly since its creation in 1999. It is estimated that in 2000 about 40% of bond transactions were traded through this platform.[7]

The evidence in this section suggests that overall trading activity and, as a result, liquidity has not been significantly affected by the reduction in the relative supply of bonds, which contrasts with the evidence in the US market, where liquidity seems to have deteriorated recently.[8] At the same time, some concentration of liquidity towards the main markets at the expense of others has occurred since the introduction of the euro.

4. Pricing developments

4.1 Relative pricing of euro area government bonds after the introduction of the euro

(a) Determinants of yield spreads

The removal of foreign exchange risk following the start of monetary union eliminated one of the determinants of the yield spreads between euro area government bonds. To approximate the importance of this effect, the average 10-year yield spreads over German bonds of euro area government bonds in the pre-EMU period (1996-98) are broken down into two components: (i) the foreign exchange factor; and (ii) other factors, which mainly include differences in credit risk and market liquidity. The first component is estimated as the spread between the swap rate in the currency of denomination of the bond and the swap rate in Deutsche marks.[9] Given that most of the participants present in the different currency segments of the underlying swap market (the eurodeposit market) are the same, differences in swap rates should mainly capture foreign exchange factors.[10]

Table 5 shows the results of the exercise, together with the average yield spreads over German bonds after the introduction of the euro (1999-June 2001). It can be seen that the foreign exchange factor was the main component of the spread in those countries with wider spreads, such as Italy, Spain and, to a lesser extent, Finland and Ireland. In these countries the introduction of the euro has meant a significant reduction in their debt yield spread over German bonds. The removal of foreign exchange risk has also been reflected in a reduction in the yield volatility for debt issued by these countries (Graph 1). Conversely, the yield volatility of the other countries' debt has shown minor changes between both periods and their yield spreads over German bonds have increased (Table 5).

Interestingly, on removing the foreign exchange factor from yield spreads in the pre-EMU period, it can be seen that all yield spreads over German bonds have widened. A number of factors may account for this evidence. First, the concentration of trading activity in the German market, at least in the futures segment, and the fact that the credit and liquidity component has risen more strongly for debt issued by smaller countries such as Austria, Belgium and Finland, denote that liquidity differences vis-à-vis German bonds may have widened since the introduction of the euro. Second, observed changes might partly reflect a change in the price assigned by the market to these factors, perhaps as a consequence of the higher degree of market integration - ie before monetary union differences in liquidity and credit risk were not completely priced in due to market segmentation. Finally, it cannot be ruled out that part of the change in the credit risk and liquidity component is upward-biased, due to the following two factors. First, before EMU differences in credit standing were partly captured in the

[7] See Galati and Tsatsaronis (2001).

[8] See Fleming (2000).

[9] All pricing data used in this paper are taken from Bloomberg, unless otherwise stated.

[10] Part of the difference in swap rates may also reflect differences in liquidity.

foreign exchange factor since governments had the possibility of monetising debt denominated in local currency to prevent default, which ultimately would be reflected as a devaluation of the local currency. Since the start of monetary union this option is no longer feasible given the no-bailout clause in the EU Treaty.[11] Second, if swap spreads between currencies partly reflected differences in liquidity, the estimated foreign exchange component would be biased upward and, consequently, the credit and liquidity component would be downward-biased. In any case, the increase in the yield spread for countries in which the foreign exchange component was not significant indicates that these biases do not fully explain the rise in the price of liquidity and credit risk.

Table 5

Ten-year yield spreads before and after EMU. Breakdown by factor[1]

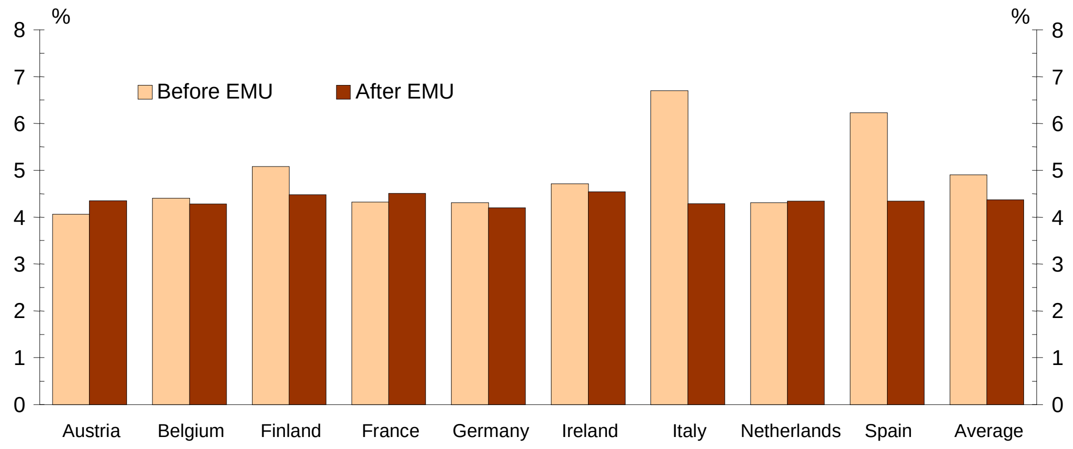
(in basis points)

	Before EMU (1996-98)			**After EMU (1999-2001)**
	Spread	**Foreign exchange factor**[2]	**Other**	**Spread**
Austria	9.7	1.3	8.4	26.2
Belgium	19.0	4.5	14.5	31.0
Finland	46.2	40.9	5.3	22.8
France	3.8	– 2.9	6.8	13.1
Ireland	45.4	36.6	8.9	23.1
Italy	154.4	132.2	22.2	31.5
Netherlands	– 2.2	– 3.8	1.6	14.8
Spain	114.9	96.4	18.6	27.0

[1] Spread over German bonds. [2] Approximated as the spread between the swap rate in the currency of denomination of the bond and the swap rate in Deutsche marks.

Graph 1

Volatility of euro area 10-year government bond yields[1]



[1] Computed as the standard deviation of daily changes in yields.

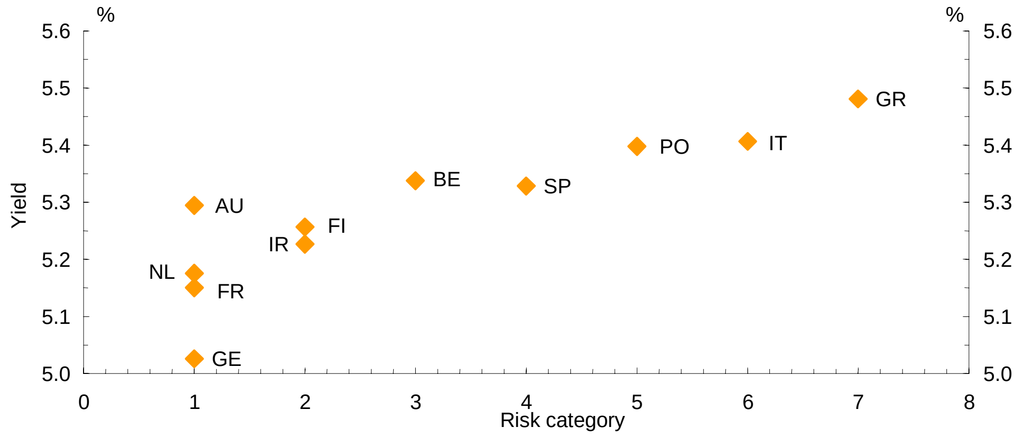
[11] However, the fact that the liquidity and credit risk component was relatively high in countries with the lowest ratings such as Italy, Belgium and Spain indicates that not all of the differences in credit standing were reflected in the foreign exchange factor.

To better understand the determinants of the yield spreads between euro area government debt, Graph 2 depicts the 10-year yields for the 12 euro area countries' government debt by risk category in June 2001. These categories have been created by combining the ratings assigned to sovereign debt by S&P and Moody's.[12] Seven different categories are considered. The first category is made up of highest-rated debts and the seventh includes the lowest-rated debts. A positive correlation between risk and yield clearly emerges from the Graph, suggesting that credit risk plays an important role in explaining yield spreads in the euro area government bond markets. However, significant differences in yields among some debt carrying a similar risk are observed, particularly within highly rated debt. For instance, it is worth noting that the yield spread between Austrian and German bonds is even higher than that between Austrian and lower-rated securities such as Greek debt. This indicates that credit risk alone is not sufficient to explain yield spreads, which means that other factors such as market liquidity must also play an important role.

Graph 2

10-year government bond yields by risk category

(June 2001)



Source: Bloomberg.

An in-depth analysis is now carried out of the importance of market microstructure factors, such as liquidity, in the relative pricing of euro area government bonds. To do this, zero coupon yield curves from January 1999 to May 2001 are first estimated for the two markets considered as having the highest liquidity, the German and French markets.[13] Initial analysis of the results of this exercise reveals some significant changes after May 2000. Given this evidence, the analysis below considers two sub periods (1 January 1999-30 April 2000 and 1 May 2000-28 May 2001). Graph 3 shows the average difference between the curves in these two subperiods. In the first, French bonds appear to have on average a lower yield for horizons between two and 12 years, whereas for longer horizons German bonds display a lower yield. These results denote that, during this period, the benchmark yield curve for euro interest rates was made up of more than one issuer. This evidence seems to indicate that, in the German market, liquidity tends to be more concentrated than in the other two exchanges.

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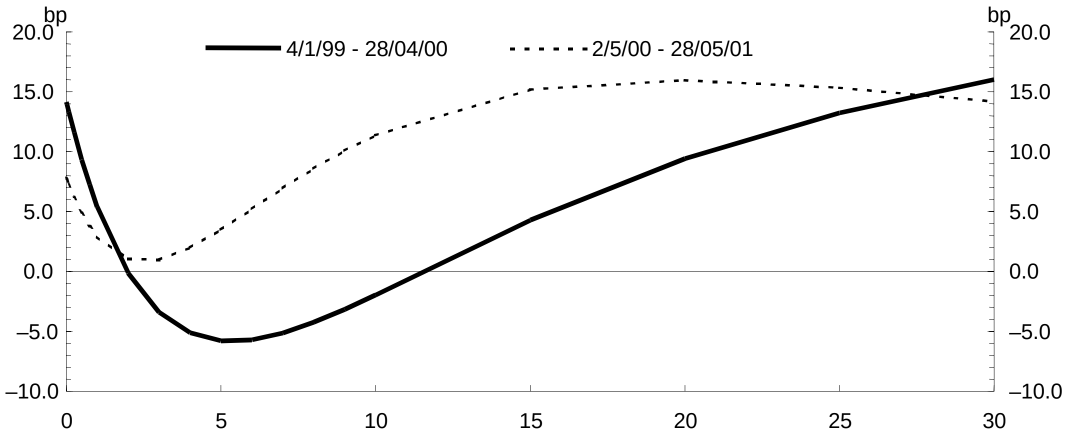
12 S&P and Moody's rate debt using different codes, but their rating categories can be ordered according to comparable levels of risk. For instance, the AAA and AA+ ratings of S&P are equivalent, respectively, to the Moody's Aaa and Aa1 ratings. In practice, these rating agencies either give equivalent ratings to the same issuer or have them differ by just one level. Taking into account this fact, debt has been included in categories 1, 3 and 5 that is equivalently rated by both agencies corresponding, respectively, to the first, second and third rate levels. Categories 2, 4 and 6 include debt that is not equivalently rated by these agencies. For instance, category 2 includes debt rated in the first level by one agency and in the second level by the other. Finally, category 7 includes debt having rates below the third level.

13 More specifically, the zero coupon yield curve is estimated using the Nelson-Siegel model and minimising the squared errors in prices adjusted by the inverse of the duration. This procedure normally estimates the medium- and long-term sector of the curve with relatively low error.

Graph 3

Zero coupon yield spread between French and German government bonds



Note: Zero-coupon yields are estimated using the Nelson-Siegel model.

In the second subperiod, a widening of spreads in favour of German bonds is observed to the extent that these securities display a lower yield for all horizons. This result probably reflects an improvement in the relative liquidity of German bonds, especially in the medium-term sector. The increasing turnover observed in the two- and five-year futures contracts based on German bonds (see Section 3) seems to support this view. Thus, it is apparent from this evidence that over the last few months the German market has achieved benchmark status for all maturities. Nonetheless, it cannot be ruled out that part of the widening is attributable to other factors such as credit risk considerations, although that does not seem plausible.

With the aim of confirming these findings, the liquidity effects for certain groups of bonds are now studied. More specifically, a comparison is made of the yield errors - ie the difference between observed and estimated yields - for certain groups of bonds within a range of maturities. In this case, a single zero coupon yield curve using German and French bonds is estimated. Note that this approach, unlike the simple comparison of yields, allows us to control for differences in cash flow structures. Table 6 shows some descriptive statistics of the differences in yield errors for different groups of securities between January 1999 and May 2001. Results are shown for the whole sample and for two sub periods (1 January 1999-30 April 2000 and 1 May 2000-28 May 2000).

Regarding on-the-run issues for typical maturities (newly issued bonds with two-, five- 10- and 30-year maturities),[14] three main results emerge from Table 6. First, German bonds appear to have, on average, a lower yield in both subperiods, suggesting that the German market is the most liquid for on-the-run issues. Second, liquidity differences seem to be relatively more important for 10-year bonds. Finally, a widening of spreads is observed in the second subperiod, denoting an increasing preference for German bonds on the part of investors.

The evidence for off-the-run issues is slightly different, especially for bonds with a term to maturity lower than 10 years. More specifically, it is found that, in the first subperiod, French bonds with a term to maturity lower than 10 years used to trade at a lower yield than comparable German bonds. This implies a higher degree of liquidity in the French market in this maturity sector. However, in the second subperiod, German bonds appear to have a lower yield in the same maturity sector, indicating an improvement in their degree of liquidity. In the 10- to 30-year sector, the German market appears in both subperiods as having the lowest yields. And, again, a widening of spreads in favour of German

[14] These are the only maturities issued by the German Treasury during the sample period. Over the same period, the French Treasury issued mainly at these maturities. However, it sometimes issued at other maturities such as seven to eight years and 15 years.

bonds is found in this sector. These results seem to confirm that the German market has finally achieved benchmark status for all maturity ranges.

Table 6

Yield discrepancies between French and German government bonds, adjusted for different cash flow structure

(in basis points)

	1/1/99 - 28/5/01 Mean (5%; 95%)		1/1/99 - 30/4/00 Mean (5%; 95%)		1/5/00 - 28/5/01 Mean (5%; 95%)	
On-the-run issues						
2 years	4.0	(– 0.5; 9.0)	3.3	(– 1.4; 9.0)	5.0	(1.7; 9.0)
5 years	4.6	(– 3.3; 10.4)	2.6	(– 6.6; 9.1)	7.2	(3.5; 11.2)
10 years	11.6	(6.3; 16.3)	9.3	(5.9; 12.8)	14.7	(11.9; 17.0)
30 years	8.5	(2.4; 13.7)	5.9	(1.9; 9.9)	11.8	(9.3; 14.8)
Other issues						
2-5 years	0.1	(– 2.7; 3.3)	– 1.0	(– 3.2; 1.5)	1.6	(– 1.4; 4.0)
5-10 years	– 0.4	(– 8.1; 9.5)	– 5.2	(– 8.5; -0.9)	6.0	(1.1; 10.8)
10-30 years	6.6	(– 1.0; 13.0)	3.3	(– 2.7; 7.6)	11.0	(7.7; 13.4)

Note: Yield discrepancies are computed as the differences in yield errors in order to control for differences in cash flow structure. Yield errors are the difference between observed and estimated yields. The latter were estimated using the Nelson-Siegel model.

Let us now examine in depth the impact on pricing of market microstructure factors. To do this, the focus is placed on the German market and the estimated yield errors from 1999 to May 2001 are analysed using securities issued by the German Treasury. Of particular interest here are liquidity effects and the impact on yields of the futures market. Observation of these errors shows that newly issued bonds normally display a negative yield error - ie the observed yield is below the estimated curve - that is sometimes very significant (up to about 20 basis points), especially in the 10-year sector. Yield errors of the bonds with cheapest-to-deliver status (CTD hereafter) in the futures market also tend to be negative, but they are normally much closer to zero. These results imply that liquidity factors play an important role in determining relative yields in the German market, whereas the impact of the futures market seems much more limited.

To test more formally for these effects, the zero coupon yield curve is re-estimated introducing a dummy variable that takes the value 1 for the last two on-the-run issues and 0 otherwise. Table 7 shows the main results of the exercise. The parameter of this variable is negative and statistically significant for most of the sample and its average value is –6.4 basis points. The results by subperiod show no significant changes. This evidence points to the existence of significant liquidity premia in the relative pricing of German bonds. The exercise is replicated for both the French and the Spanish markets in order to make comparisons. Table 7 shows the results. Liquidity premia in these markets appear, on average, to be less significant than in the German market.

The analysis now turns to the impact on yields of the CTD status in the German market. Given the small sample of securities affected by this status - a maximum of three - the yield errors of the CTD security are compared with those of a similar security, instead of introducing a dummy variable. More specifically, a match is made, for every futures contract and maturity, between the CTD bond and another security with a similar duration and age.[15] The difference in yield errors between these two bonds is then regressed on a constant and a dummy variable that takes the value 1 during the period in which the bond has CTD status. For each case, the period considered runs from the delivery day of the previous maturity up to three months after the delivery day of the current maturity. The parameter

[15] The CTD bond is approximated as the bond of which the largest amount was delivered.

of the dummy variable captures the relative impact on pricing caused by the futures market on CTD bonds. However, this parameter does not capture other possible general effects caused by the futures market on all securities within a maturity sector. The parameter of the dummy variable turns out to be negative (–2.8 basis points) and statistically significant, suggesting that CTD bonds tend to have a yield below otherwise similar bonds. However, this effect is quantitatively less significant than the impact on yields associated with benchmark status.

To check the robustness of this result and to analyse the effect for the different maturities and contracts, the regression is repeated separately for every maturity and contract. In the individual regressions, the parameter that captures the impact of the futures market turns out to be negative and statistically significant in 12 out of 13 cases. The minimum value of the parameter (–8.8 basis points) corresponds to the two-year CTD bond of the June 1999 contract, which was affected by a squeeze.

Table 7

Relative liquidity premia in selected euro area government securities markets

(in basis points)

	1/1/99 - 28/5/01 mean (5%; 95%)	**1/1/99 - 30/4/00 mean (5%; 95%)**	**1/5/00 - 28/5/01 mean (5%; 95%)**
German market	– 6.4 (– 9.3; – 3.3)	– 6.5 (– 9.5; – 2.8)	– 6.2 (– 8.5; – 4.8)
French market	– 2.8 (– 5.0; – 1.0)	– 2.3 (– 3.8; – 0.7)	– 3.5 (– 5.3; – 1.4)
Spanish market	– 4.6 (– 8.3; – 1.1)	– 6.1 (– 8.5; – 3.6)	– 2.8 (– 4.7; – 0.7)

Note: A dummy variable that takes the value 1 for the last two on-the-run issues is introduced into the Nelson-Siegel model. Liquidity premia are approximated as the estimates of the dummy parameter.

(b) Implications for the information content of the yield curve and for market functioning

The multiplicity of sovereign issuers in the euro area and the impact on pricing of market microstructure effects have implications for both the information content of the yield curve derived from government bond markets and for market functioning. From the point of view of the information content of interest rates, these factors complicate the estimation of a benchmark yield curve for euro interest rates using government debt markets. In fact, the previously reported evidence indicates that, for some of the period analysed, the benchmark yield curve was made up of more than one issuer. In addition, the existence of market microstructure effects may distort the information content of certain indicators frequently used by central banks, such as the term and quality spreads. From the point of view of market functioning, the usefulness of government bonds for pricing private debt and for hedging interest rate risk may be affected, especially if the market microstructure effects are time-varying.

4.2 Reduction in the relative supply of government bonds

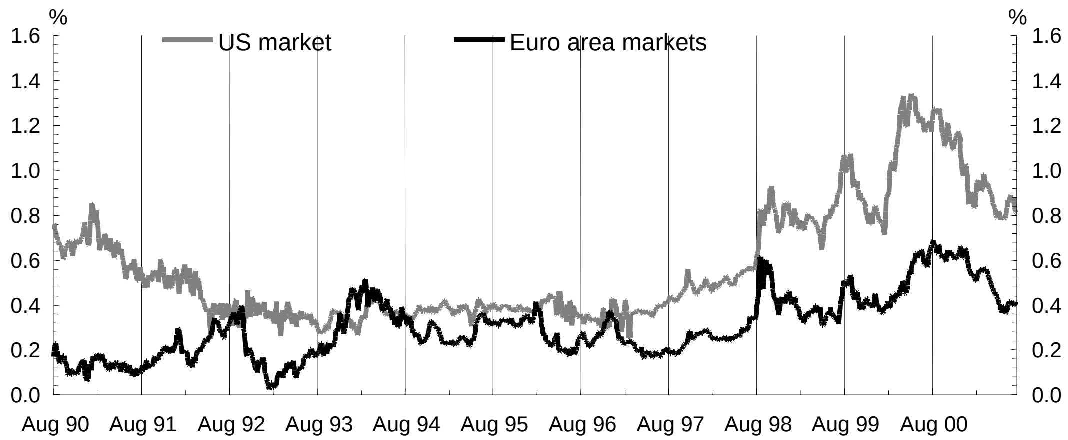
(a) Impact on yields

In Section 2, it was argued that the reduction in the relative supply of government bonds may have three different effects on yield levels: it may reduce the yield due to the improvement in the credit standing of treasuries, increase (or introduce) a scarcity premium and increase the liquidity premium. The first two imply a reduction in the yield level, whereas the latter has the opposite effect. This section tests for these effects in both the euro area and the US markets. The focus will be on yield spreads over other securities rather than yield levels in order to control for general movements in interest rates caused, for example, by changes in expectations about future interest rates or inflation. More specifically, the swap spread (the differential between swap rates and government bond yields) will be used, given the high liquidity of the swap market. However, part of the movement of the swap spreads may reflect changes in credit risk.[16] To control for this effect, a credit risk-adjusted swap spread will be computed.

Graph 4 shows 10-year swap spreads in the US and euro area markets. The latter series is proxied using German bonds and, in the pre-EMU period, Deutsche mark swap rates. As is apparent from the graph, in the US market the swap spread has changed significantly over the last two to three years, in contrast to its relative stability between 1992 and 1997. The widening of the spread during the autumn of 1998 possibly reflected the flight to quality resulting from the financial crisis and events such as the LTCM hedge fund crisis. Between mid-1999 and 2000 Q2 the swap spread widened again, coinciding with the announcement and implementation of the buyback programme by the US Treasury. During this latter period, the swap spread reached record levels (more than 135 basis points), about 95 basis points above the average level of 1991-97 and significantly above the level observed during the autumn 1998 events. Since 2000 Q3, the swap spread has trended downwards. Nevertheless, in mid-2001 it stood above average historical levels.

Graph 4

Ten-year swap spreads



Note: Five-day moving averages. The swap spread in the euro area market is computed using German bonds and, before 1999, swap rates in Deutsche marks. All data are taken from Bloomberg.

In the euro area markets, a similar pattern to that followed by the corresponding swap spread in the US market was observed, although some notable differences appear. First, the spread showed a much more stable pattern as from 1999. For example, the peak level during this period was around 70 basis points, ie 40 basis points above the average level in 1991-97. Second, the spread peaked later (August 2000), coinciding with the auction of UMTS licences in Europe, which provided high revenues to some European governments. Third, the level observed in mid-2001 was closer to average historical levels.

To analyse to what extent recent patterns in swap spreads are driven or not by credit risk factors, the following regression is used:

$SP_{i,t} = \alpha_i + \beta cred_t + \in_{i,t}$

where $sp_{i,t}$ is the 10-year swap spread in market i (i = dollar, euro) at time t, and $cred_t$ is the yield spread between 10-year B and AAA-rated corporate bonds in the US market. This variable proxies global credit risks. It is implicitly assumed that credit risk shocks proportionately affect lower-rated bonds more and, as a consequence, the yield spread between risk categories should proxy credit risk.

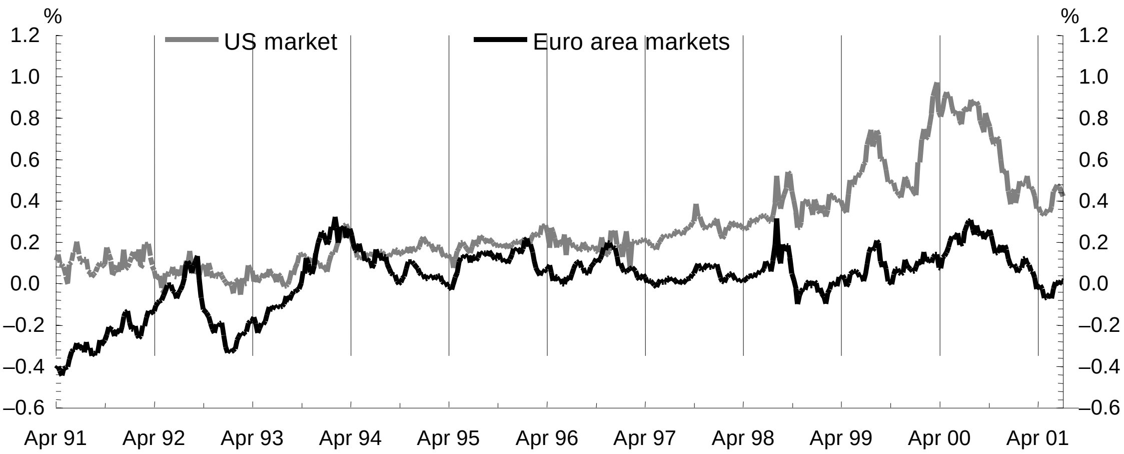
[16] Most of the banks in the Libor contributor are rated AA (see BIS (2001b)).

It is also assumed that the coefficient of this variable is the same for both currencies given that most of the counterparties present in the underlying market for swaps are the same (eurodeposit market).[17] The data used are weekly data computed as an average of daily rates to limit the impact of measurement errors such as the lack of synchronous rates. As expected, the estimated coefficient β is positive and significant, meaning that swap spreads are partly driven by changes in credit risk.

Graph 5 shows 10-year swap spreads adjusted for credit risk, which are computed as the sum of the constant and residuals of the regression, for both the US and euro area markets. The adjusted spreads show, over the last three years, a similar pattern to that followed by the corresponding unadjusted spreads, although movements appear to be slightly more stable. This evidence suggests that the swap spreads have been partly driven by idiosyncratic factors affecting the treasury market.

Graph 5

10-year swap spread adjusted for credit risk



Note: Weekly data. To adjust the swap spread for credit risk, we first regress the swap on a constant and a proxy for credirisk (yield spread between B and AAA-rated corporate bonds). The adjusted spread is computed as the difference between the swap rate and the estimated credit risk term.

In the US market, the adjusted swap spread peaked in April 2000 at about 100 basis points - ie about 80 basis points. above the average level between 1991 and 1997. Since 2000 Q3, this spread has trended downwards and in July 2001 it stood around 30 basis points above the average level of 1991-97. In other words, this evidence suggests that the shrinking supply of treasury bonds in the US market has had a negative impact on the yields of treasury securities, meaning that the scarcity premium has prevailed over the liquidity premium, despite the evidence of decreasing liquidity of the US government bond market reported by some authors.18,19 The downward trend of the adjusted spread since 2000 Q3 may reflect some correction of the imbalances between supply and demand. Possibly, some market participants have found highly rated private instruments as replacements for government securities, such as those issued by US agencies. In this regard, some of these agencies (Freddie Mac, Fannie Mae) have announced the regular issuance of large amounts of bonds in a range of maturities and, in March 2000, the CME, the CBOT and the Cantor Exchange launched futures and options contracts on agency bonds.

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[17] Since 1999 the euro area swaps have been based on Euribor instead of Libor. The contributor panel in Euribor is much wider than that of Libor.

[18] See Fleming (2000).

[19] Note that this approach does not allow for the analysis of potential effects on yields caused by the improved credit standing of the US Treasury since this effect will probably be reflected, at least partially, in the foreign exchange risk premium demanded by investors and, therefore, will also affect other debt securities denominated in dollars.

In the euro area, the adjusted swap spread peaked in August 2000 at around 30 basis points - ie about 30 basis points above the average level of the period 1991-97. In July 2001, this spread was around the average level of 1991-97, meaning that the scarcity premium was no longer embedded in euro area government bond prices.

All told, this evidence seems to indicate that the effects on yields of the relative reduction of government bond supply have been much more limited in the euro area than in the US. This result is not surprising bearing in mind that, contrary to what has occurred in the US, in the euro area the stock of government bonds has continued growing and will foreseeably continue on this path in the coming years.

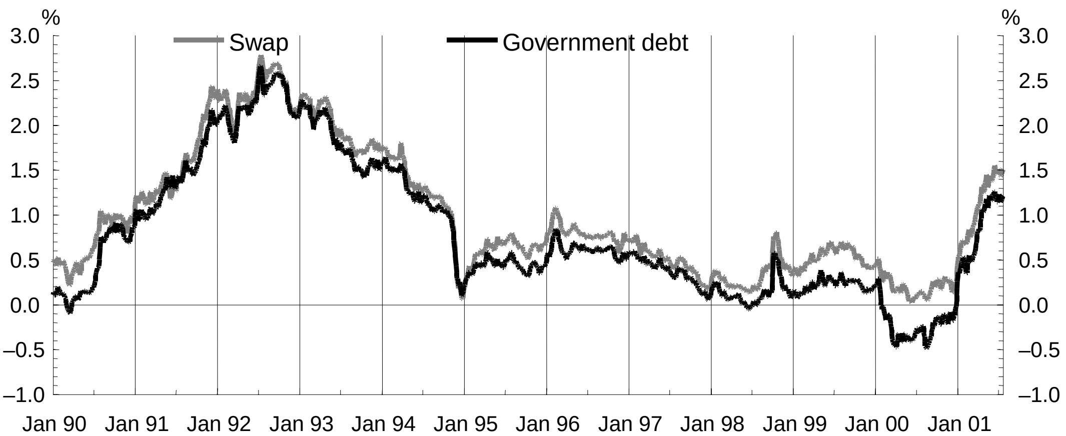
(b) Implications for the information content of the yield curve and for market functioning

The above discussion suggests that the quality spread in the US was significantly affected by changes in the scarcity premium embedded in government bond yields, ie movements in this spread did not only reflect changes in the private credit risk premium.

Similarly, the possible different behaviour of the scarcity premium along the yield curve may have affected the information content of the term spread. Graph 6 shows the term spread computed as the difference between the 10-year and the two-year yields using data from both the government debt and swap markets in the United States. Between 1999 and 2000, large discrepancies between the indicators are observed in both the level and the intensity of changes. In this respect, it is worth noting that during 2000 even the sign of this indicator was different depending on the data used: it was negative when using data from the government debt market, but positive in the other case. The evidence above implies that the information content of the government bond yield curve for inflation and output has been significantly affected in the United States by imbalances between supply and demand.

Graph 6

Slope of the yield curve, US markets

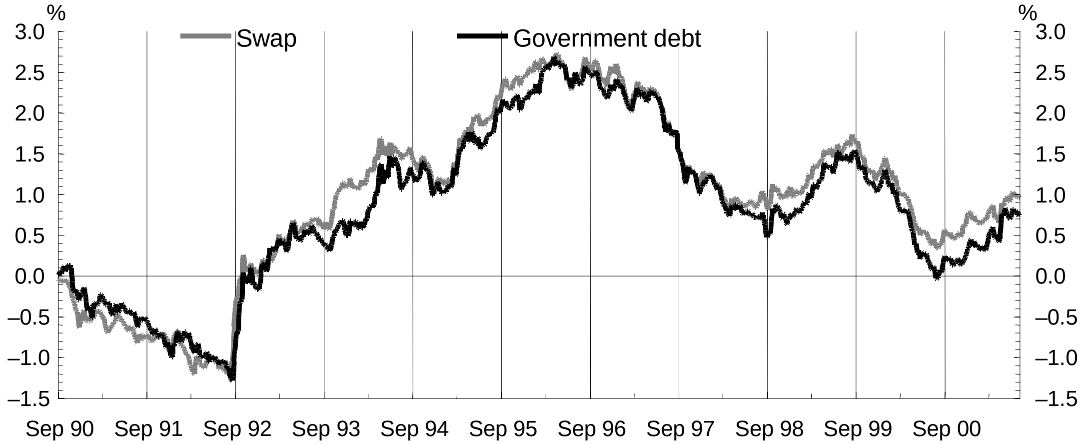


Note: Slope computed as the spread between 10-year and two-year yields. Five day moving averages.
Source: Bloomberg.

In the euro area, the relatively higher stability of the adjusted swap spread during 1999 and 2000 means that the information content of the government bond yield curve was less affected by the reduction in the relative supply of these securities. Graph 7 confirms that discrepancies in the term spread derived from the swap and the government debt market were relatively limited, although a widening between both indicators was also observed during 2000.

Graph 7

Slope of the yield curve, euro area markets



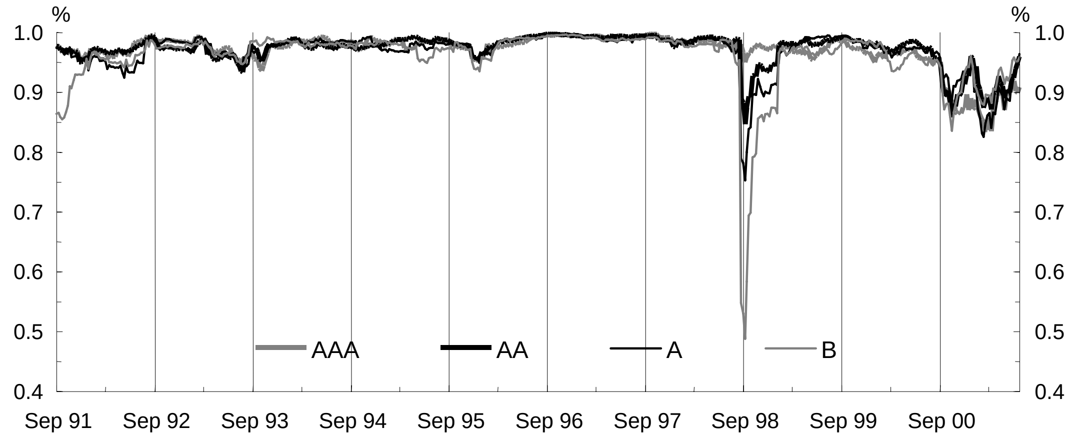
Note: Slope computed as the spread between 10-year and two-year yields. Five-day moving averages. German bonds used for government debt. Before 1999, swap rates in Deutsche marks.

Source: Bloomberg.

Apart from the impact on information content, the distortions in the US government bond yield curve caused by the shrinking supply of these securities may have affected some other functions performed by the treasury securities market. For instance, the usefulness of treasury securities for pricing private securities and the efficiency of using these assets for hedging private interest rate risk may have diminished. To test for these effects, the correlation between 10-year government and private bond yields is now analysed using a weekly frequency. It is apparent from Graph 8 that these correlations dropped significantly during the autumn 1998 crisis for all rating categories. More recently, they have dropped again, although less dramatically. Graph 9 shows that a similar pattern is found when computing these correlations using swap rates instead of government securities yields. This evidence seems to indicate that, at least at a weekly frequency, the decreasing efficiency of using treasury securities to hedge interest rate risk has not been driven by idiosyncratic factors of the treasury market.

Graph 8

Correlation between 10-year private and government debt yields, US markets

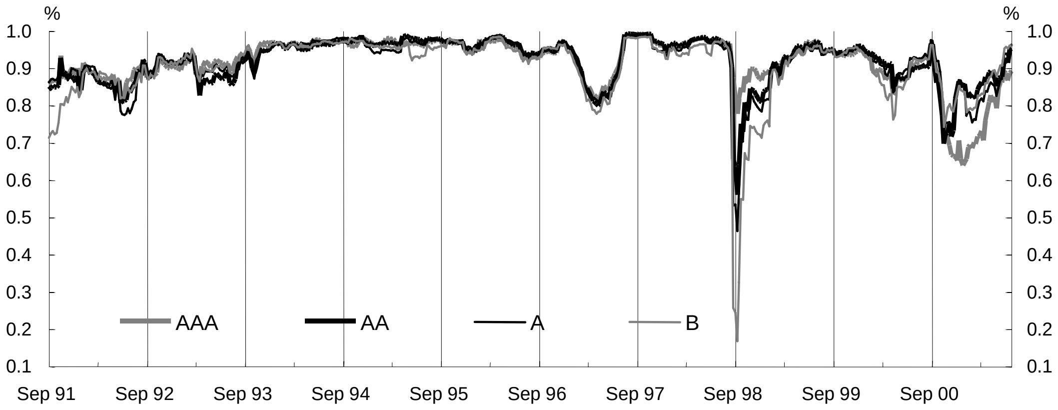


Note: Twenty-week rolling correlations of weekly changes. Data computed as the average of daily rates.

Source: Bloomberg.

Graph 9

Correlation between 10-year private debt yields and 10-year swap rates, US markets



Note: Twenty-week rolling correlations of weekly changes. Data computed as the average of daily rates.
Source: Bloomberg.

Table 8 reports correlations of treasuries and swaps with corporate bonds, using different frequencies (one week, four weeks and eight weeks) and for two subperiods: 1991-97 and 1999-2001.[20] Three important features emerge from Table 8. First, correlations decrease between the subperiods irrespective of the frequency and instrument (treasury bond or swap). Second, the relative performance of swaps as a hedging vehicle tends to increase with the horizon. Third, in the second subperiod swaps appear to be the best hedging instruments for horizons of eight weeks, in contrast to the first period, in which treasuries were relatively superior.

Thus, this evidence indicates that idiosyncratic factors affecting the pricing of US government securities have contributed somewhat to lowering the efficiency of using treasury securities to hedge interest rate risk at horizons of eight weeks or more. However, other factors, such as credit risk, have also contributed to this phenomenon.

In the euro area, a similar process of decreasing correlations between the yields on private and government securities has also been observed recently (Graph 10), likewise implying the decreasing efficiency of hedging private interest rate risk using government bond yields.[21] A similar result is also obtained when using swaps instead of government bond securities (Graph 11), which means that credit risk factors possibly account for this development. Table 9 shows correlations of treasuries and swaps with corporate bonds between 1999 and 2001.[22] As in the United States, the relative superiority of swaps tends to increase with the horizon. But, in contrast to the US evidence, swaps appear to be the best hedging vehicle for all horizons.

[20] 1998 is not considered given the anomalous behaviour of markets during the autumn crisis.

[21] Data on corporate bond yields in the euro area are taken from Merrill Lynch.

[22] Unfortunately, no data are available on corporate bond yields denominated in euro area currencies before 1998.

Table 8

Correlations with corporate bond yields. US market, 10-year yields

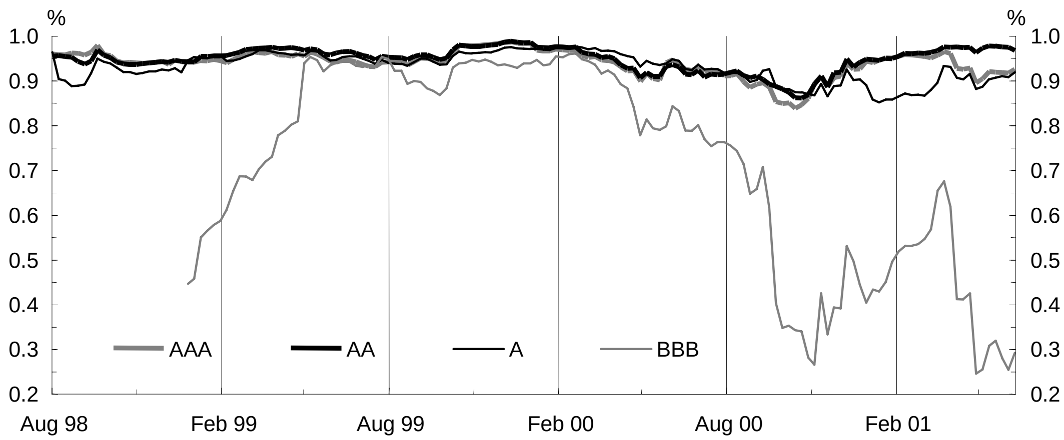
(in %)

	1991-97		1999-2001	
	Treasury	**Swap**	**Treasury**	**Swap**
Weekly				
AAA	0.982	0.939	0.941	0.891
AA	0.980	0.936	0.959	0.920
A	0.978	0.936	0.953	0.914
B	0.972	0.928	0.946	0.906
Four-week				
AAA	0.990	0.979	0.944	0.920
AA	0.986	0.975	0.953	0.942
A	0.984	0.975	0.947	0.939
B	0.975	0.968	0.925	0.923
Eight-week				
AAA	0.994	0.985	0.947	0.952
AA	0.994	0.986	0.939	0.952
A	0.989	0.983	0.921	0.951
B	0.980	0.975	0.892	0.942

Note: Weekly changes. Data computed as weekly average of daily rates. All data are taken from Bloomberg.
Source: Bloomberg.

Graph 10

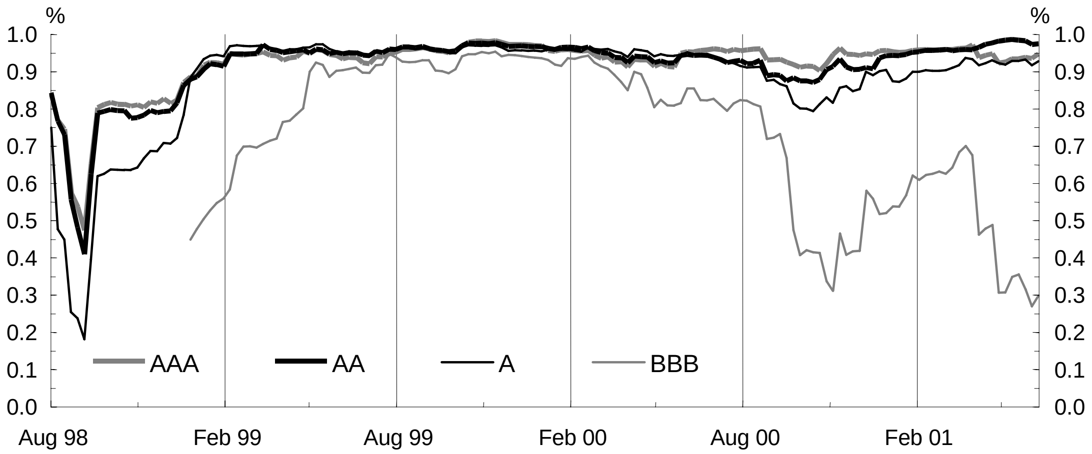
Correlation between 10-year private and government debt yields, euro area markets



Note: Twenty-week rolling correlations of weekly changes. Data computed as the average of daily rates. German bonds used for government debt.
Sources: Bloomberg; Merrill Lynch.

Graph 11

Correlation between 10-year private debt yields and 10-year swap rates, euro area markets



Note: Twenty-week rolling correlations of weekly changes. Data computed as the average of daily rates. Before 1999 swap rates in Deutsche marks.

Sources: Bloomberg; Merrill Lynch.

Table 9

Correlations with corporate bond yields. Euro area market 10-year yields, 1999-2001

(in %)

	Treasury	**Swap**
Weekly		
AAA	0.951	0.956
AA	0.959	0.960
A	0.943	0.949
BBB	0.754	0.773
Four-week		
AAA	0.943	0.976
AA	0.936	0.981
A	0.875	0.943
BBB	0.517	0.654
Eight-week		
AAA	0.976	0.990
AA	0.970	0.991
A	0.948	0.978
BBB	0.860	0.870

Note: Weekly changes. Data computed as weekly average of daily rates.

Sources: Bloomberg; Merrill Lynch.

5. Outlook

5.1 Market integration and changes in market structure

The introduction of the euro has contributed, among other factors, to a reduction in the degree of fragmentation among euro area government bond markets. However, at present these markets are not fully integrated due to remaining barriers such as the heterogeneous tax regimes within the euro area and the lack of integration of its clearing and settlement systems.

The lack of coordination between issuers is sometimes cited as another element hampering market integration. However, a higher homogeneity of products is neither a sufficient nor a necessary condition for market integration.

Progress in market integration will involve obvious gains for both investors and issuers due to the reduction in trading costs. This, in turn, would positively affect the market liquidity of traded securities. All these developments would ultimately improve some of the functions performed by government bond markets.

Another area in which changes in market structure can improve market functioning is futures contracts. As discussed in Section 3, the futures contracts based on German bonds are currently used for managing euro interest rate risks as well as German bond interest rate risks. As a result, the futures market is large compared with the underlying market. This has created ideal conditions for squeezes. The existence of squeezes may introduce distortions into the pricing of securities traded in the cash, derivatives and repo markets that negatively affect market functioning. In IMF (2001b), some measures are proposed to reduce the chance of squeezes, such as increasing issue sizes, reopening issues when a squeeze is likely, introducing cash settlement for futures contracts and enlarging the basket of deliverable bonds.

5.2 The search for substitutes for treasury securities

As argued in Section 4, a number of factors, including the multiplicity of issuers, the existence of market microstructure factors and, to some extent, the reduction in the relative supply of bonds, have affected some functions traditionally performed by government bond markets. The effects of the reduction in the relative supply of bonds have hitherto been limited in the euro area compared with what has occurred for the United States. However, the evidence for the US markets shows that an acceleration of the reduction in the relative supply of bonds in the euro area may have important effects for market functioning. The appearance of such effects would largely depend on the existence of substitute instruments.

Against this background, an analysis is made of what securities could replace treasury securities in such functions, and their relative advantages and shortcomings compared with government bonds. More specifically, the focus is on the following functions: (i) benchmark for extracting information on the inflation and output outlook, (ii) risk-free securities for investment and collateral, (iii) benchmark for pricing other fixed income securities, and (iv) instruments for hedging interest rate risks.

Interest rate swaps are frequently cited as instruments that can stand in for some of these functions.[23] In this regard, swaps have a number of advantages over government securities. First, coupon-related effects do not appear in their valuation since they always reflect the rate of a par bond. Second, the relative liquidity of this market, compared with that of government bond markets, has improved significantly since the introduction of the euro.[24] This effect is mainly a consequence of the concentration of liquidity in one single instrument. Third, a single curve is observed in the swap market. Fourth, the absence of underlying fundamental assets for swaps means that there is no supply limit and no need to borrow securities to go short. Finally, unlike government bonds, this market is completely integrated.

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[23] See BIS (2001b), IMF (2001a), IMF (2001b) and Fleming (2000).

[24] The average bid-ask spread for 10-year euro swap rates was 2.7 basis points between January 1999 and July 2001, which compares with an average of 3.4 basis points for the 10-year Deutsche mark euro swap rate between 1996 and 1998.

Another distinctive feature of swap rates is the presence of a credit risk premium embedded in their pricing, related to the risk of highly rated financial institutions. Depending on the aim pursued and what the market circumstances are, this feature of swaps may be an advantage or a shortcoming. For the purpose of extracting information on expectations about certain macroeconomic variables, the existence of credit risk premia in the swaps market will distort the information content of interest rates. Conversely, for the purpose of hedging private interest rate risk or pricing other private fixed income securities, the existence of a credit risk premium embedded in swap rates will normally be an advantage since this premium tends to be highly correlated with credit risk premia for other private securities. In this regard, the surge in the size of the swap market in the euro area suggests that an increasing number of participants are using this market to hedge interest rate risks.[25] Nonetheless, under certain circumstances - for instance, stress in the financial sector - these correlations may be low or even negative.

The existence of counterparty credit risk is another shortcoming of swaps. However, this risk is currently very low given the set of collateralisation and documentation standards recently developed by dealers and customers.

Swaps cannot be used to replace government securities in other functions such as investments and collateral. At the same time, some market indicators, such as those derived from inflation indexed bonds, are not currently available from swaps markets. To perform these functions, an alternative highly rated instrument is needed. Recent developments in the euro area indicate that asset- and mortgage-backed securities, such as German Pfandbriefe, may meet this need. Their increasing liquidity and the fact they are normally highly rated are the main advantages. In this respect, these securities are increasingly used as collateral by some institutions and the ECB currently accepts most of them as collateral in its monetary policy operations. But they currently have shortcomings that limit their advantages over government bonds, namely their lower liquidity and the existence of a prepayment risk embedded in their pricing. In addition, the fact that these instruments normally have a higher credit risk than government bonds means that they cannot be perfect substitutes. More specifically, some investors might be forced to assume a level of risk above that desired. In collateral transactions, higher risk can be easily overcome by introducing higher haircuts than those applied to comparable government bonds.

The above discussion suggests there are currently certain instruments capable of assuming some of the functions traditionally performed by government bonds. Although these instruments have some advantages over government bonds, they also have shortcomings. Thus, the optimal instrument is not easy to establish and will depend on a number of factors, including the aim pursued. For the purpose of extracting information on the inflation and output outlook, the advantage of using an alternative security in the euro area is not clear. Possibly, a better option would be to complement the information provided by the government bond market rather than replace it. Conversely, for the purpose of hedging private interest rate risk or pricing private fixed income securities, swaps will normally be better instruments. In this regard, Section 4 reveals that, in the euro area, swaps are a better hedging vehicle than treasuries.

6. Conclusions

This paper has analysed recent key developments in euro area government bond markets and their main implications for central banks and market functioning. The introduction of the euro and the relative reduction in the supply of bonds have been identified as the two main driving forces.

The introduction of the euro has affected the trading strategies of investors and has prompted some reorganisation of the markets, ultimately reflected in greater market integration. However, euro area government bond markets are at present far from being fully integrated. Given the advantages associated with greater integration, it would be desirable to continue efforts to eliminate obstacles that currently seem to contribute to fragmentation.

[25] According to the BIS (2001a), the size of the market, approximated by the notional amount outstanding, increased by 32% between 1998 and 2000.

The introduction of the euro has also affected the relative pricing of securities. To see this, the determinants of yield spreads before and after monetary union have been analysed. The spreads over German bonds for previously high-yield debt have narrowed significantly. By contrast, the spreads for all other euro area sovereign debt have widened since the introduction of the euro. It was argued that this evidence might reflect an increase in differences in both liquidity and genuine credit risk between German securities and other euro area sovereign debt. A change in pricing due to greater market integration is not ruled out. It has also been shown that market microstructure factors, such as relative market liquidity and the CTD status of bonds, play a part in determining relative prices in addition to differences in credit risk.

It was argued that the existence of these market microstructure effects, together with the multiplicity of sovereign issuers in the euro area, limits some of the functions traditionally performed by government bond markets, such as their status as a benchmark for pricing other fixed income securities, their usefulness for hedging interest rate risks or the extraction of relevant information for the inflation and output outlook.

The reduction in the relative supply of government bonds has hitherto had a limited effect in the euro area, contrasting with the evidence for the United States market. The experience in the United States shows that the continuation of this process in the euro area may have relevant effects and implications for market functioning. The appearance of such effects would largely depend on the existence of substitute instruments.

Against this background, interest rate swaps appear to be instruments capable of replacing government securities in some of their functions. However, the existence of a time-varying credit risk premium embedded in swap rates means that, depending on the aim pursued and under certain market circumstances, the relative advantages of these instruments might be offset by their costs. For the purpose of hedging private interest rate risk or pricing private fixed income securities, swaps are probably better instruments. Conversely, for the purpose of extracting information on the inflation and output outlook, the advantage of using an alternative security to government bonds is not clear. Possibly, a better option would be to complement the information provided by the government bond market rather than replace it.

Finally, swaps cannot be used to replace government securities in certain other functions, such as investments and collateral. To perform these functions, highly rated private paper is needed, but the higher credit risk of these alternative instruments compared with government bonds means that they are not perfect substitutes.

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The effects of bank consolidation on risk capital allocation and market liquidity[1]

Chris[2] and Alexandra Lai,[3]
Bank of Canada

Abstract

This paper investigates the effects of financial market consolidation on risk capital allocation in a financial institution and the implications for market liquidity in dealership markets. We show that an increase in financial market consolidation can have ambiguous effects on liquidity in foreign exchange and government securities markets. The framework employed assumes that financial institutions use risk management tools (for example value-at-risk) in the allocation of risk capital. Capital is determined at the firm level and allocated among separate business lines, or divisions. Market-makers' ability to supply liquidity is influenced by their risk-bearing capacity, which is directly related to the amount of risk capital allocated to this activity. A model of inter-dealer trading is developed similar to the framework of Volger (1997). However, we allow for heterogeneity among dealers with respect to their risk-bearing capacity.

The allocation of risk capital within financial institutions has implications for what types of mergers among financial institutions can be beneficial for market quality. This effect depends on the correlation among cash flows from business activities that the newly merged financial institution will engage in. A negative correlation between market-making and the new activities of a merged firm suggests the possibility of increased market liquidity. Our results suggest that, when faced with a proposed merger between financial institutions, policymakers and regulators would want to examine the correlations among division cash flows.

1. Introduction

Change in financial markets is ubiquitous. Historically, regulatory restrictions have often inhibited the ability of financial institutions operating in one area of the financial services industry to expand their product set into other areas, but deregulation has allowed financial institutions to offer a broader range of banking, insurance, securities and other financial services.[4] Innovations in financial engineering and evolving market structures have altered the way financial markets and institutions operate. At the same time, deregulation in the industry has increased competition, prompting financial institutions to look for new profitable lines of business. Some financial institutions have found it advantageous to merge in order to generate higher returns through economies of scope or scale. The impact of consolidation on market liquidity, in particular liquidity in government securities and foreign exchange markets, is of increasing importance to policymakers. Ensuring liquidity in these two markets is important to governments and central banks interested in maintaining or enhancing the functioning of these markets so that they can effectively implement fiscal and monetary policies. In Canada,

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[2] Bank of Canada, Financial Markets Department.

[3] Bank of Canada, Monetary and Financial Analysis Department. Correspondence: Alexandra Lai, Bank of Canada, MFA, 234 Wellington Street, Ottawa, Ontario, K1A 0G9. Tel: (613) 782 7667, e-mail: laia@bankofcanada.ca.

[4] For example, the Glass-Steagall Act of 1933 sought to impose a rigid separation between commercial banking (deposit-taking and loan-making) and investment banking (underwriting, securities issuance). The Act limited the ability of banks and securities firms to engage directly or indirectly in each other's activities.

policymakers are concerned with the declining number of dealers in both Government of Canada fixed income markets and foreign exchange markets, and worry that increased consolidation among financial institutions will cause liquidity in these markets to fall.

This paper analyses the impact of financial consolidation on market liquidity by studying the effects of consolidation on the risk-bearing capacity of market-makers, or dealers, in dealership markets. To carry out our analysis, two previously separate areas of research are bridged. The first, market microstructure theory, focuses on how market participants and the trading mechanism affect price discovery and market liquidity.[5] The second, risk management, influences the way in which firms look at both the returns and risks of individual business operations. Our analysis traces the impact of a merger on the capital allocation decisions of the new merged financial institution and the resulting change in the behaviour of dealers.

Using a model in which a financial institution, henceforth referred to as a bank in this paper, allocates risk capital across its business activities in order to satisfy a firm-wide capital requirement, we show that the optimal capital allocation conditions the risk aversion of division managers and traders. This key result relates risk management by the bank to the behaviour of its market-makers in asset markets. The risk-bearing capacity of a dealership market depends on the number of market-makers present as well as the risk aversion of each market-maker. Since market liquidity in dealership markets is determined by the inherent riskiness of the market and the risk-bearing capacity of the market, capital allocation affects market liquidity by influencing the risk aversion of market-makers.

We apply this framework to examine the effects of financial consolidation on market liquidity. We find that consolidation has an ambiguous effect on market liquidity. In particular, market liquidity can increase upon consolidation. Whether this happens depends on the correlation among the cash flows from the merged bank's division. This is in contrast to other results in the literature, which argue that market liquidity will necessarily deteriorate with consolidation. These other studies only consider the effects of a reduction in market-makers on risk-sharing, while our paper shows that the effect on liquidity of a bank merger will also depend critically on the risk-bearing capacities of the old and new banks. Therefore, policymakers and regulators faced with a proposed merger between banks would want to examine the correlations among division cash flows. A negative correlation between market-making and the new activities of a merged firm suggest the possibility of increased market liquidity.

Capital allocation decisions are more complicated than a simple application of the capital asset pricing model (CAPM), since frictions exist in capital markets. Imperfect capital markets impose deadweight costs that must be covered by the cash flows of a business line if the business line is to be profitable. Froot and Stein (1998) and Perold (2001) model the capital structure decision by positing frictions in capital markets and/or in the internal management of firms that lead to deadweight costs. In Froot and Stein (1998) firms engage in risk management to avoid ex post penalties resulting from a cash flow shortfall. Perold (2001), on the other hand, derives ex ante deadweight costs associated with actions undertaken by the firm to provide performance guarantees on its customer contracts through the purchase of insurance and a cash cushion. Both papers demonstrate that there is a trade-off between managing risk via ex ante capital structure policies and via capital budgeting and hedging policies. Hence, the capital structure, hedging and capital budgeting policies of a firm are interrelated and jointly determined. In a multi-divisional firm, risk management tools are also used for performance evaluation. Specifically, risk capital allocation is an important component of the process of determining the risk-adjusted rate of return and ultimately the economic value added of each business unit. Such calculations can then form the basis for incentive compensation. Stoughton and Zechner (1999) examine performance evaluation and managerial compensation issues but we will abstract from those issues in this paper. In addition to the internal risk management that financial institutions engage in, regulators impose capital requirements on banks. Externalities from bank failures, risk-shifting in the presence of fixed premium deposit insurance, and the protection of uninformed investors who hold most of a bank's debt are the main justification for regulating bank capital. For all these reasons, financial institutions often maintain capital levels over and above the amounts they need to finance their operations.

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[5] See O'Hara (1995) for a survey of the theoretical literature on market microstructure and Madhavan (2000) for a survey of the empirical literature.

Market liquidity is influenced by the way the market is structured. For example, most foreign exchange and government bond markets are characterised by price competition (quote-driven) among multiple dealers and inter-dealer trading rather than by Cournot competition (order-driven), and the actions of the dealers in the public and inter-dealer markets provide much of market liquidity. Such markets are referred to as *dealership markets*. This paper develops a dealership market model similar to the framework of Volger (1997). However, we allow for heterogeneity among dealers with respect to their risk-bearing capacity.

The paper is organised as follows: Section 2 presents the capital allocation model for a bank with multiple divisions; Section 3 provides an analysis of a dealership market model in which dealers can be heterogeneous with respect to their risk aversion; Section 4 looks at the effects of financial consolidation on capital allocation and liquidity in the dealership market; and Section 5 suggests implications for regulators and policymakers, and for further research.

2. Capital allocation in a multi-divisional firm

Effective risk management promotes both financial institution and industry stability by protecting a financial institution against market, credit, liquidity, operational and legal risk. The primary means of protection is the financial institution's risk (or economic) capital. One goal of risk management is to determine the firm's optimal capital structure. This process involves estimating how much risk each business unit, or division, contributes to the total risk of the firm and thus to overall capital requirements. Since investment decisions and risk exposures are determined at the division level, correlations between portfolios held by different divisions are externalities among units that create a need for centralised risk management. Hence, risk management in a multi-divisional firm also involves determining the capital charge to each division whose activities contribute to firm risk in order to induce the appropriate risk-taking behaviour by division managers.

The framework that we use in this section is adapted from Stoughton and Zechner (1999). Consider an economy with N + 1 banks, indexed i = 0,. . , N.6 Each bank is engaged in a number of financial activities that generate income or cash flows. These activities are indexed by j. We denote the set of all possible financial activities by J. One activity that all banks participate in is market-making in a dealership market for a particular security.[7] In this section, we analyse the problem of a bank that engages in a subset K J of activities, each of which generates cash flows to equity holders.[8] Each business line j is undertaken by a division, so we will denote the division by the same index j.

Each division j has an expected cash flow μ_j determined by the function

$$\mu_j = \mu_j\left(\sigma_j^2\right), j \in K \tag{1}$$

where σ_j^2 is the variance of cash flow from division j. It is assumed that more risk-taking by a division yields a higher expected return,

$$\frac{\partial \mu_j}{\partial \sigma_j^2} > 0, j \in K.$$

In addition, we assume that the function μ_j is strictly concave in σ_j^2 and the Inada conditions hold, or

$$\frac{\partial^2 \mu_j}{\partial \sigma_j^2} < 0, \left.\frac{\partial \mu_j}{\partial \sigma_j^2}\right|_{\sigma_j^2=0} \to \infty, \lim_{\sigma_j^2 \to \infty} \frac{\partial \mu_j}{\partial \sigma_j^2} = 0, j \in K.$$

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6 Later, we analyse the case where a merger occurs and N banks remain in the economy.

7 This may be a foreign exchange, fixed income or equity market.

8 We will drop for now the index i corresponding to the N + 1 banks. In later sections of the paper, the index is brought back into our notation.

To simplify the analysis without loss of generality, investment activities are assumed to require zero cash outlay, or cash flows are defined after the appropriate interest costs. Furthermore, for any j, $h \in J$, the correlation between project j's and project h's cash flows is given by ρ_{hj}.

The opportunity cost of equity capital, $r > 0$, is assumed to be constant and identical across banks. Financial institutions must allocate the scarce equity capital without violating regulatory constraints. A bank's equity capital requirement is determined as a fixed proportion of the risk of its portfolio, as measured by the variance of its total cash flows,

$$C \geq \alpha\sigma_p^2, \alpha > 0 \tag{2}$$

The bank's overall risk, σ_p^2, can be expressed as

$$\sigma_p^2 = \sum_{j \in K} \sigma_j^2 + \sum_{h \in K} \sum_{j \in K,\, j \neq h,} \rho_{hj}\sigma_h\sigma_j \tag{3}$$

The bank's objective function is to maximise the net present value of cash flows, taking into account the opportunity cost of capital. This is equivalent to maximising the economic value added (EVA) or the contribution to shareholder value, where

$$\text{EVA} = \sum_{j \in K} \mu_j - rC \tag{4}$$

2.1 First-best: centralised investment decisions

Before we examine the problem of allocating capital across divisions in a delegated environment, we first derive the solution to the bank's centralised problem. Continuing with our analysis of a bank with multiple divisions, indexed by $j \in K$, the centralised problem is

$$\begin{aligned} &\max_{\{\sigma_j\}_{j \in K}} \sum\nolimits_{j \in K} \mu_j\left(\sigma_j^2\right) - rC \\ &\quad s.t. \qquad C \geq \alpha\sigma_p^2 \end{aligned} \tag{5}$$

where σ_p^2 is defined in (3). Since capital is costly, the constraint in the maximisation problem is always satisfied with equality.

The first-order conditions (for an interior optimum) are

$$\frac{\partial\mu_j\left(\hat{\sigma}_j^2\right)}{\partial\sigma_j^2} = r\alpha\left[1 + \sum_{h \neq j, h \in K} \rho_{hj}\left(\frac{\hat{\sigma}_h^2}{\hat{\sigma}_j^2}\right)^{1/2}\right], j \in K \tag{6}$$

where $\hat{\sigma}_j, j \in K$ is the optimal risk level for division j.

The right-hand side of the above equation is just the marginal contribution to the overall risk of the bank by division j's activities multiplied by the cost of capital. At a given risk level, σ_j^2, division j's marginal contribution to the overall risk of the bank is

$$\frac{\partial\alpha\sigma_p^2}{\partial\sigma_j^2} = \alpha\left[1 + \sum_{h \neq j, h \in K} \rho_{hj}\left(\frac{\sigma_h}{\sigma_j}\right)\right], j \in K \tag{7}$$

Intuitively, investment (in terms of risk undertaken) will occur up to the point where the marginal increase in expected returns from activities by division j is balanced by the marginal cost of risk undertaken by that division.

2.2 Delegated investment decisions

In an environment where investment decisions are delegated to each division, the bank's problem is one of allocating the appropriate amount of risk capital across divisions to maximise the bank's economic value added. It is straightforward to determine the capital allocation function that implements the first-best solution to the delegated problem. Suppose that the bank establishes a capital allocation rule for each division, T_j, $j \in K$. The formal delegation problem can be written

$$\max_{\{T_j\}_{j \in K}} \sum_{j \in K} \left[\mu_j \left(\sigma_j^2 \right) - rC - U_j \right] \tag{8}$$

$$s.t.\ \sigma_j^2 \in \arg\max_{\sigma^2} \mu_j \left(\sigma^2 \right) - rT_j \left(\sigma_j^2 \right), j \in K \tag{9}$$

$$C \geq \alpha \sigma_p^2 \tag{10}$$

where U_j denotes the compensation that the firm transfers to division managers. This compensation function is designed so that each division makes optimal investment decisions and is assumed to consist of a fixed (salary) component, S_j, and a performance component in the form of a share of the EVA generated by the division. The division's EVA is, in turn, defined as the mean return from the division's project adjusted for the appropriate capital charge, rT_j, that is,

$$U_j = \tau [\mu_j - rT_j] + S_j, j \in K \tag{11}$$

This compensation scheme induces each division to solve the problem

$$\max_{\sigma_j^2} \mu_j \left(\sigma_j^2 \right) - rT_j, j \in K$$

which yields constraint (9) in the bank's delegation problem. We present the solution to the delegation problem and its implication in the following proposition.

Proposition 1. *The optimal capital allocation function to each division j, j $\in$ K, is a linear function of the risk undertaken by the division:*

$$T_j \left(\sigma_j^2 \right) = \theta_j \sigma_j^2, j \in K \tag{12}$$

where

$$\theta_j = \alpha \left[1 + \sum_{h \neq j, h \in K} \rho_{hj} \left(\frac{\hat{\sigma}_h^2}{\hat{\sigma}_j^2} \right)^{1/2} \right] \tag{13}$$

This capital allocation function conditions the division manager's risk aversion so that the manager, by maximising his utility, behaves like a risk-averse agent with exponential utility and risk-aversion parameter given by

$$\gamma_j = r\theta_j, j \in K \tag{14}$$

in the presence of normally distributed cash flows.

Proof: See Appendix.

The optimal capital allocation to a division is thus proportional to the risk undertaken by the division, where risk is measured by the variance of the cash flow generated by the division. One can think of this as a charge to the division for the risk imposed on the bank by the division's activities. More importantly, this proposition relates the risk management of a bank to the behaviour of its dealers in the bank's trading activities. We elaborate on this point in the next section, where a dealership market model is presented.

3. Model of the dealership market

Liquidity is an important dimension of all financial markets.[9] For example, government securities markets perform several important functions that hinge on the fact that they are very liquid. They are the markets in which governments raise funds and are thus of particular interest to central banks with fiscal agency responsibilities. Furthermore, because of their virtually riskless nature, government securities serve as the pricing benchmark and hedging vehicle for other fixed income securities. While market liquidity is a concept that is difficult to measure or define because of its multidimensional nature, most market participants would agree on the following characterisation. A *liquid* market is *one in which large transactions can be completed quickly with little impact on prices*.[10] The various dimensions of liquidity also tend to interact.[11] In this paper, we focus on bid-ask spreads as a measure of liquidity.

In this section, we develop a model of the dealership market in which banks provide market-making services. Each bank's market-making activity is carried out by a dealer who is constrained in his risk-taking behaviour by the bank's capital allocation. This allows us to study how the capital allocation decisions by individual banks impact market liquidity. We will then apply this framework to a merger between two banks by first examining how capital allocation is affected by the merger and the consequences of that for market liquidity.

Consider a security that trades in a dealership market with $N + 1$ market-makers (or dealers). The security is traded at price p between dealers and outside investors in the public market, and at price p_d among dealers in a separate inter-dealer market. The exogenously given liquidation value of the security is denoted by v, a random variable which is normally distributed with zero mean and standard deviation σ_v. We assume that no market participant has private information about the future liquidation value of the traded security. There is one investor in the market who trades a quantity w, the realisation of a random variable which is independent of the asset's liquidation value, v, and distributed with zero mean and standard deviation σ_v. By convention, $w > 0$ denotes an investor's buy order and $w < 0$ a sell order. We consider one trading period where trade takes place in two stages.

In stage 1, all dealers simultaneously quote a price schedule over customer orders, w, in the public market. The investor observes the quotes of all the competing dealers and submits the whole order w to the dealer quoting the best price. It is a defining characteristic of dealership markets that market-makers compete for the whole order. We assume that each dealer starts with a zero inventory position which is observable to all dealers.[12] Bargaining between investors and market-makers is resolved by assuming that market-makers compete à la Betrand. That is, all bargaining power is on the investor's side.

Trading between market-makers to reallocate inventories takes place in stage 2. Once an investor gives the whole order to one of the $N + 1$ competing dealers, that particular dealer's inventory changes by $-w$.This dealer now has an incentive to trade in the inter-dealer market to reduce his risk exposure. Hence, inter-dealer trading allows dealers to risk-share. Dealers are assumed to behave as strategic competitors by submitting their demand functions in the inter-dealer market. That is, they take into account the effect their quantities are expected to have on the market-clearing price. The equilibrium concept we employ is that of a non-competitive rational expectations Nash equilibrium in demands (Kyle (1989)). The security will be liquidated at the end of the inter-dealer trading in stage 2.

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9 The discussion of liquidity is taken from Gravelle (1999, 2001).

10 In the literature, market liquidity is typically defined over four dimensions: immediacy, depth, width (bid-ask spread) and resiliency. Immediacy refers to the speed with which a trade of a given size at a given width is completed. Depth refers to the maximum size of trade that can be carried out for any given bid-ask spread. Width refers to the cost of providing liquidity, with narrower spreads implying greater liquidity. Resiliency refers to how quickly imbalances in transaction flows dissipate. An imbalance in transaction flows means that there is a one-way market, or prices are gapping. If imbalances tend to persist, or when imbalances tend not to generate a counterbalancing order flow (once prices have moved enough to attract this counterbalancing order flow), the market is not resilient.

11 For example, width will generally increase with the size of a given trade, or, for a given bid-ask spread, all transactions under a given size can be executed immediately with no movement in the price or spread.

12 Allowing for different initial inventories only complicates the analysis without qualitatively affecting our merger analysis results in the next section.

The $N + 1$ dealers are indexed by $i = 0,...,N$. Each dealer behaves like a risk-averse agent with a coefficient of absolute risk aversion given by γ_i.[13] Specifically, dealer i with risk aversion parameter γ_i maximises the exponential utility function

$$U(\pi_i) = -e^{-\gamma_i \pi_i}$$

where $\pi_i = v(x_i - w) + pw - p_d x_i$ is the profit of dealer i if he gets an order from the investor, while $\pi_i = vx_i - p_d x_i$ is his profit if he gets no customer order, x_i is the demand of dealer i in the inter-dealer market, p is the price at which the customer order is transacted, and p_d is the price that prevails in the inter-dealer market.

We will solve the model under two different scenarios. In the first, we assume that dealers have identical risk aversion, γ. In the second, we assume that dealers are one of two types. Type 1 dealers have risk aversion $\gamma_1 = \delta\gamma$, $\delta > 0$ and type 2 dealers have risk aversion $\gamma_2 = \gamma$. There are N_1 type 1 dealers and N_2 type 2 dealers. Naturally, $N_1 + N_2 = N + 1$.

Later, when we analyse the effects of a merger between two banks (and consequently two dealers), the starting point is a market with identical dealers. This is the case when potentially differentiated banks allocate the same amount of capital to market-making. When two of those banks merge, we allow for the case that the merged entity engages in a different set of activities, thus allocating risk capital differently across business lines. To this end, we will need an analysis of a dealership market with heterogeneous dealers.

3.1 Dealership market with identical market-makers ($\delta = 1$)

In this section, dealers have an identical coefficient of absolute risk aversion, given by γ. We solve the model by backward induction. That is, we first solve stage 2 of the model for a symmetric equilibrium in the inter-dealer market, taking the equilibrium price in the public market as given. Then, we solve stage 1 of the model for the equilibrium reserve prices (the price that leaves the dealer indifferent between getting the customer order and not getting it) in the public market. For reservation prices that differ, the equilibrium price in the public market is given by the second-best reservation price which is quoted by the dealer with the best reservation price. When all dealers have the same reservation price, they each quote their reservation prices and receive the customer order with equal probability.

3.1.1 Equilibrium in the inter-dealer market (stage 2)

We simplify the analysis by assuming that the inter-dealer market is a call market. All market-makers submit their orders simultaneously to an inter-dealer broker who executes the set of multilateral transactions at one market-clearing price.

A symmetric linear equilibrium in the inter-dealer market is obtained if the demand schedules of the each dealer i can be written

$$x_i = \alpha - \beta p_d + \eta w_i, \qquad i = 0,...,N \tag{15}$$

Proposition 2. *There exists a linear equilibrium in the inter-dealer market in which market-makers' demand is given by (15). The parameters are given by*

$$\alpha = 0, \qquad \beta = \frac{N-1}{N\Psi}, \qquad \eta = \frac{N-1}{N} \tag{16}$$

where $\Psi = \gamma\sigma_v^2$. The equilibrium price in the inter-dealer market is

$$p_d = \frac{\Psi}{N+1}w. \tag{17}$$

Proof: See Appendix.

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[13] In our framework, dealers' risk aversion is determined by the amount of risk capital allocated to market-making in that security by the financial institutions that own the dealers.

The equilibrium price in the inter-dealer market depends on the size of the investor's order. η is the proportion of the investor's order that a dealer passes on in the inter-dealer round of trading and hence a measure of risk-sharing. It is increasing in N. Therefore, risk-sharing improves as the total number of dealers in the market increases and the inter-dealer market becomes more competitive.

Using the fact that $w_i = w$ if dealer i receives the customer order and $w_i = 0$ otherwise, demands and inventories after inter-dealer trade are

$$x_i = \begin{cases} \frac{N-1}{(N+1)} w & \text{if } w_i = w \\ -\frac{N-1}{N(N+1)} w & \text{if } w_i = 0 \end{cases} \tag{18}$$

$$I_i = \begin{cases} \frac{N-1}{(N+1)} w - w = -\frac{2}{N+1} w & \text{if } w_i = w \\ -\frac{N-1}{N(N+1)} w & \text{if } w_i = 0 \end{cases} \tag{19}$$

Notice that risk-sharing is not perfect in this model. Since dealers are ex ante identical, perfect risk-sharing implies that all dealers will end up with identical inventory levels after inter-dealer trade, or $I^* = -\frac{w}{N+1}$. However, $|I_i| > |I^*|$ if $w_i = w$ and $|I_i| < |I^*|$ if $w_i = 0$.

Perfect risk-sharing does not obtain because of imperfect competition in the inter-dealer market. That is, each dealer has an incentive to restrict the quantity he trades in the inter-dealer market relative to what he would trade if the inter-dealer market was competitive. Notice that perfect risk-sharing will obtain if $N \to \infty$.

3.1.2 Equilibrium in the public market (stage 1)

To solve for the equilibrium in the public order market, we first determine each dealer's reservation quotes, in anticipation of inter-dealer trading in the next stage. The dealer with the best reservation price receives the public order by quoting the second-best reservation price. Recall that if dealer i gets the public order, he has a final inventory $-\frac{2}{N+1}w$ while if he does not get the public order, he has a final inventory $-\frac{N-1}{N(N+1)}w$.

Denote dealer i's reservation price by p_i^r, $i = 0,..,N$. If dealer i gets the public order at his reservation price, his expected utility will be given by

$$EU_i^w = p_i^r w - p_d x_i - \frac{\Psi}{2}\left(\frac{2}{N+1}w\right)^2 \tag{20}$$

$$= p_i^r w - \frac{(N-1)\Psi}{(N+1)^2} w^2 - \frac{\Psi}{2}\left(\frac{2}{N+1}w\right)^2 \tag{21}$$

while if he does not, his expected utility is

$$EU_i^0 = -p_d x_i - \frac{\Psi}{2}\left(\frac{N-1}{N(N+1)}w\right)^2 \tag{22}$$

$$= \frac{(N-1)\Psi}{N(N+1)^2}w^2 - \frac{\Psi}{2}\left(\frac{N-1}{N(N+1)}w\right)^2. \tag{23}$$

At his reservation price, dealer *i* is indifferent between getting the public order and not getting it. Equating $EU_i^w = EU_i^0$ and simplifying, we get dealer *i*'s reservation price, given in the next proposition.

Proposition 3. *For* $N > 0$*, the equilibrium price in the public market is*

$$p = \frac{(2N-1)\Psi}{2N^2}w \tag{24}$$

and the market bid-ask spread for a customer order of size $|w|$ *is*

$$s = \frac{(2N-1)\Psi}{N^2}|w|. \tag{25}$$

Since all dealers are identical, they quote the same price (equal to their reservation price) and have equal chances of receiving the public order. The market bid-ask spread for an order of size $|w|$ is just $s = 2|p|$.

If dealers are risk-neutral $(\Psi = \gamma\sigma_v^2 = 0)$, the equilibrium price is equal to the expected value of the security, which is normalised to zero. For risk-averse dealers and multiple dealers, $N > 0$, the equilibrium price is increasing in the size of the customer order and decreasing in *N*. The larger the size of the customer order, the higher the risk premium required by dealers to absorb this quantity. An increase in the number of competing dealers leads to better risk-sharing and hence a lower risk premium is required.

3.2 Dealership market with heterogeneous market-makers

In this section, there are two types of dealers: type 1 dealers have risk aversion $\gamma_1 = \delta_\gamma$, and $\delta > 0$ type 2 dealers have risk aversion $\gamma_2 = \gamma$. There are N_1 type 1 dealers and N_2 type 2 dealers, where $N_1 + N_2 = N + 1$. We begin this section by characterising the equilibrium for the case where N_1 and N_2 can take any values but we solve explicitly for the equilibrium with only one type 1 dealer and *N* type 2 dealers. This minimal amount of heterogeneity is all we need in order to perform the merger analysis that comprises the next part of this paper.

3.2.1 Equilibrium in the inter-dealer market (stage 2)

Let the set of type 1 dealers be denoted by χ_1 and the set of type 2 dealers be denoted by χ_2. From here on, we will denote an arbitrary type 1 dealer by *i* and an arbitrary type 2 dealer by *j*. Since each of the two types of dealers is identical with respect to the other dealers in his group, a linear equilibrium in the inter-dealer market is obtained if the demand schedules of each dealer *i* can be written

$$x_i = \alpha_1 - \beta_1 p_d + \eta_1 w_i, \qquad \forall\, i \in \chi_1 \tag{26}$$

$$x_j = \alpha_2 - \beta_2 p_d + \eta_2 w_j, \qquad \forall\, j \in \chi_2 \tag{27}$$

Proposition 4 (General case). *There exists a linear equilibrium in the inter-dealer market in which the market-makers' demand is given by (26) and (27). The parameters are given implicitly by*

$$\alpha_1 = \alpha_2 = 0, \qquad \eta_1 = \delta\Psi\beta_1, \qquad \eta_2 = \Psi\beta_2,$$

$$\beta_1 = \frac{(N_1-1)\beta_1 + N_2\beta_2}{1+\delta\Psi[(N_1-1)\beta_1 + N_2\beta_2]} = \frac{\overline{\beta}-\beta_1}{1+\delta\Psi(\overline{\beta}-\beta_1)} \tag{28}$$

$$\beta_2 = \frac{N_1\beta_1 + (N_2 - 1)\beta_2}{1 + \Psi(N_1\beta_1 + (N_2 - 1)\beta_2)} = \frac{\overline{\beta} - \beta_2}{1 + \Psi(\overline{\beta} - \beta_2)} \tag{29}$$

where $\overline{\beta} = N_1\beta_1 + N_2\beta_2$ and $\Psi = \gamma\sigma_\upsilon^2$. *Denoting the type of the dealer who received the customer order in stage 1 by y, the equilibrium price in the inter-dealer market is:*

$$p_d = \frac{\beta_1\delta\Psi w}{\overline{\beta}} \qquad \text{if } y \in \chi_1 \tag{30}$$

$$= \frac{\beta_2\Psi w}{\overline{\beta}} \qquad \text{if } y \in \chi_2. \tag{31}$$

The proof of proposition 4 follows the same steps as for proposition 1. Note that the equilibrium inter-dealer price is lower if the dealer with the public order is the one with lower risk aversion. For $\delta < 1$ ($\delta > 1$), a type 1 dealer has a lower (higher) risk aversion than a type 2 dealer. As well, the equilibrium inter-dealer price is increasing in the size of the customer order, $|w|$.

Although the solutions to the two equations for $\beta 1$ and $\beta 2$ are difficult to derive explicitly, we can characterise the solutions.

1. β_1, β_2 and $\overline{\beta}$ are increasing in δ.
2. $\beta_1 - \beta_2 > 0$ and $\delta\Psi\beta_1 - \Psi\beta_2 < 0$ for $N > 2$ and $\delta < 1$.

   $\beta_1 - \beta_2 < 0$ and $\delta\Psi\beta_1 - \Psi\beta_2 < 0$ for $N > 2$ and $\delta > 1$.
3. β_1, β_2 and $\overline{\beta}$ are decreasing in Ψ.
4. Holding N constant, β_1, β_2 and $\overline{\beta}$ are decreasing in N_1 if $\delta < 1$ and increasing in N_1 if $\delta > 1$.

For the special case of $N_1 = 1$, the explicit solutions for β_1 and β_2 are given in the next proposition. This special case is relevant when we analyse a merger between two banks, and hence two dealers.

Proposition 5 (Special case). *For* $N_1 = 1$ *and* $N > 3$, *there exists a linear equilibrium in the inter-dealer market in which the market-makers' demand is given by (26) and (27). The parameters are given implicitly by*

$\alpha_1 = \alpha_2 = 0, \qquad \eta_1 = \delta\Psi\beta_1, \qquad \eta_2 = \Psi\beta_2,$

$$\beta_1 = \frac{N_2\beta_2}{1 + \delta\Psi N_2\beta_2} \tag{32}$$

$$\beta_2 = \frac{\delta N_2^2 + 1 - 2N_2(1+\delta) + \sqrt{\left[\delta N_2^2 + 1 - 2N_2(1+\delta)\right]^2 + 4\delta N_2(N_2 - 1)(2N_1 - 2)}}{2\delta N_2(N_2 - 1)} \tag{33}$$

where $\Psi = \gamma\sigma_v^2$.

3.2.2 Equilibrium in the public market (stage 1)

In this section, we carry through the assumption that $N_1 = 1$ and $N_2 = N$. As before, we first determine each dealer's reservation quotes in the public market, in anticipation of inter-dealer trading in the next stage. Since there are two types of dealers, there will be two different reservation prices. The dealer with the best reservation price receives the public order by quoting the second-best reservation price.

Let p_1^r be the reservation price of the type 1 dealer and p_2^r be the reservation price of a type 2 dealer.

Proposition 6. *Let* $\Psi_1 = \delta\gamma\sigma_v^2$ *and* $\Psi_2 = \gamma\sigma_v^2$. *The type 1 dealer has a reservation price given by*

$$p_1^r = \left\{\left(1 - \frac{\beta_1}{\overline{\beta}}\right)\frac{\beta_1^2\Psi_1^2}{\overline{\beta}} + \frac{\beta_1}{2\overline{\beta}^2}\beta_2^2\Psi_2^2(2 - \beta_1\Psi_1) - \frac{\Psi_1}{2}\left[1 - \left(1 - \frac{\beta_1}{\overline{\beta}}\right)\beta_1\Psi_1\right]^2\right\}w \tag{34}$$

while a type 2 dealer has a reservation price given by

$$p_2^r = \left\{ \left(1 - \frac{\beta_2}{\overline{\beta}}\right) \frac{\beta_2^2 \Psi_2^2}{\overline{\beta}} + \frac{\beta_2}{2\overline{\beta}^2} \beta_1^2 \Psi_1^2 \left(2 - \beta_2 \Psi_2\right) - \frac{\Psi_2}{2} \left[1 - \left(1 - \frac{\beta_2}{\overline{\beta}}\right) \beta_2 \Psi_2 \right]^2 \right\} w \tag{35}$$

if the winning dealer is a type 1 dealer, and

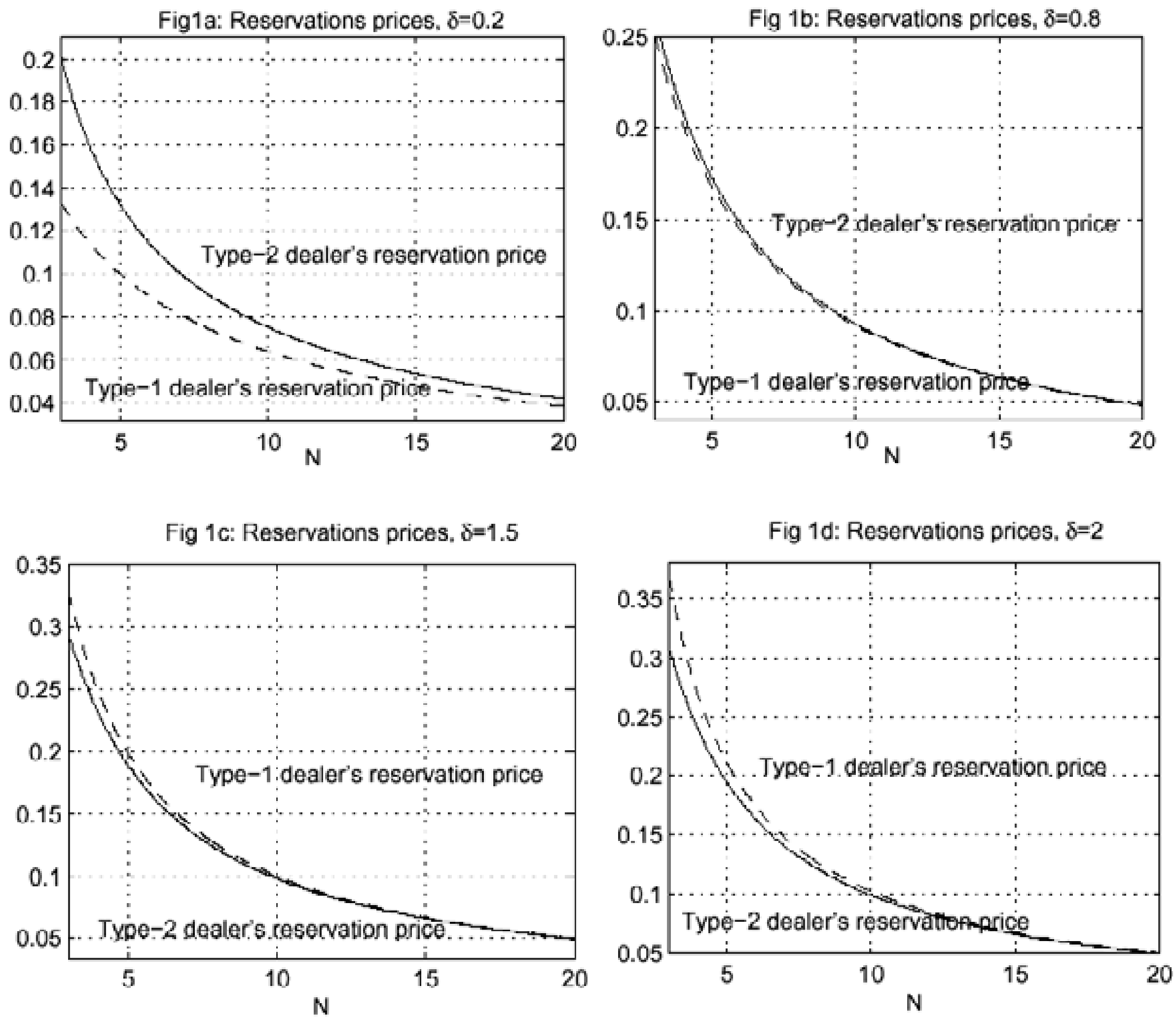
$$p_2^r = \left\{ \left(1 - \frac{\beta_2}{\overline{\beta}}\right) \frac{\beta_2^2 \Psi_2^2}{\overline{\beta}} + \frac{\beta_2}{2\overline{\beta}^2} \beta_2^2 \Psi_2^2 \left(2 - \beta_2 \Psi_2\right) - \frac{\Psi_2}{2} \left[1 - \left(1 - \frac{\beta_2}{\overline{\beta}}\right) \beta_2 \Psi_2 \right]^2 \right\} w \tag{36}$$

if the winning dealer is another type 2 dealer.

We turn to numerical examples (Figure 1) to illustrate the following proposition, which lays out the equilibrium price in the public market.

Figure 1

Reservation prices for type 1 and type 2 dealers



Proposition 7. *Assuming that* $N \geq 3$*, then the following is true.*

(1) *If* $\delta < 1$*, the type 1 dealer has the better reservation price,* $p_1^r < p_2^2$*. Hence, the equilibrium price is given by (35) and the type 1 dealer receives the customer order.*

(2) *If* $\delta > 1$*, type 2 dealers have the better reservation price,* $p_1^r > p_2^2$*. Hence, the equilibrium price is given by (34) and a type 2 dealer receives the customer order.*

In addition, the gap between type 1 and type 2 dealers' reservation prices is increasing in the difference in the two types' risk parameter. That is, the gap in reservation prices is decreasing in δ for δ > 1 and increasing in δ for δ > 1. Note that the two types are identical when δ = 1.

4. Merger analysis

In order to analyse the effects of a merger between two banks on capital allocation and market making, we impose restrictions on the model in order to derive closed-form solutions with which we can perform numerical simulations.

It is assumed that before a merger, a bank engages in two of three available financial activities. As before, we assume that all banks are engaged in market-making. In addition, each bank chooses one of two activities, project X or project Y. Hence, banks can be differentiated according to whether they are engaged in project X (type X banks) or in project Y (type Y banks). However, we will impose symmetry between project X and Y so that both types of banks will end up allocating the same amount of risk capital towards market-making.

We will conduct the analysis of a merger assuming that prior to the merger, all N + 1 banks have the same capital allocation functions and hence have the same amount of risk capital allocated to market-making. This is the case of N + 1 dealers with identical risk preferences. A merger is then considered between two banks which results in (1) a reduction in the number of firms and hence dealers in the dealership market considered, and, potentially, (2) the creation of a new type of dealer with a different risk preference from all the other dealers, in which case we have a dealership market with heterogeneous dealers.

4.1 The stylised model

Prior to a merger, all banks consist of two divisions, or business lines. Type X banks are engaged in market-making and project X while type Y banks are engaged in market-making and project Y. We denote the variance and expected return from project X by σ_X^2 and $\mu_X(\sigma_X^2)$, from project Y by σ_Y^2 and $\mu_Y(\sigma_Y^2)$ and from market-making by σ_M^2 and $\mu_M(\sigma_M^2)$. We assume that the relationship between the expect return and variance of any particular project's cash flow, $\mu_j(\sigma_j^2), j \in \{X,Y,M\}$, is increasing and satisfies the Inada conditions. We further restrict the relationship between expected return and variance to be the same across projects X and Y.

$\mu_X(\sigma^2) = \mu_Y(\sigma^2) = \mu(\sigma^2)$

Finally, the correlation between cash flows from projects X and Y is denoted by $\rho_{XY} \in [-1,1]$, the correlation between cash flows from project X and market-making by $\rho \in [-1,1]$ and the correlation between cash flows from project Y and market-making by $\rho \in [-1,1]$.

The assumption of symmetry between activities X and Y implies that type X and type Y banks are identical from a risk-return perspective. Hence, each bank allocates the same amount of risk capital to market-making and this results in N + 1 identical dealers in the dealership market with risk aversion coefficient denoted by γ.

Recall from equation (6) that the first-order conditions for optimality for a bank engaging in set K of financial activities are

$$\frac{\partial \mu_j\left(\hat{\sigma}_j^2\right)}{\partial \sigma_j^2} = r\alpha \left[1 + \sum_{h \neq j, h \in K} \rho_{hj} \left(\frac{\hat{\sigma}_h^2}{\hat{\sigma}_j^2}\right)^{1/2}\right], j \in K.$$

Specialising this condition for our two-division banks yields

$$\frac{\partial \mu\left(\hat{\sigma}_X^2\right)}{\partial \sigma_X^2} = r\alpha \left(1 + \rho \frac{\hat{\sigma}_M}{\hat{\sigma}_X} \right) \tag{37}$$

and

$$\frac{\partial \mu_M\left(\hat{\sigma}_M^2\right)}{\partial \sigma_M^2} = r\alpha \left(1 + \rho \frac{\hat{\sigma}_X}{\hat{\sigma}_M} \right) \tag{38}$$

for a type X bank. The conditions are identical for a type Y bank since $\hat{\sigma}_Y = \hat{\sigma}_X$ due to the symmetry assumptions.

4.2 Effect of a merger on capital allocation

In this section, we show that *a merger between two banks can have ambiguous effects on the risk-taking it undertakes in its various divisions*. The results depend on the correlation in cash flow among different divisions of the newly merged bank, and hence on the types of banks that participate in the merger.

4.2.1 Merger between two banks of the same type

Consider a merger between two type X (or type Y) banks. By assumption, there are no economies of scale to any of the banking activities considered. We proceed by assuming that the risk-return characteristics of all banking activities, represented by the functions $\mu(\cdot)$and $\mu_M(\cdot)$, are unchanged by the merger.[14] Since the merged bank remains engaged in the same two activities with the same risk-return characteristics as before the merger and there are no economies of scale present, the merged bank is identical to each of the banks prior to the merger. That is, the merged bank's optimisation and capital allocation problem is the same as before. The only change is that there are now N banks instead of $N + 1$. This will have an unambiguously negative impact on market quality in the dealership market considered since the decrease in the number of dealers results in less efficient risk-sharing than before and hence higher risk premiums charged by dealers, or higher spreads.

Recall that the pre-merger market spread is given by

$$s = \frac{2N-1}{N^2} \Psi |w|.$$

This is decreasing in N since

$$\frac{\partial s}{\partial N} = -\frac{2(2N-1)}{N^3} \Psi |w|.$$

4.2.2 Merger between two banks of different types

Consider a merger between a type X and a type Y bank. Assuming that the merged bank retains all three business activities, M, X and Y, this merged bank is now different from all the other banks in the economy. The merged bank's market-making activities are now carried out by a dealer who is potentially different from the rest of the dealers in the market. This dealer is denoted as a type 1 dealer who has a risk aversion coefficient denoted by $\delta\gamma$.

[14] These are rather restrictive assumptions but they are made so as to focus attention on the economies of scope effects from a bank merger.

The risk associated with the merged bank's total cash flow is

$$\sigma_p^2 = \sigma_X^2 + \sigma_Y^2 + \sigma_M^2 + 2\rho_{XY}\sigma_X\sigma_Y + 2_\rho(\sigma_X + \sigma_Y)\sigma_M. \tag{39}$$

The first-order conditions (for an interior optimum) facing the merged bank are simply

$$\frac{\partial\mu_X(\tilde{\sigma}_X^2)}{\partial\sigma_X^2} - r\alpha\left(1 + \rho_{XY}\frac{\tilde{\sigma}_Y}{\tilde{\sigma}_X} + \rho\frac{\tilde{\sigma}_M}{\tilde{\sigma}_X}\right) = 0 \tag{40}$$

$$\frac{\partial\mu_Y(\tilde{\sigma}_Y^2)}{\partial\sigma_Y^2} - r\alpha\left(1 + \rho_{XY}\frac{\tilde{\sigma}_X}{\tilde{\sigma}_Y} + \rho\frac{\tilde{\sigma}_M}{\tilde{\sigma}_Y}\right) = 0 \tag{41}$$

$$\frac{\partial\mu_M(\tilde{\sigma}_M^2)}{\partial\sigma_M^2} - r\alpha\left(1 + \rho\ \frac{\tilde{\sigma}_X}{\tilde{\sigma}_M} + \rho\frac{\tilde{\sigma}_Y}{\tilde{\sigma}_M}\right) = 0. \tag{42}$$

The symmetry between activities X and Y implies that, at the optimum, $\tilde{\sigma}_X^2 = \tilde{\sigma}_Y^2$, where the ~ denotes optimal risk levels for the merged bank. The next proposition outlines two factors driving the change in risk-taking by the merged bank in each if its business lines.

Proposition 8. *Suppose that a unique solution exists to the capital allocation problem. Then, the merged bank tends to undertake more risk in projects X and Y relative to its pre-merger level* $(\tilde{\sigma}_X^2 > \hat{\sigma}_X^2)$

(1) The more negatively correlated are the cashflows of division X and the new division Y, and

(2) The more positively correlated are the cash flows from market-making and division X or Y if more risk is undertaken in market-making, or the more negatively correlated are the cash flows from market-making and division X or Y if less risk is undertaken in market-making after the merger.

The merged bank tends to undertake more risk in market-making $(\tilde{\sigma}_M^2 > \hat{\sigma}_M^2)$

(1) the more negatively correlated are the cash flows from market-making nd the new division, Y, and

(2) the more positively correlated are the cash flows from market-making and division X if more risk is undertaken in division X after the merger, or the more negatively correlated are the cash flows from market-making and division X if less risk is undertaken in project X after the merger.

Proof: See Appendix.

A lower (higher) level of risk-taking in any division corresponds to less (more) risk capital being allocated to that division by the merged bank. Finally, since the merged bank's market-making activities are carried out by a type 1 dealer with a coefficient of risk aversion given by $\delta\gamma$, the merged bank undertakes more (less) risk in market-making if and only if $\delta < 1$ ($\delta > 1$).

Numerical examples for a given function form for the expected return to each division illustrate the proposition. Suppose that the expected return to risk-taking in each division can be expressed as

$$\mu_X\left(\sigma_X^2\right) = a_X\left(\sigma_X^2\right)^{b_X},$$

$$\mu_M\left(\sigma_M^2\right) = a_M\left(\sigma_M^2\right)^{b_M}.$$

We find that the following is true.

(i) The merged firm undertakes more risk in market-making if and only if the cash flow from market-making is (strictly) negatively correlated with cash flows from the other divisions, X and Y. If that correlation is zero, there is no change in the level of risk-taking in market-making.

(ii) The merged bank undertakes more risk in division X if the cash flows from division X and Y are not too correlated.

Graphs from the numerical examples are presented in the Appendix.

4.3 Effect of a merger on market liquidity

Here, we show that the impact on market liquidity of a merger between two banks depends crucially on whether more or less risk capital is allocated to market-making by the newly merged bank. *If the newly merged bank allocates more capital to market-making, market liquidity can improve.* On the other hand, market liquidity will deteriorate if the newly merged bank allocates less capital to market-making.

Prior to the merger, the equilibrium price in the public market is given by (24), or

$$p^0 = \frac{(2N-1)\Psi}{2N^2}w.$$

After the merger, the equilibrium price that prevails depends on whether the type 1 dealer has a higher ($\delta > 1$) or a lower ($\delta < 1$) risk aversion. This depends on whether the merged firm allocates more or less risk capital to market-making. If more risk capital is allocated, the type 1 dealer has a higher risk-bearing capacity and hence $\delta < 1$. The reverse is true if the merged firm allocates less risk capital to market-making. From proposition 6, we know that if $\delta < 1$, the new equilibrium price in the public market is given by

$$p^m(\delta < 1) = \left\{\left(1 - \frac{\beta_2}{\bar{\beta}}\right)\frac{\beta_2^2\Psi_2^2}{\bar{\beta}} + \frac{\beta_2}{2\bar{\beta}^2}\beta_1^2\Psi_1^2(2-\beta_2\Psi_2) - \frac{\Psi_2}{2}\left[1 - \left(1 - \frac{\beta_2}{\bar{\beta}}\right)\beta_2\Psi_2\right]^2\right\}w \tag{43}$$

However, if $\delta > 1$, the new equilibrium price in the public market is given by

$$p^m(\delta > 1) = \left\{\left(1 - \frac{\beta_1}{\bar{\beta}}\right)\frac{\beta_1^2\Psi_1^2}{\bar{\beta}} + \frac{\beta_1}{2\bar{\beta}^2}\beta_2^2\Psi_2^2(2-\beta_1\Psi_1) - \frac{\Psi_1}{2}\left[1 - \left(1 - \frac{\beta_1}{\bar{\beta}}\right)\beta_1\Psi_1\right]^2\right\}w. \tag{44}$$

Proposition 9. *Market liquidity improves, in the sense that market spreads are smaller, when δ is small enough, and the number of dealers in the market is large enough. That is, for values of $\delta < 1$ small enough, a merger improves liquidity for any number of dealers. For intermediate values of $\delta < 1$ a merger improves liquidity only if the number of dealers in the market is large enough. For $\delta > 1$ a merger always results in a deterioration of liquidity.*

Figures 2 to 4 illustrate the proposition. What the figures show is the following. For any $\delta < 1$ there is a critical N^* for which liquidity improves if $N > N^*$ while liquidity deteriorates if $N < N^*$. $N^*(\delta)$ is implicitly defined as the N that solves

$$p^0 - p^m(\delta) = 0 \tag{45}$$

where p^0 and $p^m(\delta)$ are defined by equations (24), (43) and (44). For small values of δ, this critical N^* is negative. For intermediate values of $\delta < 1$, this critical N^* becomes positive (and finite) and is increasing in δ. For $\delta > 1$, however, $N^* \rightarrow \infty$.

As stated at the beginning of this section, the merger that we consider between two banks has the following consequences: *(1) a reduction in the total number of dealers in the dealership market*, and *(2) the creation of a new type of dealer with a different risk preference from all the other dealers* (a type 1 dealer and N type 2 dealers). The first effect reduces the efficiency of risk-sharing among dealers in the market. As we have already argued, risk-sharing is inefficient in this market because of imperfect competition among dealers. That is, the efficiency of risk-sharing is increasing in the number of dealers in the market and tends towards first-best as the number of dealers tends towards infinity. Hence, a reduction in the number of dealers will have a negative impact on market prices and spreads.

The second effect induces a change in the risk-bearing capacity of the market since there is a change in the risk preference of one dealer, the newly created type 1 dealer. If the type 1 dealer has a larger capacity for bearing risk (that is, a lower risk aversion parameter or $\delta < 1$), the second consequence of a merger has a positive impact on market price and spreads. In this case, the net impact of a merger on market prices and spreads is ambiguous. If the type 1 dealer has a smaller capacity for bearing risk ($\delta > 1$), the second consequence of the merger has a negative impact on market prices and spreads. In this case, the net impact of a merger on prices and spreads is negative.

When the type 1 dealer has a larger risk-bearing capacity, $\delta < 1$, the two consequences of the merger as outlined have offsetting effects. The greater the increase in the type 1 dealer's ability to bear risk (or, the smaller δ), the more important is the impact of the increased risk-bearing capacity in the market. Moreover, the larger the number of dealers in the market to start with (N), the less important will be the reduction in the efficiency of risk-sharing from a merger. Hence for any $\delta < 1$, the larger N, the more likely is the merger to improve market liquidity. As well, for any N, the smaller $\delta < 1$, the more likely is the merger to improve market liquidity.

Figure 2

Equilibrium prices before and after a merger, $\delta < 1$

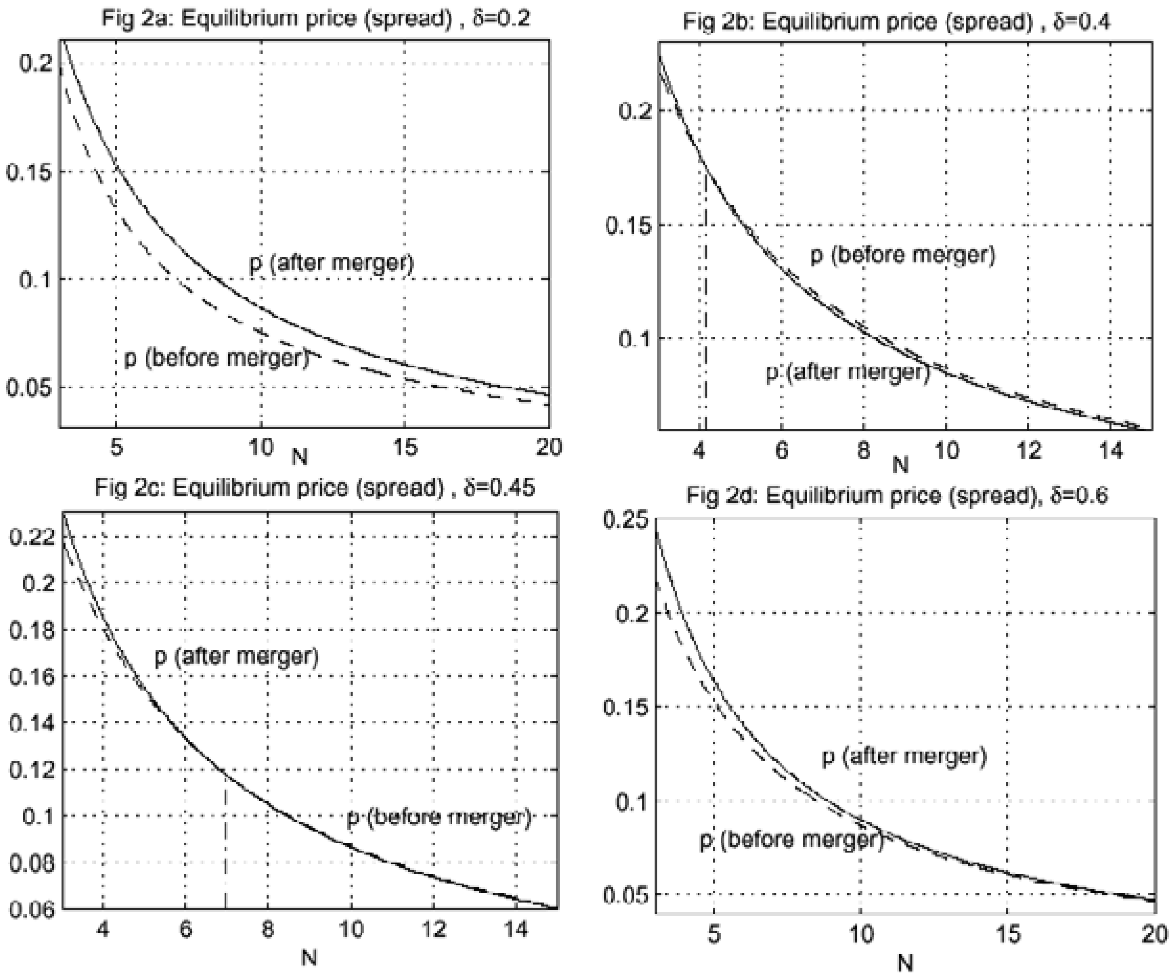


Figure 3

Equilibrium prices before and after a merger, $\delta > 1$

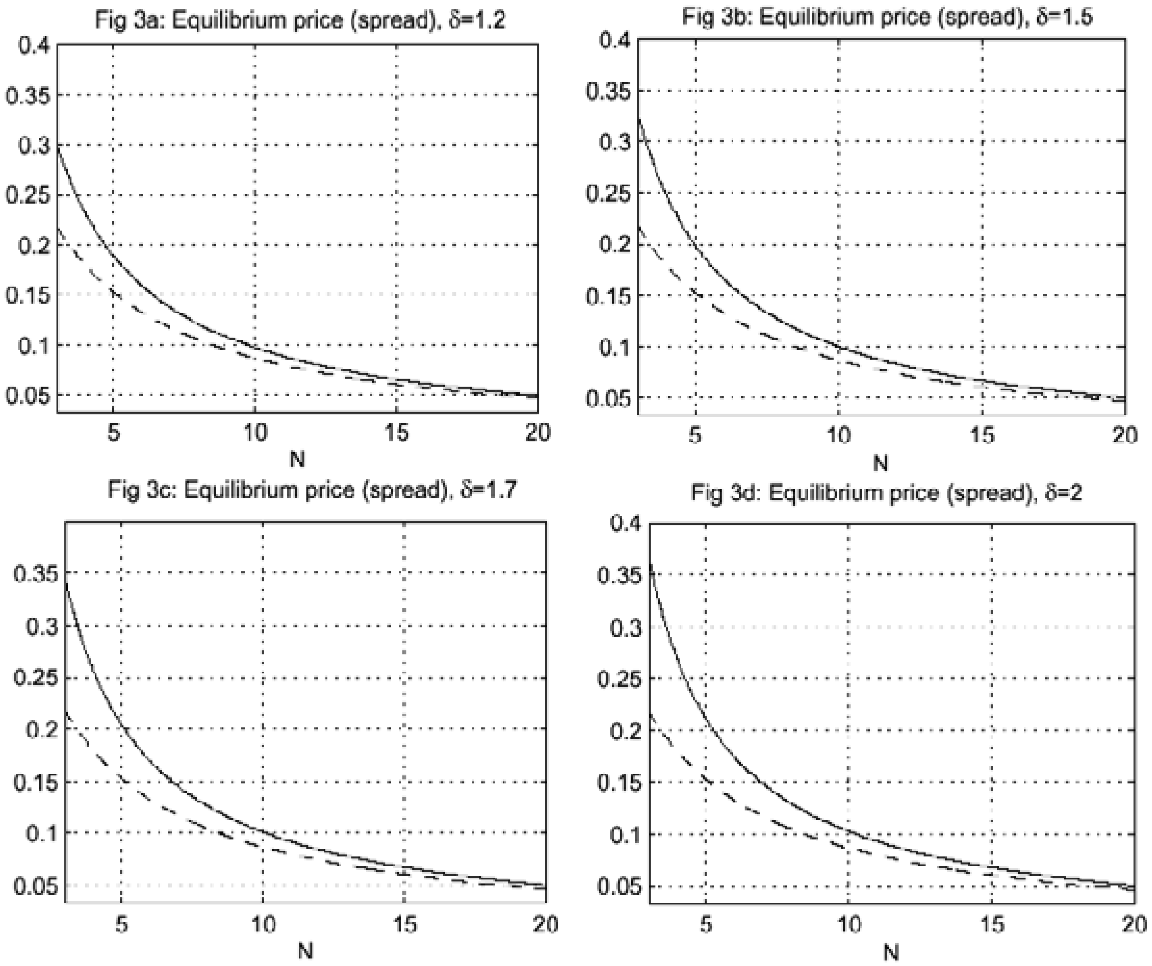
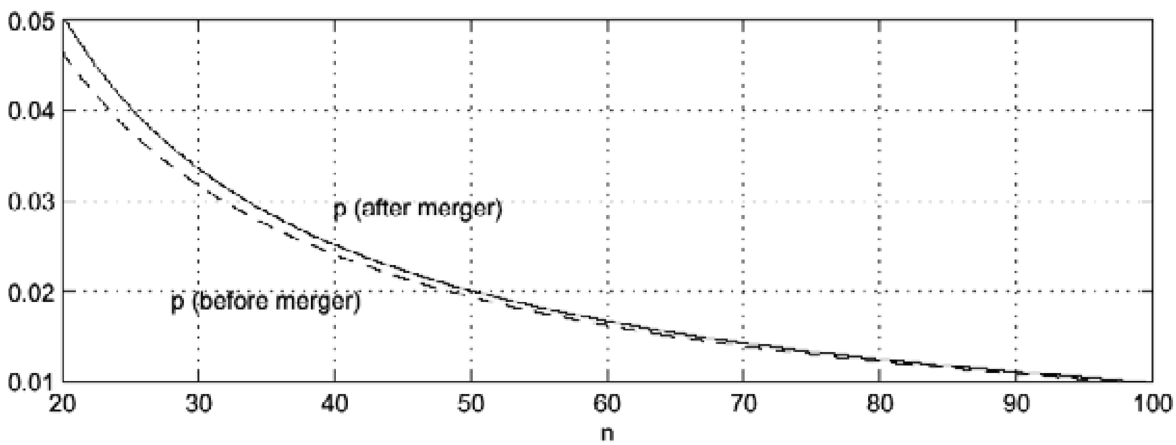


Figure 4

Equilibrium price (spread), $\delta = 2$



5. Conclusion

The paper bridges two topics in financial economics that until now have evolved as separate areas of research: market microstructure models and capital allocation decision-making within financial institutions. This is a first step towards consolidating advances made in the individual fields of study and will be a useful framework for understand how financial institutions and markets are interrelated through the interaction of risk management of institutions and the risk-bearing capacity of markets.

Although there are many possible applications for the framework we introduce, we focus in this paper on the impact of financial market consolidation on liquidity in dealership markets. Liquidity is characterised by bid-ask spreads in a model of inter-dealer trading that has been extended to allow for heterogeneity among dealers. The impact on market-making behaviour from a change in the allocation of capital across bank divisions is explicitly modelled so that we are able to characterise the potential effects of financial market consolidation on dealership markets such as foreign exchange and government securities markets.

We find that a merger of two banks can lead to increased market liquidity in dealership markets, even in highly concentrated markets, if the merger results in a sufficient increase in the risk-bearing capacity of the market. The risk-bearing capacity of the dealership market in turn depends on how the capital allocation decision in a financial institution is affected by the merger. This depends on the correlation among cash flows from business activities that the newly merged financial institution will engage in. A negative correlation between market-making and the new activities of a merged firm suggests the possibility of increased market liquidity. Our results suggest that, when faced with a proposed merger between financial institutions, policymakers and regulators would want to examine the correlations among division cash flows.

Appendix

A.1 Proof of proposition 1

The first-order condition (for an interior optimum) to division *j*'s problem is

$$\frac{\partial \mu_j\left(\sigma_j^2\right)}{\partial \sigma_j^2} = r\,\frac{\partial T_j\left(\sigma_j^2\right)}{\partial \sigma_j^2}, j \in K. \tag{46}$$

In order to induce the first-best choice of σ_j^2 at the division level, the bank's risk manager has to choose a capital allocation function T_j so that, at the optimal risk level for the division,

$$\frac{\partial T_j\left(\hat{\sigma}_j^2\right)}{\partial \sigma_j^2} = \alpha\left[1 + \sum_{h \neq j, h \in K} \rho_{hj}\left(\frac{\hat{\sigma}_h^2}{\hat{\sigma}_j^2}\right)^{1/2}\right]$$

Integrating over σ_j^2 yields the optimal capital allocation functions

$$T_j\left(\sigma_j^2\right) = \alpha\left[1 + \sum_{h \neq j, h \in K} \rho_{hj}\left(\frac{\hat{\sigma}_h^2}{\hat{\sigma}_j^2}\right)^{1/2}\right]\sigma_j^2, j \in K. \tag{47}$$

The salary component of the division manager's compensation, S_j, is chosen so that the manager obtains at least his reservation utility, $\underline{U}_j$,

$$S_j = \underline{U}_j - \tau\left[\mu\left(\hat{\sigma}_j^2\right) - rT_j\left(\hat{\sigma}_j^2\right)\right].$$

If we define γ_j such that

$$\gamma_j = r\alpha\left[1 + \sum_{h \neq j, h \in K} \rho_{hj}\left(\frac{\hat{\sigma}_h^2}{\hat{\sigma}_j^2}\right)^{1/2}\right], j \in K,$$

we can rewrite the objective function of the manager of division *j* as

$$\max_{\sigma_j^2} \mu_i\left(\sigma_j\right) - \frac{\gamma_j}{2}\sigma_j^2. \tag{48}$$

Hence, the optimal capital allocation function induces the (otherwise risk-neutral) manager of division j to behave like a risk-averse agent with exponential utility function and risk-aversion parameter γ_j with net payoff $\mu_j\left(\sigma_j^2\right)$.[15]

A.2 Proof of proposition 2

Each dealer takes into account the effect his trade has on the equilibrium inter-dealer price when determining his trading strategy. A dealer's strategy is an excess demand function. These functions are communicated to the inter-dealer broker who chooses a market-clearing price. By changing the excess demand function he sends to the inter-dealer broker, a dealer changes the equilibrium price. Therefore, each dealer has an incentive to restrict the quantity he trades in comparison with the competitive level, since he is trading against an upward-sloping residual supply curve, much like a monopolist.

Consider the problem of a dealer i. Market clearing implies that $x_i + \Sigma_{j \neq i}\alpha - \beta p_d + \mu w_j = 0$, or

$$P_d = \frac{x_i + N\alpha + \mu \sum_{j \neq i} w_j}{N\beta}. \tag{49}$$

The assumption that the market-clearing price and the investor's order do not convey any information and are normally distributed random variables along with an exponential utility implies that maximising expected utility of profits is equivalent to maximising the certainty equivalent, given by $E[\pi_i] - \frac{\Psi}{2}\mathrm{var}(\pi_i)$ or,

$$(x_i - w_i)E[v] + pw_i - p_d x_i - \frac{\Psi}{2}(x_i - w_i)^2. \tag{50}$$

The first-order condition with respect to X_i yields

$$-p_d \frac{\partial p_d}{\partial x_i} x_i - \Psi(x_i - w_i) = -p_d - \frac{x_i}{N\beta} - \Psi(x_i - w_i) = 0$$

or

$$x_i = \frac{N\beta(-p_d + \Psi w_i)}{1 + \Psi N\beta} \tag{51}$$

Equating coefficients yields the desired results.

A.3 Proof of proposition 8

The pre-merger problem for a bank is the following.

$$\max_{\sigma_M^2,\, \sigma_X^2} \mu_M + \left(\sigma_M^2\right) + \mu_X\left(\sigma_X^2\right) - r\alpha\left[\sigma_M^2 + \sigma_X^2 + 2\rho\sigma_M\sigma_X\right]. \tag{52}$$

---

15 For a risk-averse manager with risk-aversion parameter λ who maximises $U_j - \frac{\lambda}{2}var(U_j) \equiv \mu_j - rT_j - \frac{\tau\lambda}{2}\sigma_j^2$. The capital allocation function is $T_j(\sigma_j^2) = \left\{\alpha\left[1 + \sum_{h \neq j,\ h \in K} \rho_{hj}\left(\frac{\sigma_h^2}{\sigma_j^2}\right)^{1/2}\right] + \frac{\tau\lambda}{2}\right\}\sigma_h^2$.

The first-order conditions are

$$\mu_M'\left(\hat{\sigma}_M^2\right)=r\alpha\left[1+\rho\frac{\hat{\sigma}_X}{\hat{\sigma}_M}\right] \tag{53}$$

$$\mu_X'\left(\hat{\sigma}_X^2\right)=r\alpha\left[1+\rho\frac{\hat{\sigma}_M}{\hat{\sigma}_X}\right]. \tag{54}$$

Note that $\mu_M\left(\sigma_M^2\right)$ is a function of σ_M^2 only and $\mu_X\left(\sigma_X^2\right)$ is a function of σ_X^2 only.

Now, we turn to the merged bank's problem.

$$\max_{\sigma_M^2,\sigma_X^2,\sigma_Y^2} \mu_M\left(\sigma_M^2\right)+\mu_X\left(\sigma_X^2\right)+\mu_Y\left(\sigma_Y^2\right)-r\alpha\left[\sigma_M^2+\sigma_X^2+\sigma_Y^2+2\rho\sigma_M\left(\sigma_X+\sigma_Y\right)+2\rho_{XY}\sigma_X\sigma_Y\right]. \tag{55}$$

Taking derivatives with respect to σ_M^2, σ_X^2, and σ_Y^2 yields

$$\mu_M'\left(\sigma_M^2\right)-r\alpha\left[1+\frac{\rho\sigma_X+\rho\sigma_Y}{\sigma_M}\right]\equiv D_M\left(\sigma_M^2\middle|\sigma_X^2,\sigma_Y^2\right) \tag{56}$$

$$\mu_X'\left(\sigma_X^2\right)-r\alpha\left[1+\frac{\rho_{XY}\sigma_Y+\rho\sigma_M}{\sigma_X}\right]\equiv D_X\left(\sigma_X^2\middle|\sigma_M^2,\sigma_Y^2\right) \tag{57}$$

$$\mu_Y'\left(\sigma_Y^2\right)-r\alpha\left[1+\frac{\rho_{XY}\sigma_X+\rho\sigma_M}{\sigma_Y}\right]\equiv D_Y\left(\sigma_Y^2\middle|\sigma_M^2,\sigma_X^2\right) \tag{58}$$

Post-merger optimum $\tilde{\sigma}_M^2,\tilde{\sigma}_X^2=\tilde{\sigma}_Y^2$ is implicitly defined by

$$D_M\left(\tilde{\sigma}_M^2\middle|\tilde{\sigma}_X^2\right)=D_X\left(\tilde{\sigma}_X^2\middle|\tilde{\sigma}_M^2\right)=0. \tag{59}$$

Now, consider the function

$$D_M\left(z\middle|\tilde{\sigma}_X^2\right)=\mu_M'(z)-r\alpha\left[1+\frac{\rho\tilde{\sigma}x+\rho\tilde{\sigma}y}{z^{1/2}}\right]. \tag{60}$$

Notice we have taken $\tilde{\sigma}_X=\tilde{\sigma}_Y$ as (fixed) parameters. This defines a function in z that we know is decreasing in z (from the existence and uniqueness of the solution to the merged bank's problem). We also know that evaluated at $z=\tilde{\sigma}_M^2$ the function is equal to zero.

Therefore, for a value $z = z'$, $D_M\left(z'\middle|\tilde{\sigma}_X^2\right)<0$ implies that $z'>\tilde{\sigma}_M^2$ and $D_M\left(z'\middle|\tilde{\sigma}_X^2\right)>0$ implies that $z'<\tilde{\sigma}_M^2$. Since we are interested in comparing $\hat{\sigma}_M^2$ with $\hat{\sigma}_M^2$, we want to know whether the function $D_M\left(z\middle|\tilde{\sigma}_X^2\right)$ evaluated at $z=\hat{\sigma}_M^2$ is positive or negative.

$$D_M\left(\hat{\sigma}_M^2\middle|\tilde{\sigma}_X^2\right)=\mu_M'\left(\hat{\sigma}_M^2\right)-r\alpha\left[1+\frac{\rho\tilde{\sigma}_X+\rho\tilde{\sigma}_Y}{\hat{\sigma}_M}\right]. \tag{61}$$

From equation (2), we can substitute $r\alpha\left[1+\rho\dfrac{\hat{\sigma}_X}{\hat{\sigma}_M}\right]$ for $\mu_M'\left(\hat{\sigma}_M^2\right)$. (Remember that $\mu_M'\left(\hat{\sigma}_M^2\right)$ does not depend on σ_X^2 or σ_Y^2.) So the above works out to

$$D_M\left(\hat{\sigma}_M^2\middle|\tilde{\sigma}_X^2\right)=-r\alpha\left[\frac{\rho\left(\tilde{\sigma}_X-\hat{\sigma}_X\right)+\rho\tilde{\sigma}_Y}{\hat{\sigma}_M}\right]. \tag{62}$$

The same can be done for project X to obtain

$$D_X\left(\hat{\sigma}_X^2 \middle| \tilde{\sigma}_M^2\right) = -r\alpha \left[\frac{\rho_{XY}\tilde{\sigma}_Y + \rho\left(\tilde{\sigma}_M - \tilde{\sigma}_M\right)}{\hat{\sigma}_X}\right]. \tag{63}$$

Expression (63) is more likely to be positive if ρ_{XY} is negative and large in absolute value. That is, *post-merger risk-taking in division X is influenced by the correlation of its cash flow with division Y's cash flow.* In addition, it is also more likely to be positive when ρ is negative if $\tilde{\sigma}_M - \hat{\sigma}_M > 0$ and vice versa. That is, *post-merger risk-taking in division X is also influenced by the correlation of its cash flow with market-making and by what happens to the risk-taking level in market-making as a result of the merger*. The net effect on σ_X^2 of the merger, of course, depends on the combination of the two effects. The same analysis can be made for market-making: expression (62) is positive if $\rho\left(2\tilde{\sigma}_X - \hat{\sigma}_X\right) < 0$ and negative if the reverse is true.

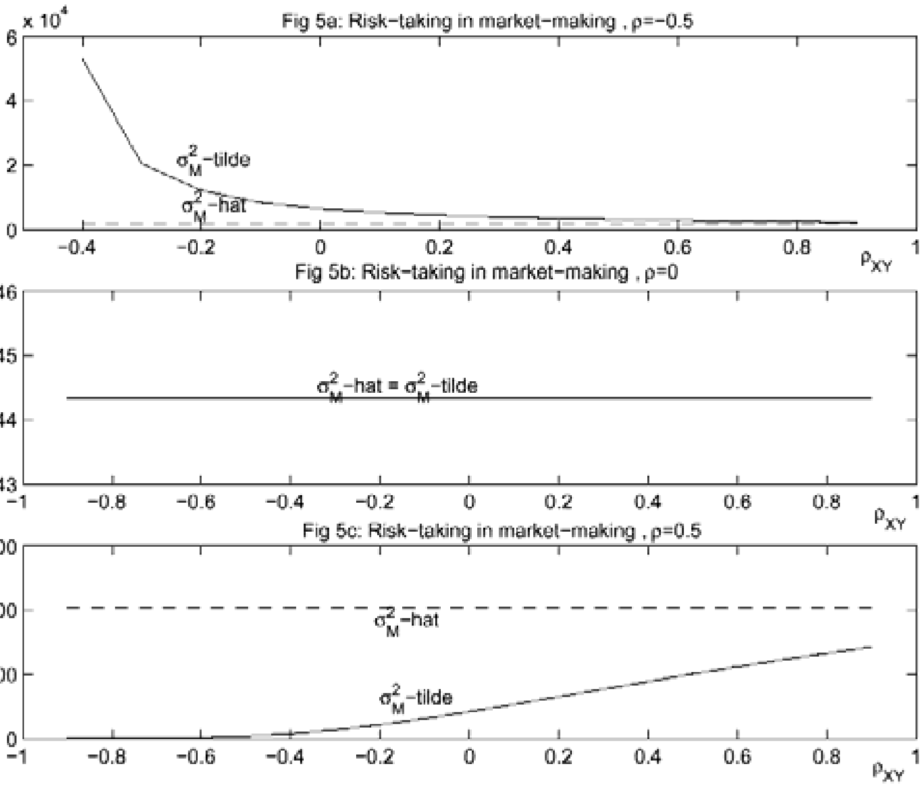
A.4 Numerical examples

For return functions characterised by

$$\mu_X\left(\sigma_x^2\right) = a_X\left(\sigma_X^2\right)^{b_X},$$

$$\mu_M\left(\sigma_M^2\right) = a_M\left(\sigma_M^2\right)^{b_M},$$

we obtain the following results with the parameter values: a_X = 1.5, a_M =1, b_X = b_M = 1/3, r = 0.1, and a = 0.05. Changing the parameters does not affect the results.



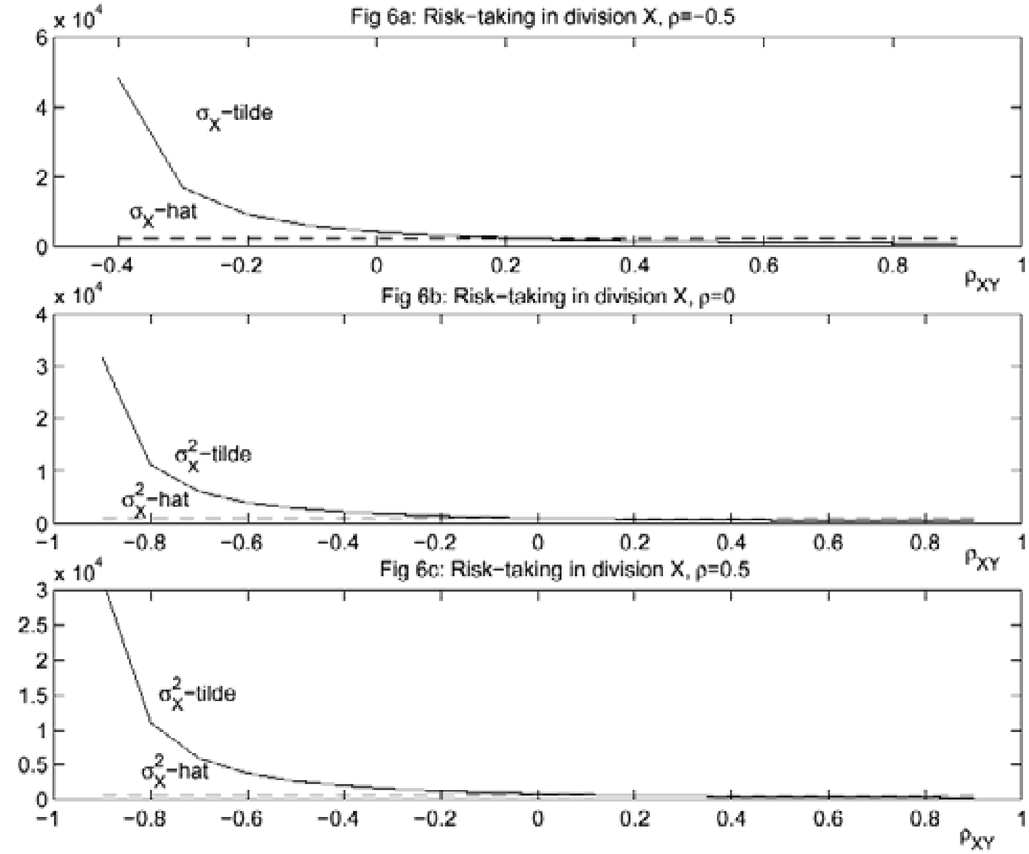


Fig 6a: Risk-taking in division X, ρ=−0.5
x 10^4
σX-tilde
σX-hat
ρXY
Fig 6b: Risk-taking in division X, ρ=0
x 10^4
σ2X-tilde
σ2X-hat
ρXY
Fig 6c: Risk-taking in division X, ρ=0.5
x 10^4
σ2X-tilde
σ2X-hat
ρXY

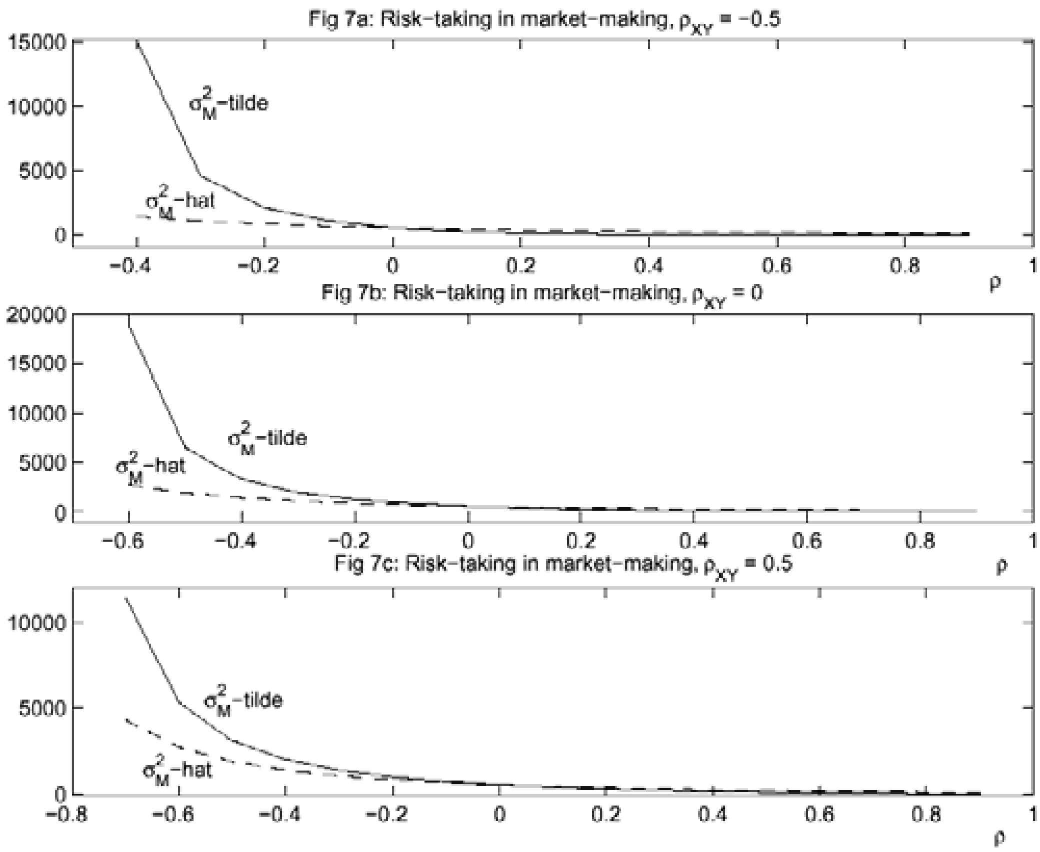
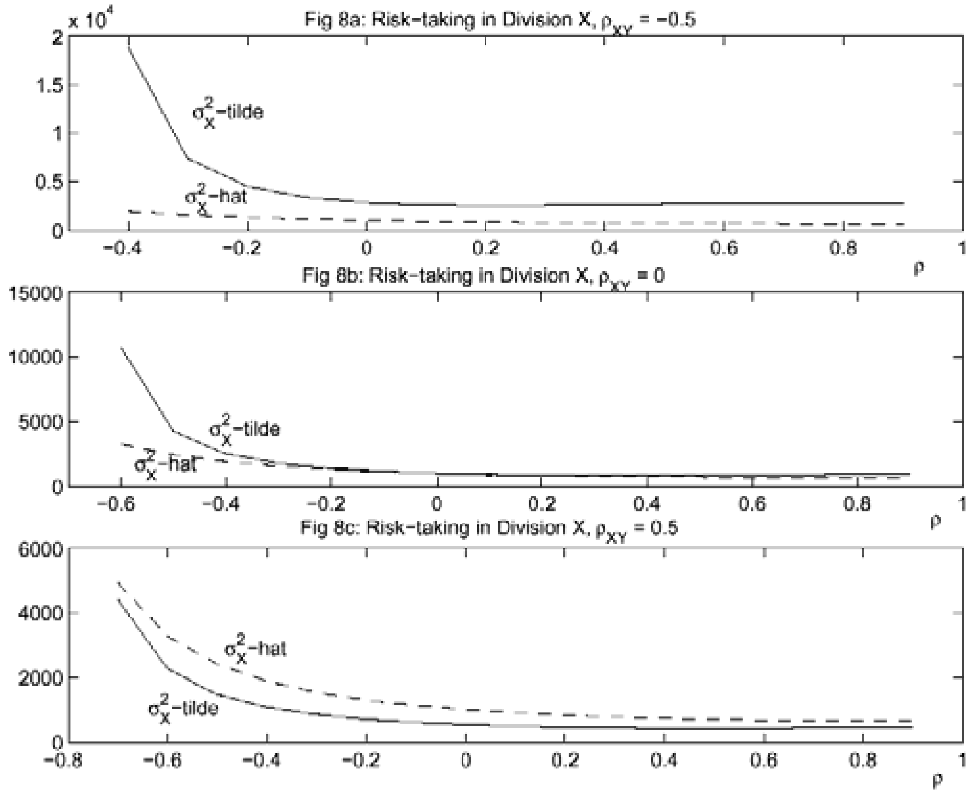


Fig 7a: Risk-taking in market-making, ρXY = −0.5
σ2M-tilde
σ2M-hat
ρ
Fig 7b: Risk-taking in market-making, ρXY = 0
σ2M-tilde
σ2M-hat
ρ
Fig 7c: Risk-taking in market-making, ρXY = 0.5
σ2M-tilde
σ2M-hat
ρ



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How resilient are financial markets to stress? Bund futures and bonds during the 1998 turbulence

Christian Upper and Thomas Werner,[1]
Deutsche Bundesbank

1. Motivation

The integrity of financial markets is of great importance to central banks, both as an aim in itself and as a precondition for ensuring monetary stability. In terms of formulating and implementing monetary policy, central banks rely on financial markets in a number of ways. Firstly, they use financial indicators to assess the current state of the economy and to obtain information on the expectations of private agents.[2] Financial variables have the advantage that they can be observed (almost) in real time and that they incorporate the information available to a wide spectrum of agents. However, their use in monetary policy hinges on the assumption that markets are efficient. If they are not, and if prices are distorted, then this could have serious consequences for monetary policy. At best it would reduce the set of available indicators, making monetary policy more difficult. At worst, "wrong" indicators would induce a serious misreading of what is going on in the economy and, as a consequence, mistaken policies. Secondly, central banks accept financial assets as collateral in their monetary policy operations. Functioning financial markets provide prices that can be used to value assets used as collateral[3] and permit the central bank's counterparties to obtain assets eligible as collateral. Thirdly, and related to the last point, central banks rely on the ability of the market to allocate liquidity to where it is most needed. If it does not, then the choice of counterparties for monetary policy operations matters, and central banks would discriminate in favour of some institutions at the expense of others.

Despite the increasing importance of financial variables in the formulation and implementation of monetary policy, it is not clear whether the preconditions that underly their prominent role continue to hold in times of stress. If not, then central banks would be following a "fair weather strategy" that could easily break down when times get rough.

This paper analyses the liquidity of, and pricing relationships between, the spot and futures markets for German government bonds during 1998. The events during the summer and autumn of that year represent the worst turbulence in international financial markets of the past few decades and are therefore well suited to study the behaviour of markets under stress. Although 1998 was before the advent of the euro, at that stage EMU was taken for granted by all but a few market participants.

Our choice of market segments is driven by the fact that the bund future has become the prime vehicle for hedging long-term interest rate risk in the euro area. Similarly, 10-year Bundesanleihen have established themselves as the benchmark in the long-term segment of the euro yield curve. The two markets are linked by an arbitrage condition which in the absence of market frictions should ensure that the cost of the future is identical to the cost of the underlying plus a cost of carry. Any divergence in prices from this parity indicates mispricing of either the future or the underlying or both. A sudden breakdown of the arbitrage relationship may result in large unintended exposures since traders tend to hedge positions in one market with offsetting positions in the other.

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[1] We thank the participants of the 2001 Central Bank Economists' Autumn Meeting at the BIS for their comments. The opinions expressed in this paper are the authors' own and do not necessarily reflect those of the Deutsche Bundesbank.

[2] Financial variables feature prominently in the second pillar of the strategy of the ECB (see ECB (2001)).

[3] Alternatively, collateral could be valued at book value with the appropriate haircuts. This is regularly done with collateral that is not marketable.

We begin by summarising evidence on the liquidity of the market for German government bonds presented by Upper (2000) and then extend the analysis to futures. The second half of the paper studies the pricing relationships between the two markets. In addition to more standard cointegration analysis, we use a recently developed technique (De Jong and Nijman (1997)) which allows us to estimate lead-lag relationships using irregularly spaced data. This is particularly relevant in our case since there are by an order of magnitude more transactions in the futures than in the spot market.

Our data comprise all transactions in bund futures and the underlying German government bonds during 1998. The use of high-frequency data is very important in this respect, since it allows us to capture possible imperfections in the arbitrage relationships between the two markets. The sample period comprises a rather tranquil episode during the first half of the year, followed by the worst turbulence in international financial markets in recent memory. In addition, in August 1998 there was a fear of a shortage of deliverable bonds relative to the amount outstanding of the future, which put further strain on the market.[4]

The paper is structured as follows. We begin with a theoretical discussion of the pricing relationship between futures and the underlyings and possible limits to arbitrage. A brief overview of the turbulence of 1998 and "safe haven" flows to Germany follows. The next section describes the microstructure of the bond and futures markets and presents the data. This is followed by a section on market liquidity during 1998. Section 6 presents estimates of the pricing relationship between bonds and futures, and a final section concludes.

2. Spot-futures pricing relation and obstacles to arbitrage

Under the assumption that no arbitrage opportunities exist, the price f of a futures contract corresponds to the price s of the underlying on the spot market plus a cost of carry c:

$$f = s + c \tag{1}$$

In the case of bond futures, the cost of carry can be decomposed into the interest earned on the bond and the cost of financing the bond position, typically by a repo transaction.

The deviation between the theoretical futures price described in equation (1) and its actual price f^* on the market is called the basis. In algebraic terms, $b = f^* - f = f^* - s - c$. In practice the basis is normally close to, but not identical to, zero. This suggests that arbitrage is less than perfect. There are several reasons why this may be the case. Bid-ask spreads in the futures, spot and repo markets may prevent arbitrageurs from ironing out small deviations of the basis from zero. In this case, we would expect prices to fluctuate freely until the basis reaches a threshold given by the trading costs in the relevant market segments and arbitrage kicks in. Another reason for a basis different from zero is the fact that in the real world arbitrage does involve risks. This is the case if it is not possible to transact in the spot, futures and repo market simultaneously. We should therefore not expect equation (1) to hold strictly at any point in time. Instead, it can be seen as an attractor, to which prices should return after temporary deviations.

3. The German bond market as a "safe haven"

In the summer and autumn of 1998, the international financial system experienced a period of severe stress which provoked fears of a worldwide recession and deflation. Asset prices became highly volatile as positions were delevered, hitherto stable pricing relationships between different assets broke down, and market liquidity dried up even in markets that in normal times were highly liquid.[5] A chronology of the events is provided in Table 1.

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[4] For a discussion of squeezes of the deliverable bonds, see Schulte and Violi (2001).

[5] For an overview of the turbulence, see IMF (1998) and BIS (1999).

Table 1

Chronology

Dates	Events
I. 6 July - 14 August	***Mounting tensions***
	6 July: Salomon Brothers arbitrage desk disbanded
	20 July: first Wall Street Journal headline on LTCM losses
II. 17 August - 22 September	***Russia***
	17 August: Russian effective default and rouble devaluation
	2 September: LTCM shareholder letter issued
III. 23 September - 15 October	***LTCM***
	23 September: LTCM recapitalisation
	29 September: Federal Reserve interest rate cut
	Early October: interest rate cuts in Spain, UK, Portugal and Ireland
	7-8 October: large appreciation of yen relative to US dollar related to closing of "yen carry trades".
	14 October: Bank America reports 78% fall in earnings
	15 October: Federal Reserve cuts rate between meetings
IV. 16 October - 31 December	***Cooling down***
	13 November: Brazil formally requests IMF programme
	17 November: Federal Reserve cuts rates
	2 December: IMF Board approves programme for Brazil
	3 December: coordinated rate cut by European central banks

Source: BIS (1999).

While it is tempting to date back the start of turbulence in the international financial markets to the Thai devaluation in July 1997, it was not until after the Russian default on 17 August 1998 that the turbulence spread to the markets of the developed economies. However, as early as the beginning of July there had been signs that strategies of relative value arbitrage had led to losses at several large investors. Such strategies involve buying an asset that is perceived to be undervalued and simultaneously selling a similar asset that is expected to fall in price. The dating in BIS (1999) therefore begins with a period of mounting tensions, lasting from 6 July to 14 August. Nevertheless, asset price and exchange rate volatility as well as bid-ask spreads were relatively low during this subperiod.

Russia's devaluation and effective default on its short-term debt on 17 August caused sizeable losses to some investors - among them several German banks - and triggered a general deleveraging of positions. This affected primarily the yield spreads of non-benchmark securities relative to the benchmarks and, to a lesser extent, price volatility and bid-ask spreads. The beginning of the third, most turbulent, subperiod was marked by the recapitalisation of LTCM on 23 September. Subsequently, yield spreads, volatility and bid-ask spreads soared to record levels. The turbulence reached its climax on 8 and 9 October, after the liquidation of carry trades led to an appreciation of the yen against the dollar of the order of 10% within two trading days. The turbulence began to subside after the inter-meeting rate cut by the Federal Reserve on 15 October, which marks the beginning of the cooling-down period, although yield spreads, volatility and bid-ask spreads remained high until the end of the year.

As part of the large-scale portfolio rebalancing that took place during the turbulence, investors shifted a substantial part of their holdings into cash and into instruments that were perceived as having a low risk and being highly liquid. One of these "safe havens" was the market for German government securities. Purchases of German government securities by non-residents, which had averaged just over DM 1 billion per month during the first half of 1998, soared to DM 22.7 billion in July and remained close to this level in August. In the latter month, investment abroad by German residents collapsed. It seems likely that some of the funds which would normally have been invested abroad found their way into the German bond market. The “safe haven” effect disappears from the data as the turbulence reached its climax. Purchases of German government bonds by non-residents fell back to DM 1.8 billion in September and were actually negative in October.

4. Market microstructure and data

The bund future does not refer to any actual security but to a notional bond with a face value of DM 250,000,[6] a residual maturity of 8.5 to 10.5 years and a coupon of 6%. Futures contracts have staggered maturities ending in March, June, September and December. At expiry of the contract, the sellers of the future can choose to deliver any German government bond with this residual maturity at a predetermined price. The bonds are converted into the notional bond by multiplying the face value with a conversion factor that accounts for differing coupons and maturities. Since this adjustment is not perfect, it may be cheaper to fulfil one’s obligations from a futures position by delivering one rather than another contract. Consequently, only one of the bonds contained in the basket, the so-called cheapest-to-deliver, tends to be delivered.[7]

In 1998, the microstructure of the futures market for German government bonds was very different from that of the spot market. Futures were traded electronically on the derivatives exchange Eurex,[8] while spot trading was mainly over the counter, either by telephone or through inter-dealer brokers. Bonds were also traded on the Frankfurt Stock Exchange as well as on regional exchanges. However, transactions tended to be small and the share of the exchanges in total turnover was low. More recently, the spot market for German government bonds has been transformed, first by the advent of the electronic trading system EuroMTS in early 1999. However, it was not until the inclusion of bonds in the Eurex trading platform in late 2000 that it became possible to trade futures and bonds simultaneously on a unified trading platform, thus eliminating the risks arising from non-synchronous trading. Since these changes took place after the end of our sample period, they need not concern us here.

Data on bund futures were obtained from Deutsche Börse AG covering all transactions in bund futures with the expiry dates March, June, September and December 1998 on Eurex between 2 January and 7 December 1998. Given the staggered nature of the bund future, we create a long time series by considering only the contract that on a given trading day was most actively traded. Since trading is concentrated on the nearby maturity and switches to a new contract in the days just before expiry, our long series contains more than 95% of all transactions.

The data on the German bond market were obtained from the German securities regulator (Bundesamt für den Wertpapierhandel - BAWe) and cover all transactions during 1998 in the four bonds delivered for the future contracts in our sample.[9] A detailed description of the data can be found in Upper (2000). In contrast to futures of different maturities, existing bonds continue to be traded after a new one has been issued. Nevertheless, the most recent issue tends to be more liquid than the off-the-run bonds, presumably because the latter have been picked up by long-term investors who transact less frequently. Another feature of particular interest for our analysis is whether a bond is cheapest-to-deliver. We therefore do not use the data on the individual bonds directly, but construct

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6 The euro bund future, which replaced the bund future in the transition to EMU, has a contract value of 100,000 Euro.

7 For the precise formula as well as the intuition behind it, see Steiner and Bruns (2000) or any other derivatives textbook. An extensive discussion of the institutional arrangements behind the bund future is provided in Schulte and Violi (2001).

8 A virtually identical contract was traded on LIFFE, but had lost most of its market share by 1998.

9 A fifth 10-year bond was issued on 28 October 1998, but was not delivered for any contract traded in 1998. It is not included in our sample.

series for the on-the-run issue[10] and the cheapest-to-deliver, respectively. In order to ensure comparability with the futures, we convert bond prices into future-equivalents.

Unfortunately, repo rates with maturities coinciding with the expiry dates of the future contracts could not be obtained. Instead, we use two-month Fibor.

Summary statistics of the three series are reproduced in Table 2. They confirm anecdotal evidence that the bund future rather than any individual bond is the main instrument for trading interest risk. The number of transactions in futures exceeds that of the on-the-run bond by a factor of 50. Related to this, the effective bid-ask spread,[11] which measures the cost of an instantaneous return trade, is far lower for futures than for bonds. In addition to the lower transaction costs, trading in futures is also cheaper since they do not involve cash outlays except to meet margins. Perhaps related to the future's role as a hedging instrument, the average trade size is only about half of that in bonds. Among the bonds, activity is much heavier and trading costs lower for the on-the-run bond relative to the cheapest-to-deliver. The former was traded more than twice as often and with double the volume of the latter.

Table 2

Summary statistics

(2 January to 7 December 1998)

Series	Bund future	Cheapest-to-deliver bond	On-the-run bond
No trades	2,111,602	19,186	46,607
Total volume (DM billions)	20,786	375	746
Average trade size (DM millions)	9.8	19.6	16.0
Effective bid-ask spread[1] (bp of face value)	1.2	10.5	8.5

[1] Roll (1984) statistic.

5. Market activity and liquidity

The turbulence was characterised by intense trading activity and a sharp increase in trading costs. The increase in activity was particularly noticeable in the case of the bund future, as can be seen from Figure 1. The vertical lines mark the four subperiods of the turbulence as defined in Table 1 above. The average number of transactions per trading day between the Russian default on 17 August and the Fed's inter-meeting rate cut on 15 October was more than twice as high as during the first half of the year. Trading was heaviest on 8 and 9 October, with more than 25,000 transactions on either day, compared to a daily average of 6,600 between January and June. The number of transactions is not the only measure of market activity, though. Only in the week following the Russian default was the increase in the number of trades matched by a corresponding rise in turnover (Figure 2). During September, the volume traded was higher than during the first half of the year, but by not nearly as much as the number of trades. Turnover again rose on 8 and 9 October, but it remained below its peak during late August. This disparate behaviour of the number of transactions and volume resulted in a sharp fall in the average trade size from an average of around DM 11 million during the first half of the year to 7 million in early September and 6 million during the cooling-down period after the Fed's inter-meeting rate cut on 15 October. The move towards smaller trade sizes may reflect the generalised deleveraging that took place during the turbulence. What is surprising, though, is that the

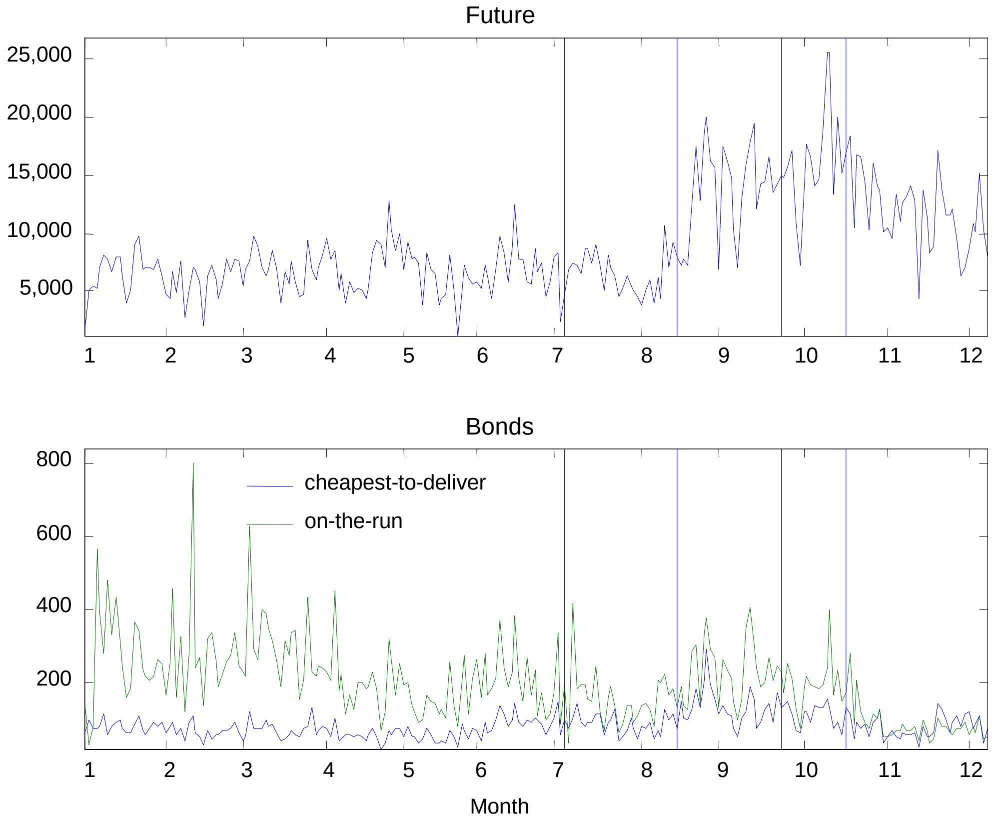
[10] On 28 October 1998, a new Bundesanleihe was issued which is not contained in our data set. Hence our data cover only the second most recent issue during the last two months of the sample period.

[11] Measured by the Roll (1984) method. Refer to Upper (2000) for details on the computation.

fall in average trade size that occurred during the turbulence was preceded by a rise in trade sizes during July and the first half of August - a period during which traders like LTCM or the trading desk of large banks suffered large losses. Unfortunately, we do not have any information on whether this has anything to do with attempts of such traders to cut losses.

Figure 1

Number of transactions per trading day



The change in trading activity after the Russian default was less pronounced in the bond market than in the futures market. The number of trades and trading volume rose for both the cheapest-to-deliver and the on-the-run a few days after the Russian default, although for the latter they remained below the level of the first quarter. Trading remained relatively heavy until the cut in US interest rates on 15 October, but then declined rapidly.[12]

[12] The decline in trades of the on-the-run in November and December may be due to the fact that during this period another bond not included in our sample was on-the-run.

Figure 2

Daily turnover (DM billions)

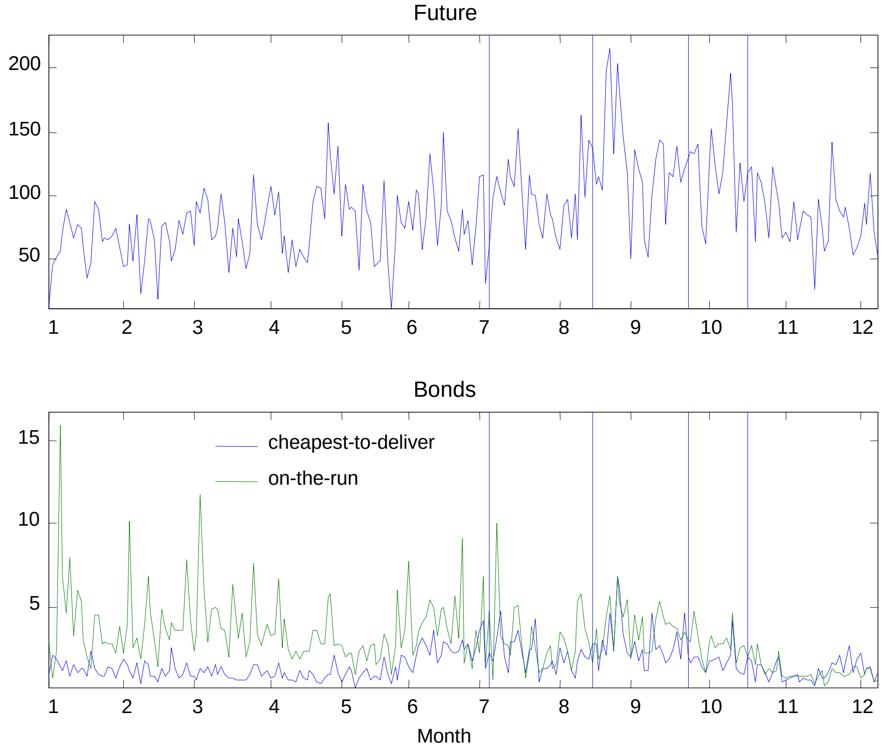


Figure 3

Average trade size (DM millions)

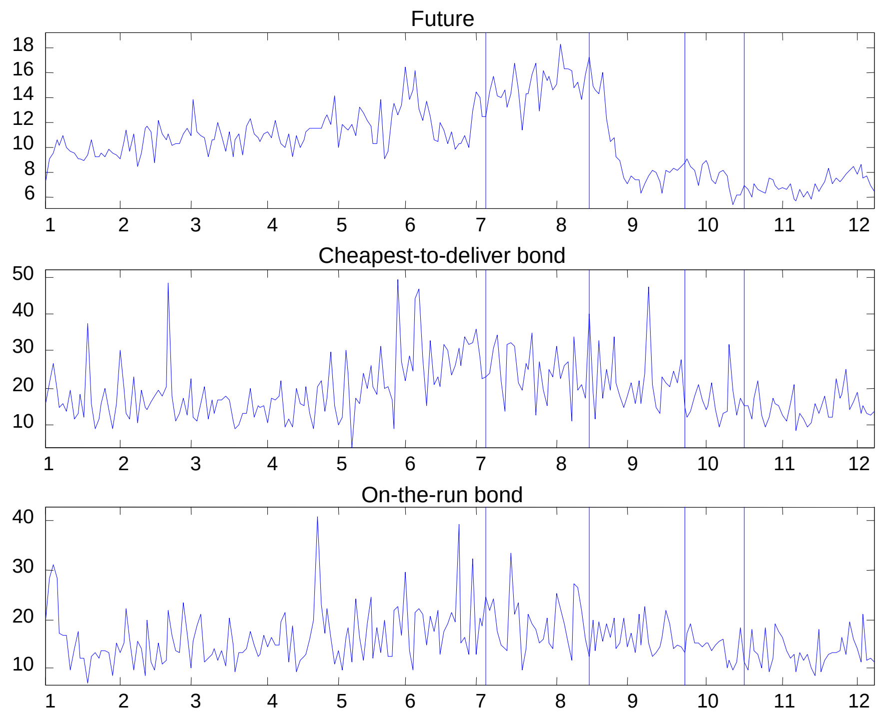
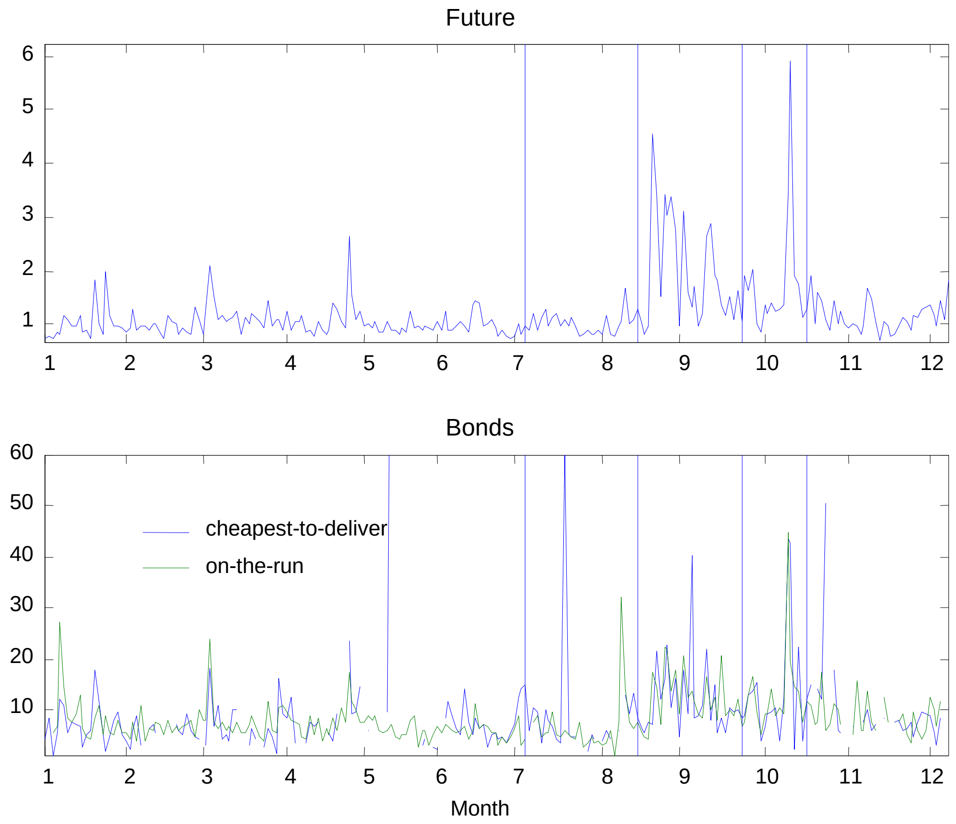


Figure 4
Effective bid-ask spreads



The effect of the turbulence on the cost of trading was particularly pronounced. The effective bid-ask spread of the bund future more than quadrupled a few days after the Russian default. It then gradually declined to more normal levels during September, but soared to almost six times the average during the first half of the year on 9 October. Afterwards, it quickly normalised. The increase in spreads was similar for the two bond series.[13]

The increase in trading activity during the turbulence suggests that markets continued to be very liquid, while the rise in spreads points in the opposite direction. However, looking at these two factors in isolation can be misleading. The increase in spreads after the Russian default looks less menacing if we consider that the market was able to handle considerably more trades and a larger volume than during normal times. This does not apply to the second peak of the turbulence on 8 and 9 October, though. On these two days, turnover in all three instruments analysed was lower than in late August, and nevertheless spreads rose to a much higher level, suggesting that the provision of liquidity was seriously impaired.[14]

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[13] The series for the bid-ask spread of the bonds is relatively noisy due to the lower quality of the data. Even so, the more detailed analysis in Upper (2000) suggests that the findings are robust in the sense that they apply to all bonds included in the data set.

[14] See Upper (2001) for a brief discussion of how to measure market liquidity under stress.

6. Spot-future pricing relationship

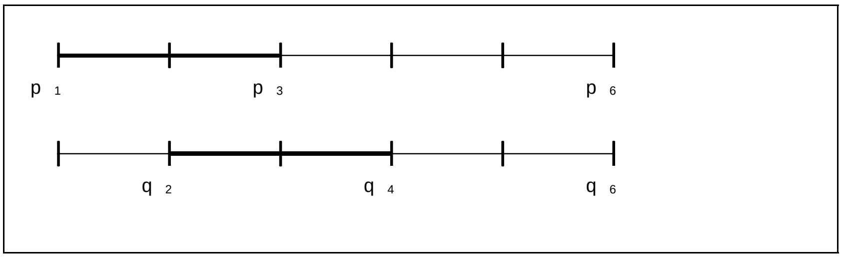
6.1 Short-run information flow

The information flow between spot and futures is reflected by the lead-lag relationship between the two markets. If the transactions in the two markets are equally spaced and synchronous, then it is easy to calculate the lead-lag structure using ordinary correlation coefficients. In our case, transactions occur at irregular intervals, and their frequency differs between the two markets. The usual approach to handle unequally spaced data is to split the time axis into subperiods of a fixed length and consider the last transaction in every interval only. If an interval is empty, then the last available value is used. This "fill-in" approach has an important drawback: non-trading may produce positive lead-lag covariances between observed returns of assets even if their returns are only contemporaneously correlated. To circumvent this problem we use a method proposed by de Jong and Nijman.[15]

We assume that prices follow an equally spaced process with five-minute intervals. However, prices are observed only at irregular intervals. In practical terms, this means that we consider the last transaction within each interval, but we do not fill in if no transaction takes place. As a consequence, especially in the spot market, there are not always transactions during every five-minute interval. If is therefore impossible to compute returns for all intervals. Figure 5 shows an example.

Figure 5

Sampling at irregular intervals



In Figure 5, p represents the logarithm of the price in the spot market and q the log of the price in the futures market. In our example, we can calculate the spot market return between t = 1 and t = 3 and the futures market return between t = 2 and t = 4. The spot market return (p_3–p_1) is a composition of the two underlying returns Δp_1 and Δp_2. A similar decomposition is possible for the future market return (q_4–q_2). The observable cross product of the prices can be decomposed as:

$$(p_3 - p_1)(q_4 - q_2) = (\Delta p_1 + \Delta p_2)(\Delta q_2 + \Delta q_3) = \Delta p_1 \Delta q_2 + \Delta p_2 \Delta q_2 + \Delta p_1 \Delta q_3 + \Delta p_2 \Delta q_3$$

or, after taking expectations, as

$$E[(p_3 - p_1)(q_4 - q_2)] = \gamma_{-1} + \gamma_0 + \gamma_{-2} + \gamma_{-1}$$

with γ_k = Cov$(\Delta p_t\, \Delta q_{t-k})$. The γ_k's are the cross-correlations of the underlying processes. Restricting the maximum order of leads and lags to 3, the last equation can be written as:

$$E[(p_3 - p_1)(q_4 - q_2)] = 0\gamma_{-3} + 1\gamma_{-2} + 2\gamma_{-1} + 1\gamma_0 + 0\gamma_{+1} + 0\gamma_{+2} + 0\gamma_{+3}$$

This cross product consists of one contemporaneous correlation of the underlying processes, two one-period leads of the underlying spot price and one two-period lead of the underlying spot price. The γ_k's (lead-lag structure) can be estimated by regressing all observable cross products of the prices for all overlapping intervals on a matrix with suitable dummies.

The estimated lead-lag structure between the spot price and the future price is summarised in Figure 6 for the cheapest-to-deliver bond and in Figure 7 for the on-the-run bond. Black bars signal significance

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15 For more details see de Jong and Nijman (1997) and de Jong et al (1998).

at the 1% level and grey bars signal significance at the 5% level. The bar at zero shows the contemporaneous correlation between spot and future prices. A bar to the right (positive numbers) shows a lead of the future and a bar to the left (negative numbers) shows a lead of the spot price. With the exception of the period between 6 July and 14 August, the contemporaneous correlations between the prices of the bonds and the future are always positive and significant at least at the 5% level. The reason for the lack of a significant correlation between the cheapest-to-deliver and the future in the 6 July to 14 August period is the low number of bond transactions. A striking feature is the highly significant and positive five-minute lead of the future during the first half of the year (1 January to 3 July), ie our control period of tranquillity. This suggests that in normal times, information is first released in the futures market and then works its way into the spot market. In the second half of the year, the lead of the future breaks down for the cheapest-to-deliver bond. During the LTCM phase (23 September to 15 October), a strong, and significant at the 5% level, lead of the cheapest-to-deliver bond appears. While the short-run information flow is changed in this period for the cheapest-to-deliver bond, no systematic change is observed for the on-the-run bond.

Figure 6

Lead-lag structure between the cheapest-to-deliver and the future

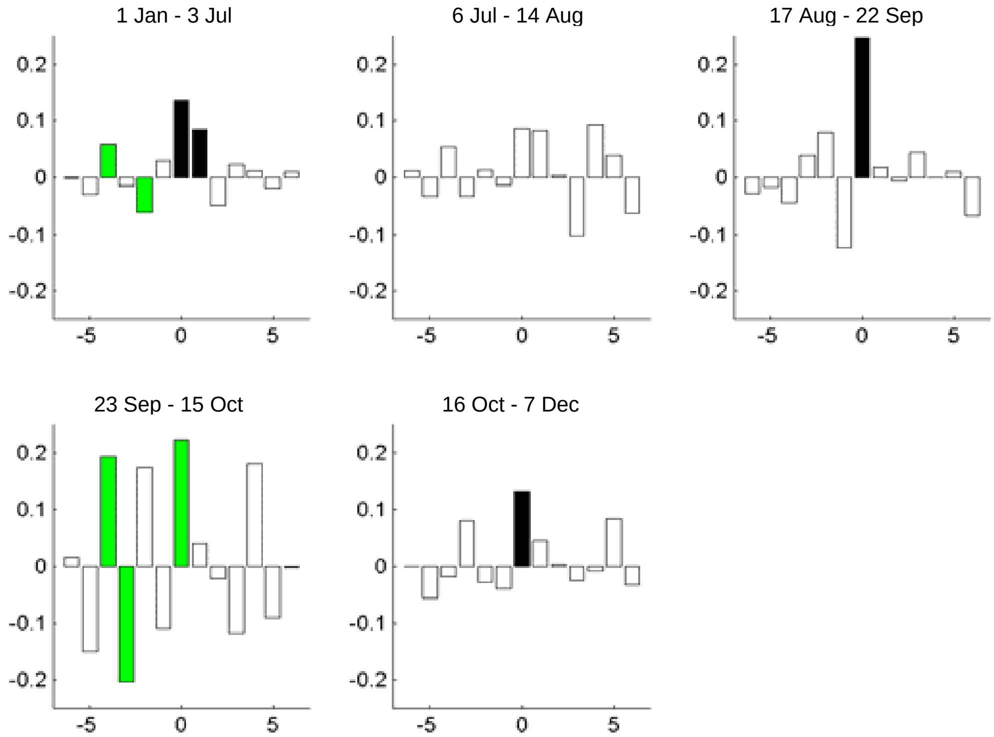
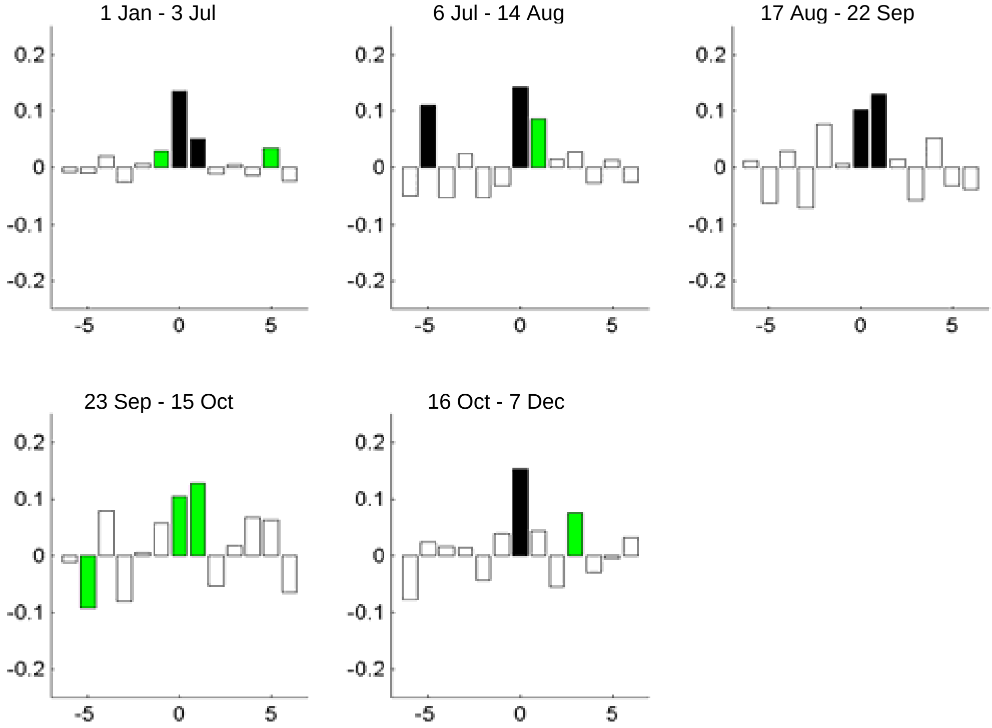


Figure 7

Lead-lag structure between the on-the-run and the future



6.2. Equilibrium adjustment

The leads and lags estimated in the previous subsection describe the short-run information flow between the two markets, but do not say anything about whether a long-run equilibrium relation between the spot and the futures markets actually exists. However, this is important for judging the market performance, since it tells us whether and to what extent arbitrage between the two market segments does occur. The statistical tool to analyse long-run relationships is cointegration analysis. To use the standard cointegration methods like Johansen's ML procedure, it is necessary to have equally spaced data without missing values. We use the "fill-in" method (using the last available value) to achieve this. The drawbacks of the "fill-in" method mentioned above mainly affect the estimates for the short-term information flow and not the long-run relationship equilibrium, so it seems sensible to use it here.

If no arbitrage possibilities are present, the difference between the price of the future f_t and the price of the bond s_t (the basis) must not stray too far from zero. This implies that the basis is stationary. More generally, there may be a stationary linear combination ($f_t - \mu - \theta s_t$) or a "cointegrating vector" between the prices. According to Engle and Granger, a cointegration relation between two variables implies an error correction representation.

$$\Delta s_t = \alpha_s(f_{t-1} - \mu - \theta s_{t-1}) + a_{1s}\Delta s_{t-1} + a_{2s}\Delta s_{t-2} + \ldots + b_{1f}\Delta f_{t-1} + b_{2f}\Delta f_{t-2} + \ldots$$

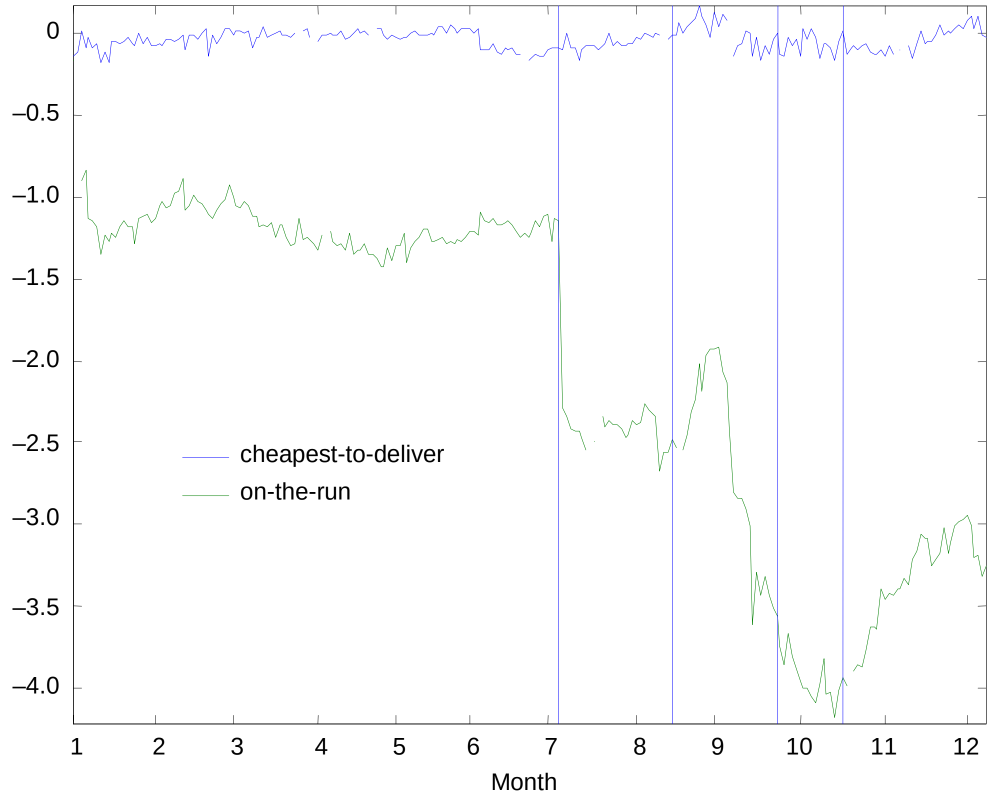
$$\Delta f_t = \alpha_f(f_{t-1} - \mu - \theta s_{t-1}) + a_{1f}\Delta f_{t-1} + a_{2f}\Delta f_{t-2} + \ldots + b_{fs}\Delta s_{t-1} + b_{2s}\Delta s_{t-2} + \ldots$$

The parameter α_s is a measure for the speed of adjustment of the bond (spot price) to the arbitrage equilibrium and α_f is the corresponding parameter for the future.

Before we carry out cointegration analysis, it is helpful to look at a time plot of the basis. Figure 8 shows the difference between prices of the future and the bonds at noon[16] of each trading day. We find that the prices of the future and of the cheapest-to-deliver track each other rather precisely even at the height of the turbulence, never diverging by more than 0.2 basis points. Two changes in the pricing relationship merit attention. The jump in early June occurs during the switching of the June to the September contract and a corresponding change in cheapest-to-deliver. It is probably due to measurement problems as we use a two-month money market rate rather than a repo rate with a maturity coinciding with the expiry of the futures contract. The increase in the basis in August and September reflects the fear of a squeeze in the cheapest-to-deliver, which drove its spot price relative to that of the other bonds on the market. This fear receded by the beginning of September, and the basis gradually returned to a more normal level. Overall, we find more variation in the basis during the turbulence than during our control period before.

Figure 8

Basis



The pricing relationship between the future and the on-the-run bond was not as close as that with the cheapest-to-deliver. Even in the first half of the year, the difference between the two prices fluctuated between –1 and –1.5 basis points. In part, this probably reflects the premium commanded by the on-the-run bond due to its higher liquidity relative to previous issues, in part it may be due to the fact that the conversion factor used by Eurex penalises bonds with coupons far away from the notional bond's 6%. This last point may also explain the jump in the difference between futures and bond prices that occurred on 7 July, when the newly issued 4.75% due in July 2008 replaced the 5.25% (January 2008) as on-the-run bond. Even so, we see that during the following month the on-the-run bond continued to roughly move in parallel with the future, albeit at a higher price. After the Russian

16 Or last available during the previous hour.

moratorium on 17 August, however, the pricing relationship became very unstable. This may reflect the premium investors paid for their flight into liquidity that was observed during the turbulence, when they preferred to invest in highly liquid securities. At the height of the crisis in early October, the premium for the on-the-run bond exceeded 4 basis points, although it declined afterwards.

The results of the estimated error correction models are collected in Table 3.[17] In all cases where estimated coefficients are reported Johansen's ML-test signals a cointegration rank 1.[18] With the exception of one period[19] there is a remarkably stable cointegration relationship between the cheapest-to-deliver and the future.

Table 3

Error correction model[1]

Dates	Cheapest-to-deliver bond				On-the-run bond			
	Cointegration coefficients		Adjustment coefficients		Cointegration coefficients		Adjustment coefficients	
	μ	θ	α_s	α_f	μ	θ	α_s	α_f
1 Jan - 3 July	0	0.9997	0.0516 (10.5420)	– 0.0100 (3.8541)	0.1354	0.9878	0.0281 (10.1958)	0.0004 (0.3425)
6 July - 14 Aug	cointegration rank 2				0.6390	0.9841	0.0129 (4.9950)	– 0.0004 (0.3763)
17 Aug - 22 Sep	0	0.9996	0.0460 (4.4282)	– 0.0109 (– 1.679)	no cointegration			
23 Sep - 15 Oct	0	0.9996	0.2236 (7.9576)	0.0011 (0.0772)	no cointegration			
16 Oct - 31 Dec	0	0.9996	0.034 (3.3758)	– 0.0093 (– 1.8455)	no cointegration			

[1] t-values in parenthesis.

The cointegration parameters θ are close to 1 and the constant μ can be restricted to zero. This implies a stationary basis. The adjustment coefficients of the cheapest-to-deliver bond are always significant and always much greater then the adjustment coefficients of the future. The adjustment to the arbitrage equilibrium is therefore driven by the bond rather than by the future and also works in the turbulent phases. For the on-the-run bond, the results are very different. In correspondence with the graphical analysis above, the cointegration relationship with the on-the-run is less strong than it was for the cheapest-to-deliver. In the first two phases, cointegration is only detectable with a constant in the cointegration vector and the coefficient θ is more than 1 basis point different from 1. After 17 August, the cointegration breaks down and a long-term pricing equilibrium ceases to exist.

[17] The estimations are carried out with EViews 4.0. A preliminary unit-root analysis has shown that the series, examined over the whole year 1998, are I(1). For the subperiods the results are mixed and dependent on the test specifications. For the cointegration analysis we suppose that the series are I(1).

[18] Because the optimal lag length in the VAR depends strongly on the information criteria used and ranges from 3 to 20, we use a lag length of 12 (1 hour) for all estimations.

[19] For the period between 6 July and 14 August, the test shows a cointegration rank of 2. This implies a stationary system, where cointegration analysis is not sensible. It is very likely that this result is a statistical artefact. We have mentioned the small numbers of transactions for the cheapest-to-deliver bond during this period.

7. Conclusions

The paper looked at developments in the market for bund futures and the underlying bonds during 1998 in order see how markets function under stress. Let us briefly summarise our main findings before drawing some lessons for central bank policy.

We find that trading costs rose considerably, first in the wake of the Russian default in mid-August and, more severely, in early October. The former episode coincided with much heavier trading than normal. This suggests that part of the rise in trading costs may be due to the fact that effective spreads tend to get larger as transaction size increases. The rise in bid-ask spreads thus seems to overstate the reduction in liquidity. We are not as confident when it comes to explaining the skyrocketing of spreads on 8 and 9 October. Turnover was somewhat higher than normal in the futures market but close to normal in the spot market. This indicates that the provision of liquidity was severely impaired.

The finding that markets seem to have weathered the Russian default better than the deleveraging during the LTCM episode comes as a surprise. Although in both cases the trigger was outside the German financial system, some local banks were heavily exposed to Russia but apparently much less so to LTCM. If anything, we would therefore have expected the strain on German markets to be more severe in August than in October.

In the second part of the paper we analysed the pricing relationship between the futures and the spot market. We find that the link between the bund future to the underlying cheapest-to-deliver remained relatively stable, although the short-run information flow between the two market segments seems to have changed during the turbulence. Those investors that used the bund future to hedge positions in bonds other than the cheapest-to-deliver could have suffered heavier losses, though. For example, the pricing relationship between the future and the on-the-run bond is not particularly stable even during normal times. During the turbulence, faced with a massive inflow of funds related to the flight into quality and liquidity, the relationship broke down and any hedge became much less effective.

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Electronic trading in Hong Kong and its impact on market functioning

Guorong Jiang, Nancy Tang and Eve Law,[1]
Hong Kong Monetary Authority

1. Introduction

The use of electronic trading (ET) platforms has expanded rapidly in recent years, from liquid and homogeneous instruments on organised exchanges, such as stocks and futures, to a wide variety of instruments in foreign exchange and fixed income markets, in both wholesale inter-dealer markets and retail markets. The introduction of ET platforms has the potential to change the way the market functions. Such platforms increase the operational and informational efficiency of the market through reductions in transaction costs and improvements in market access and transparency. However, increased competition could reduce dealers' incentive to make markets and adversely affect market depth. The overall effect of ET on market liquidity is an unresolved issue.

This paper examines the recent emergence of ET platforms in Hong Kong, and discusses its likely impact on financial market functioning, drawing on recent studies by the Committee on the Global Financial System (CGFS) and others, and results from our empirical work. Based on intraday transactable, firm quote prices and trade data in the Hong Kong stock index futures market, we find evidence that ET helps to improve market liquidity by reducing bid-ask spreads (BASs), after controlling for the effects of price volatility and trading volume. Furthermore, BASs widen under ET relative to a floor-based trading system when trading volume increases at times of market stress. However, ET will underperform a floor-based system only under extreme market conditions. As a result, this study sheds some light on how market liquidity behaves under ET during normal times and under stress.

The rest of the paper focuses on two topics. Section 2 describes the characteristics of major trading platforms in Hong Kong in the over-the-counter (OTC) fixed income and foreign exchange markets, as well as in the stock market at the retail level. This will be discussed in a qualitative analytical framework. Section 3 focuses on the impact of ET on market functioning, and presents the empirical evidence on such impact in an organised exchange environment. Section 4 concludes.

2. Electronic trading platforms in Hong Kong

An ET system is a facility that provides some or all of the following functions: electronic order routing (the delivery of orders from users to the execution system), automated trade execution (the transformation of orders into trades), and electronic dissemination of pre-trade (bid/offer quotes and depth) and post-trade information (transaction price and volume data) (CGFS(2001)).

ET systems differ from traditional systems, such as floor-based or telephone trading, in a number of ways. ET is location-neutral, ie users do not need to be in the same physical location, and allows continuous multilateral interaction (whereas telephone trading is bilateral). This facilitates cross-border trading and cross-border cooperation of trading systems. Furthermore, ET offers large scope for economies of scale and reduction of operational costs, as it is cheap and easy to increase trading capacity, which tends to encourage consolidation. Finally, ET allows straight through processing by easily integrating different parts of the trading process, starting from display of pre-trade information, through to risk management.

[1] The views expressed in this paper are those of the authors and do not necessarily reflect the opinion of the Hong Kong Monetary Authority. We are grateful to Stefan Gerlach, Grace Lau, Tony Latter, Priscilla Chiu, Esmond Lee and internal seminar participants for helpful comments and Polly Lai for excellent secretarial assistance. All remaining errors are ours.

Before discussing the impact of ET on market functioning, it is useful to review how markets are organised. Usually, trading is conducted in either exchange-based or over-the-counter (OTC) markets (Table 1). Centralised markets such as some of the stock and futures exchanges are order-driven with centralised order books. Market participants interact multilaterally and there is no negotiation within the system. In decentralised markets such as fixed income and derivatives markets, often referred to as OTC markets, markets are quote-driven and segmented into an inter dealer and a dealer to customer market. Market participants interact bilaterally, and the price of large orders is negotiated.

Table 1
Key features of market architectures

	Order book	**OTC market**
Access	No segmentation	Segmentation
Interaction	Multilateral	Bilateral
Price formation	Centralised, usually order-driven	Fragmented, quote-driven
Dealers	Often present, but not necessary	Necessary for trade execution
Transparency	Potentially high	Limited
Anonymity	Usually anonymous	Not anonymous, but limited disclosure
Trading protocols	Standardised	Not standardised
Continuity	Continuous or periodic	Generally continuous

Source: CGFS (2001).

ET increases the operational efficiency in both centralised and fragmented markets. Automation of the trading process lowers order-processing costs, while the integration of the trading process makes straight through processing possible. It also reduces the search costs by automating the collection of pre-trade and post-trade information and increasing the amount and timeliness of information.

Fragmented markets become more centralised under ET through increased use of multi-dealer systems and moving towards order books. ET systems provide the technology to eliminate the intermediaries in segmented markets. The bilateral OTC relationship between dealers can be replaced by a centralised marketplace with better price discovery and transparency, while the dealer-to-customer relationship can be moved from single-dealer to multiple-dealer systems. The speed of price information transmission from inter-dealer markets to customer markets will be improved.

ET is rapidly gaining ground in financial markets, from organised exchanges to a wide variety of instruments in foreign exchange and fixed income markets. This global trend has also been observed in Hong Kong (Table 2). The migration of Hang Seng Index futures and options to the ET system in June 2000 made the Hong Kong Futures Exchange fully electronic (Box 1). ET systems have also been introduced in the inter-dealer and retail markets in bond and foreign exchange trading (Boxes 2 and 3).

3. Impact of electronic trading on market functioning

Through its impact on trading costs and market architecture, ET will have a profound effect on market functioning and financial stability, in terms of market efficiency, liquidity, volatility and resilience during times of stress (CGFS (2001)). Reduced transaction costs and greater efficiency of ET facilitate trading, increase liquidity and reduce price volatility (Habermeier and Kirilenko (2001)). However, competition, in the form of lower costs and increased transparency due to ET, reduces margins, leading to fewer dealers and reducing the amount of liquidity they provide. This also reduces the bargaining power of large market players to negotiate a better price for their positions. The emergence of multiple ET platforms for trading stocks in the United States leads to concerns about market fragmentation, in terms of the dispersal of trading (CRS (2000)).

Table 2

Major ET platforms in Hong Kong

	Organised exchanges	OTC markets
Products traded	Stock and futures contracts	Fixed income and foreign exchanges
Major trading platforms	AMS/3 for stocks and HKATS for futures trading	ABP BIA and BETS for bonds and FXall, Reuters and EBS for foreign exchanges
Ownership	A listed company (went public in June 2000)	Shareholder-owned, mainly banks and information service providers
Date of introduction and implementation	Stocks: first introduced in 1993, fully electronic by March 1997	ABP: launched trading in October 2000 BIA: established in July 2000, trading expected in fourth quarter 2001 BETS: established in March 1999 in the United States, started trading Hong Kong government bonds in December 2000 by JPeX Reuters: launched in 1992 EBS: launched in 1993 FXall: launched in May 2001
Price formation	Order-driven, with strict price and time priority	Quote-driven, multi-dealer trading platforms
Information dissemination	Timely and transparent, through the internet and information service providers	Timely and transparent, through the internet and/or private networks
Trading costs	Trading fee and tariff to the Exchange, brokerage fees to the brokers, and stamp duty	ABP: transaction fees and content subscription BIA: franchise and transaction fees Reuters, EBS: transaction fees BETS and FXall: no transaction fees

Abbreviations:

AMS/3: The third generation of Automatic Order Matching and Execution System

HKATS: Hong Kong Futures Automated Trading System

ABP: AsiaBondPortal

BIA: BondsInAsia

BETS: Bloomberg Electronic Trading System

JPeX: JP Morgan eXpress

EBS: Electronic Brokering System

Sources: Hong Kong Exchanges and Clearing Limited; various websites.

ET improves pricing information collection and transmission to market participants, which leads to better informational efficiency. As a result of improved transparency, market prices reflect better and faster available information about the fundamentals. However, the reduced number of dealers may reduce risk capital from the marketplace and the provision of liquidity by dealers at times of stress. Information regarding counterparty risk is more important during times of stress: the anonymous nature of many ET platforms may affect their performance during times of stress. As ET affects multiple factors that influence the informational and operating efficiency of the market, the impact of ET on market functioning and financial stability becomes an empirical question.

Since the operation of ET platforms in OTC markets (mainly in bond and foreign exchange trading) in Hong Kong has only recently started, and trading data are not readily available yet, we turn to the organised exchange for evidence on the impact of ET on market functioning. In this section, we study the BASs, trading volumes and volatility of HSI futures trading before and after the transition to electronic systems on the Hong Kong Futures Exchange on 5 June 2000. The HSI futures contract was introduced in May 1986. It is among the most heavily traded contracts in the world, with a daily trading volume of over 17,500 contracts at end-June 2001. Contracts for the spot month, the next two calendar months, and the next two quarterly months are available, with trading concentrated in the spot month contract till the day before it expires (on the business day prior to the last business day of the month).

In the literature, whether market liquidity is better in automated trading systems or in the open outcry markets in the organised exchanges remains a controversial issue (Table 3).[2] On the one hand, it is argued that automated trading systems are less liquid than open outcry markets because automated systems cannot handle periods of intense trading as well as floor-traded systems. This is because automated systems have a higher degree of information asymmetry concerning the identity of the traders, and deprive liquidity providers such as locals and market-makers of some of their trading advantages. The delays in cancelling orders on the automated systems discourage the submission of limit orders as traders are forced to offer free options with a duration longer than those on the floor-traded systems. This effect could be especially important during periods of intensive trading, a reflection of high information arrival. Automated systems can reduce the human errors observed in floor trading, but have experienced delays or system failure when faced with unusually large trading volume.

Table 3

Comparison of open outcry and automated trading systems

	Open outcry trading	Electronic trading
Liquidity	Perceived to be inherently more liquid by some of the world's largest exchanges (CBOT, CME, NYSE)	Recent empirical studies have found evidence that ET may be better
Immediacy	Orders are changed/cancelled faster, and price discovery maintained in markets under stress	Especially during market stress, order cancellation procedure may cause delays and discourage limit orders; system may slow down or fail
Efficiency	Different prices may exist, orders may not fairly matched (front-running and curb-trading), with scope for human errors	Transparent price discovery, reduced frauds and human errors
Cost	High fixed and operating costs	High development costs, low operating costs
Anonymity	Provide more information about counter-party	Adverse selection in block trades, limiting the growth of order size
Global link	Segregated exchanges	24-hour, globally linked trading possible

Source: Adapted from Tsang (1999).

On the other hand, automated systems may enhance market liquidity because they are more cost-effective than floor trading, which leads to higher volume traded. They also offer greater transparency of the order book on prices and volumes away from the best bid and ask, which can reduce information asymmetry and provide more information for market-makers to manage their inventory exposure more effectively. This leads to a reduction in adverse selection costs and lower BASs. Furthermore, trade and quote data are disseminated faster on an automated system, which encourages off-floor participants to provide liquidity.

Empirical studies have been conducted to assess the effect of ET systems on market liquidity. Frino et al (1998) examined the trading of bund futures on the floor-based open outcry London International Financial Futures Exchange (LIFFE) and the automated Deutsche Terminbörse (DTB), which offered two different trading mechanisms operating at the same time for the same security. The paper

[2] For a detailed literature review on this topic, see Frino et al (1998), Tsang (1999) and Frino and Hill (2001).

investigated periods during which each exchange's share of total bund trading was similar and found that BASs were wider on the LIFFE than the DTB, after controlling for trading activity and price volatility. It was also found that BASs on the DTB were higher than LIFFE for a given level of volatility, after controlling for trading volumes. The result implies that ET systems are capable of providing higher liquidity than open outcry, but the relative performance of ET systems deteriorates during periods of high price volatility. Hill (2000) examined intraday trade and quote data for the nearest to maturity Share Price Index (SPI) futures contract traded on the Sydney Futures Exchange (SFE) for the period 30 September to 25 October 1999, a total of 30 trading days around the beginning of ET of the contract on 4 October 1999. The study found that BASs were significantly lower on the screen-traded system, compared to the previous open outcry market. This implies that the screen-traded market structure facilitates higher levels of liquidity than the floor-traded market, highlighting the effect of automation on the efficiency of a futures market. Frino and Hill (2001) examined the transition of trading in stock index futures from open outcry to ET in the LIFFE, SFE and HKFE during 1999-2000. Quote and trade data 50 days prior to the introduction of ET and 50 days afterwards were examined. Similar results to the Frino et al (1998) study were found: ET reduced the BASs across the three exchanges, but may increase spreads when price volatility is higher.

Table 4

Empirical studies on the effect of ET systems on market liquidity

	Frino, McInish and Toner (1998)	**Hill (2000)**	**Frino and Hill (2001)**	**Current study**
Market studied	Bund futures on LIFFE (open outcry) and DTB (automated)	SPI futures contract on SFE around the introduction of ET	Stock index futures on LIFFE, SFE and HKFE around the transition to ET	HSI futures contracts before and after the introduction of ET
Data	Intraday trade and quote data from 14 Oct to 24 Nov 1997 - 30 trading days, over five-minute intervals	Intraday trade and quote data from 30 Sept to 25 Oct 1999 - 30 trading days, over 15-minute intervals	Intraday trade and quote data 50 days pre-ET and 50 days post-ET - 100 trading days	Intraday trade and quote data from July to Sept 1998, Jan to Apr 2000, and Feb to Jun 2001 - 232 trading days
Method	Descriptive statistics for mean and median BASs on DTB and LIFFE, and regression analysis	Descriptive statistics for mean and median BASs, volume and volatility	Descriptive statistics for mean and median BASs, volume and volatility, and regression analysis	Descriptive statistics for mean and median BASs, volume and volatility, and regression analysis
Results	BASs are wider on the LIFFE than the DTB, after controlling for volume and price volatility. BASs on the DTB increase more rapidly as price volatility increases relative to the LIFFE	BASs are found to be significantly lower on the ET system, compared to the previous open outcry system	BASs are lower under the ET system across the three exchanges. However, BASs become wider in response to higher price volatility under ET, relative to floor trading	BASs are significantly lower under ET, after controlling for volume and price volatility. BASs widen under ET, relative to floor trading, when trading volume is higher

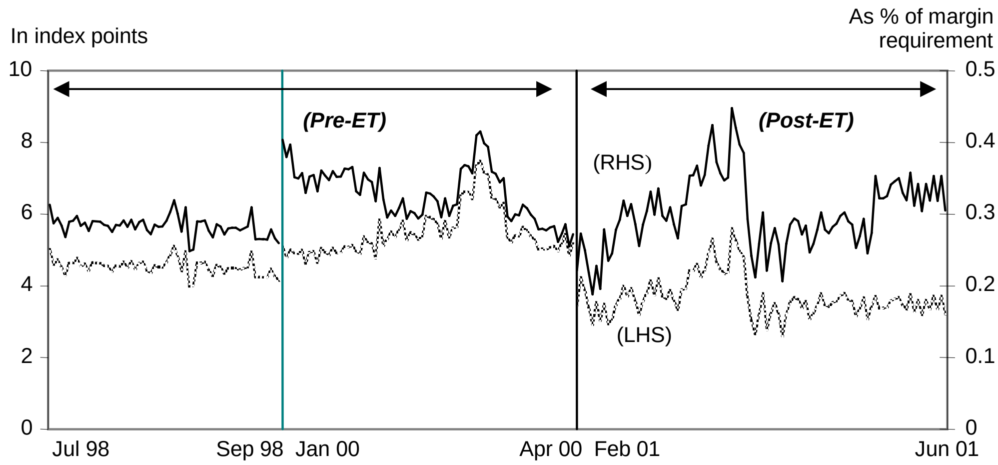
Following the methodology used in the previous studies, we examined the intraday trade and quote data for the nearest to maturity HSI futures both before and after the introduction of ET on 5 June 2000.[3] The intraday data are a record of the time and price of every trade and revision in firm (transactable) quotes on the exchange. The use of the intraday quote data avoids major shortcomings of the indicative quotes which are non-transactable prices, typically wider than the quoted spreads, and may be imprecise, especially during intensive trading as traders get too busy dealing to update

3 We are grateful to Elton Cheng of the HKEX for providing the intraday HSI futures contract trade and quote data.

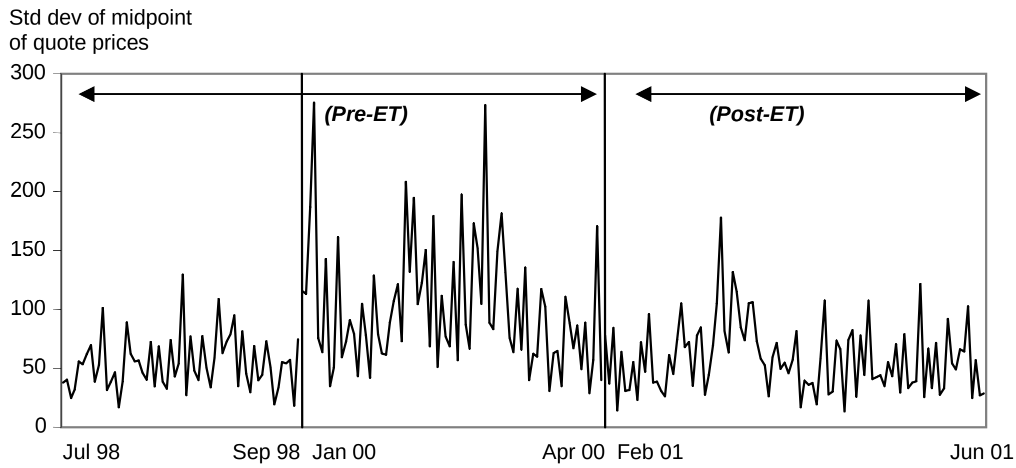
their indications (Goodhart et al (1995)). The periods covered are 2 July-30 September 1998, 3 January-28 April 2000 and 1 February-29 June 2001. Altogether, we have 136 observations before the introduction of ET, covering the period during the Asian crisis, and 96 observations afterwards.

BASs are used to measure market liquidity. Being a major part of trading costs, they are commonly used as an important indicator of the quality of the market functioning. Time-weighted, transactable BASs are calculated in index points for each day t: $BAS_t = \sum_{i=1}^{n} BAS_i t_i \Big/ \sum_{i=1}^{n} t_i$, where t_i is the amount of time bid-ask spread i was alive on day t. Time-weighted percentages of BASs are also calculated, with respect to the margin required to trade the futures contract.[4] Price volatility (*Volatility*) is calculated as the time-weighted standard deviation of the midpoint of the bid-ask quote P_i for each day t: $Volatility_t = \sqrt{\sum_{i=1}^{n} (P_i - \overline{P})^2 t_i \Big/ \sum_{i=1}^{n} t_i}$. The trading volume (*Volume*) is measured by the number of contracts traded (Graphs 1-3).

Graph 1
Bid-ask spreads of HSI futures contracts



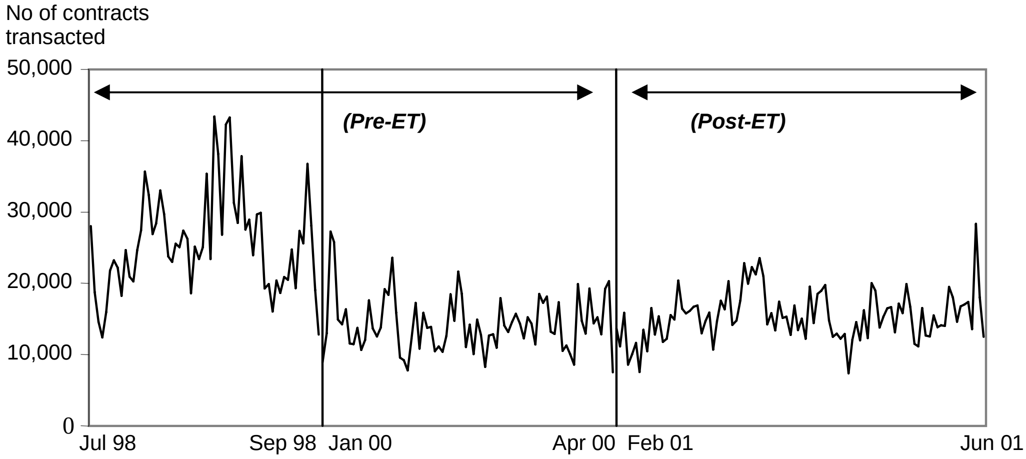
Graph 2
Price volatility of HSI futures contracts



4 The rationale for the calculation of percentage BASs in relation to the margin instead of the midpoint of the BASs quotes is that the price paid for the futures contracts is the margin, not the index levels.

Graph 3

Volume of HSI futures contracts



Source: HKMA staff estimates.

Preliminary statistical analysis is conducted by comparing the average of BASs before and after the introduction of ET on the HSI futures contracts, using a parametric t-test for the mean and a non-parametric Wilcoxon z-test for the median. This is followed by a more formal regression analysis, incorporating the main determinants of BASs - trading activity and price volatility. Finally we test whether the changes in futures trading volume and price volatility are due to changes in the underlying cash markets or to the introduction of the ET system. The results are presented in Tables 5 to 7.

Table 5 shows that average BASs measured in index points are significantly lower after the introduction of the ET - by over 1 index point compared to the floor trading. Though average BASs measured as a percentage of the margin requirements are also lower, the differences are not significant. Determinants of the BASs (price volatility and trading volume) are also significantly lower during the post ET period, which raises the question whether the lowering of BASs is due to the introduction of ET or to changes in their determinants.

Table 5

Liquidity, volatility and volume of HSI futures contracts, pre- and post-electronic trading

	Bid-ask spreads (index points)			**Bid-ask spreads (percentage)**[1]		
	Pre-ET	**Post-ET**	***t/z***	**Pre-ET**	**Post-ET**	***t/z***
Mean	5.05	3.68	16.16*	0.31	0.30	1.34
Median	4.94	3.58	11.58*	0.30	0.30	1.12
Std dev	0.68	0.56		0.04	0.05	
n	136	96		136	96	
	Time-weighted volatility			**Trading volume**		
	Pre-ET	**Post-ET**	***t/z***	**Pre-ET**	**Post-ET**	***t/z***
Mean	80.40	58.75	3.90*	19,335	15,406	4.56*
Median	67.63	55.30	3.50*	18,195	15,201	3.28*
Std dev	48.28	29.66		7,919	3,478	
n	136	96		136	96	

[1] Bid-ask spreads expressed as a percentage of the margin required for the futures contract.

* Significant at the 1% level.

Source: HKMA staff estimates.

To assess the impact of ET on BASs, the following model is specified to control for differences in the determinants of BASs before and after the introduction of ET:

$$BAS_t = \alpha + \beta_1 ET + \beta_2 Volatility + \beta_3 \sqrt{Volume} + ET \times (\beta_4 \sqrt{Volume} + \beta_5 Volatility) + \varepsilon_t$$

The impact of ET is represented by a dummy variable *(ET)* that is 0 for pre-ET observations, and unity otherwise. The square root of trading volume is for reducing the effect of outliers, consistent with McInish and Wood (1992). The interactive term between ET and trading volume is included to capture the incremental effect of ET on BASs of trading volume, after controlling for changes in price volatility and trading volume. A similar interactive term between ET and volatility is also included.

Two major findings are evident in Table 6: first, ET reduces BASs (whether measured in index points or as a percentage of margin requirements), after controlling for the effect of price volatility and trading volume. Second, the coefficient on the interactive term between ET and trading volume is positive, indicating that higher trading volume will increase BASs under ET, other things being equal. Graph 4 illustrates the relationship between BASs and trading volume, pre- and post-ET, controlling for the effect of price volatility. During the pre-ET period, higher trading volume tends to lower BASs, consistent with the common belief. In the post-ET period, higher trading volume actually raises BASs. However, the combined effect of the introduction of ET (which lowers BASs) and the interaction of ET and higher trading volume (which raises BASs) is to lower BASs during the sample period, which includes high trading volume observed during the Asian crisis (over 40,000 contracts traded daily on a few dates, compared to an average of around 17,500 contracts daily in normal times). This implies that only under extraordinary trading volumes will ET lead to higher BASs, compared to the floor-based system.

All coefficients are highly significant, except the interactive variable between ET and volatility. To address potential problems with serial correlation, Newey-West adjusted t-statistics are used to assess the significance of the estimated coefficients. Regressions with lagged independent variables yield similar results, indicating that our estimates are not affected by the possible endogeneity of the right-hand side variables, as current BASs are unlikely to affect the past trading volume and volatility.

We further examine whether declines in price volatility and trading volume observed after the introduction of ET system are due to changes in the fundamental market conditions or the change in trading system. Following the methodology used in Frino and Hill (2001), we compare the price volatility and trading volume of the HSI futures contract with those of the HSI, as the transition to the ET system only happened in the futures exchange, with no effect on the cash market. Given the availability of comparable data on the cash and futures HSI markets, price volatility is measured by the high-low volatility metric and the trading volume of HSI is measured by an estimated contract turnover, derived from the value turnover data.[5]

Table 7 shows that price volatility of both the HSI cash index and the futures contracts declined significantly after the introduction of the ET system in the futures exchange. However, the difference in price volatility between HSI index and futures contracts does not change significantly during the floor and ET periods. This result shows that the changes in the price volatility in the HSI futures market are similar to the changes in the cash HSI market, implying that the introduction of the ET system in the futures market is not likely to affect price volatility. Similar results were found for trading volume in both the HSI cash and futures markets (in log), which declined significantly after the introduction of ET, with no significant changes in the difference of volumes between HSI cash index and futures contracts across the pre- and post-ET periods. In sum, declines in price volatility and trading volume in HSI futures contracts observed after the introduction of the ET system are due to changes in the fundamental market conditions, and not to the change in trading system.

5 Volatility is defined as $(\log H - \log L)^2 / (4n * \log 2)$, where H and L are the daily high and low prices, respectively, and n the number of observations. Contract turnover is defined as value turnover/ (50*HSI closing index points), as each index point is valued at HKD 50 for HSI futures contracts.

Table 6

Effects of electronic trading on bid-ask spreads of HSI futures contracts

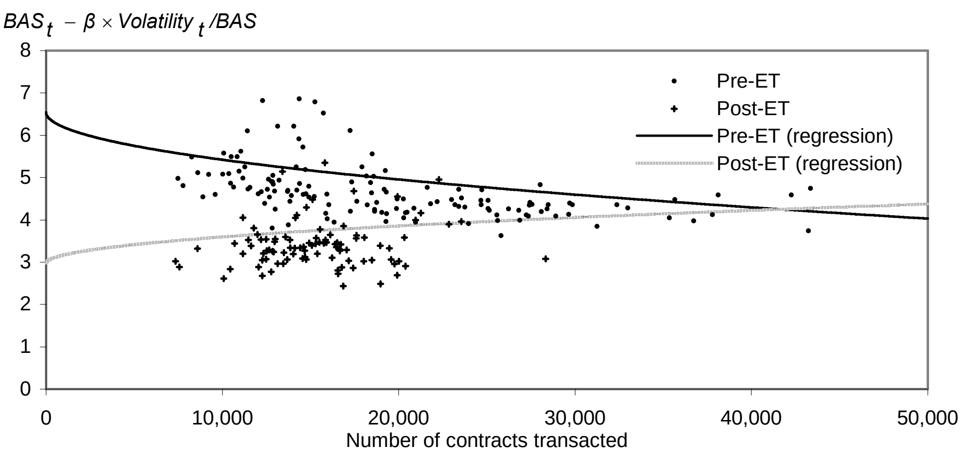
	Coefficient	**Newey-West adjusted *t*-statistics**	**Coefficient**	**Newey-West adjusted *t*-statistics**
			(Lagged independent variables)	
Bid-ask spreads (in index points)				
Constant	6.21	18.89*	6.22	20.68*
Electronic trading	– 3.59	– 4.81*	– 3.69	– 6.65*
Sqrt(volume)/100	– 11.25	– 5.25*	– 11.86	– 6.00*
Volatility/1000	4.74	3.37*	5.62	3.59*
ET*Sqrt(volume)/1000	17.70	2.69*	18.41	3.86*
ET*volatility/100	– 0.20	– 0.08	0.23	0.09
Adj R2		0.66		0.69
F-statistics		89.66		103.48
N		232.00		231.00
Bid-ask spreads (as a percentage of margin requirements)				
Constant	0.36	18.47*	0.37	20.11*
Electronic trading	– 0.20	– 2.81*	– 0.23	– 4.43*
Sqrt(volume)/1000	– 0.50	– 4.17*	– 0.60	– 5.09*
Volatility/1000	0.26	3.41*	0.26	3.33*
ET*Sqrt(volume)/1000	1.58	2.50**	1.75	3.98*
ET*Volatility/1000	– 0.04	– 0.18	0.03	0.15
Adj R2		0.19		0.25
F-statistics		12.04		16.62
N		232.00		231.00

* Significant at the 1% level. ** Significant at the 5% level.

Source: HKMA staff estimates.

Graph 4

Relationship between bid-ask spreads and trading volume



Note: The volatility is held at the sample average for the regression.

Source: HKMA staff estimates.

Table 7

Volatility and volume in the HSI cash and futures contracts, pre- and post-electronic trading

	Changes in volatility (x 10^6)			Changes in trading volume (in log x 10^2)		
	Stock index	**Future**	**Stock - futures**	**Stock index**	**Future**	**Stock – futures**
Mean	0.43	0.47	– 0.04	6.60	7.54	– 0.94
Median	0.26	0.28	– 0.03	6.08	7.81	– 0.79
T	5.62*	4.89*	0.86	3.31*	3.85*	0.48
Z	8.15*	6.71*	1.64	2.78*	3.28*	0.38
N	232.00	232.00	232.00	232.00	232.00	232.00

* Significant at the 1% level.

Source: HKMA staff estimates.

Our results are similar to what has been found by other studies. However, this study covers a longer period of time, and includes observations during the Asian financial crisis, when intensive trading took place. While previous studies found that the performance of ET systems deteriorates during periods of high price volatility, our results shows that intensive trading (measured by volume) might pose a challenge to the functioning of ET systems, but that ET will underperform floor-based trading only under extreme market conditions. These results could be potentially mutually consistent as a period of market pressure could be characterised by either price volatility or intensive trading, or both. Possible explanations for the deterioration of performance of the ET system during market pressure could be that when the market is under pressure, information intensity is high. During a period of intensive information arrival, the information contained in the electronic order book on prices and volumes away from the best bid and ask is of little value, while the delays in cancelling orders on an automated system may discourage the submission of limit orders. In addition, the higher degree of anonymity of the trading parties may lead to greater concerns about counterparty risks under ET during market pressure.

3. Conclusions

ET is a global trend in the international financial markets. Early evidence based on the relative performance of exchange-based ET systems and floor trading has shown that the impact of ET on market functioning is likely to be positive. In particular, it is likely to improve transparency and liquidity of the markets. Our empirical study finds that ET enhances market liquidity by reducing BASs. However, the performance of ET systems deteriorates during times of market pressure with high price volatility or large trading volumes, but ET will underperform floor-based trading only during extreme market conditions.

Further study will be needed to test the robustness of our results, by examining data over a longer period, or taking into consideration interday volatility, in addition to intraday volatility. We also need to deepen our understanding of the effect of ET systems on market functioning, not only in the organised exchanges, but also in OTC markets when data become available. Further study on factors underlying the performance of ET systems under market pressure will also be useful.

Box 1

ET systems in organised exchanges in Hong Kong

Hong Kong has one of the most active stock and futures markets in the Asia-Pacific region. The stock market is the third largest in terms of market capitalisation after Japan and mainland China, and the Hang Seng Index futures contract is among the most heavily traded contracts in the world, with a daily trading volume of over 17,500 contracts at end-June 2001.

Securities are traded through a computerised Automatic Order Matching and Execution System (AMS) on the Stock Exchange of Hong Kong. The AMS system was first introduced in 1993, and all listed stocks were traded under the system by March 1997. AMS is an order-driven system that accepts limit, enhanced limit and special limit orders.[6] Trading is conducted through terminals in trading halls or through the off-floor trading devices at Exchange participants' offices. Orders are executed in strict price and time priority. Order and trade information is disseminated to the market and investors through the Teletext system, market data feed, and the Exchange's website and other information systems. The third generation of the AMS (AMS/3) is a trading system developed by the Stock Exchange of Hong Kong and was launched in October 2000. The Order Routing System under the AMS/3 enables investors to place trading requests electronically over the internet and other access channels (such as mobile phones).

The Hong Kong Futures Exchange (HKFE) has become a fully electronic marketplace since June 2000. It introduced ET in 1995, using the Automated Trading System (ATS). Rolling Forex - a currency futures product - was the first product traded on ATS. The Hibor futures was migrated to ATS in September 1997, leaving HSI futures and options contracts the only two products traded on the floor. The ATS was upgraded to a new electronic screen-based trading system - Hong Kong Futures Automated Trading System (HKATS) - in April 1999 to prepare for the migration of HSI futures and options contracts to HKATS, which was completed in June 2000. Under the HKATS, the HKFE operates the central marketplace and subscribing Exchange participants can directly access the market through computer terminals in their offices. The HKATS automatically matches order in the system based on a price/time priority mechanism. The execution of orders can be made immediately. HKATS allows brokers to provide straight through processing and real-time internet trading.

With rapid technological advances and growing demand for a more efficient trading environment, most brokerage houses and banks in Hong Kong offer online stock trading to retail investors. While Boom Securities, a Hong Kong-based stockbroker, was the first company to offer online trading in Hong Kong-listed companies in 1998, an increasing number of brokers and banks have been providing online stock trading facilities to clients over the past couple of years. These e-brokers, such as Tai Fook Securities, Prudential Brokerage, KGI Securities, 2cube Securities, HSBC Broking Services, Citibank, Wing Hang Bank and Citic Ka Wah Bank, provide clients with a wide range of services, including real-time quotes, market analysis, trade execution and monitoring of account portfolios, from a single point of access. While most e-brokers offer online trading facilities in Hong Kong listed securities, some also offer trading in US securities as well as securities from other overseas markets such as Singapore, Taiwan, Thailand and Korea. With the implementation of the Order Routing System (ORS) to the AMS/3 by the Hong Kong Exchanges and Clearing Ltd. (HKEx) in February 2001, investors are able to place orders through the internet to brokers for approval and submission to the market. In this regard, given that the broker systems are connected to the ORS, securities orders can be passed electronically and directly from brokers to the Stock Exchange, thereby eliminating human intervention. This helps to shorten the time for trade execution and to reduce costs. While online stock trading provides convenient and efficient services to investors, the commission charges of some of these e-brokers are even lower than those of traditional full-service brokers. For instance, the commission charges of some e-brokers are 0.15% or below on transaction amount, much lower than the average 0.25% of traditional full-service brokers. Study has shown that lower transaction costs have positive effects on price discovery, volatility and liquidity, leading to improvement in the informational efficiency of markets (Habermeier and Kirilenko (2001)).

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[6] A limit order having a price equal to the best opposite orders will match with opposite orders at the best price queue residing in the System, one by one according to time priority. An enhanced limit order will allow matching of up to two price queues at a time. The ask order price can be input at one spread lower than the current bid price, or the bid order price can be input at one spread higher than the current ask price. Any unfilled quantity after matching will be stored in the System as a normal limit order at the input order price. A special limit order has no restriction on the limit price with respect to the best price on the other side of the market. It will match up to two price queues (ie the best price queue and the secondary queue at one spread away) as long as the traded price is not worse than the limit price input. Any unfilled quantity after matching will be cancelled and not stored in the System.

Box 2

Major ET platforms in the fixed income market in Hong Kong

The main electronic bond trading platforms that cover Hong Kong dollar debt instruments are AsiaBondPortal, BondsInAsia and Bloomberg. These portals provide ET platforms for institutions to complete fixed income deals and offer other services such as market research and information.

1. AsiaBondPortal

AsiaBondPortal (ABP), a Hong Kong-based multi-dealer online trading system for Asian debt instruments, was officially launched in October 2000. ABP is an alliance between ABN Amro, Bank of America, Commonwealth Bank of Australia, Credit Suisse First Boston, Daiwa Securities SMBC, Deutsche Bank, GIC (Government of Singapore Investment Corporation) Special Investments, Income Partners Group, J.P. Morgan and UBS Warburg. ABP currently includes G3 currency denominated bonds (Asian bonds denominated in US dollars, euros or yen) as well as Singapore and Hong Kong dollar bonds, and plans to trade Australian domestic and kangaroo bonds (Australian dollar bonds issued by foreign companies), and ringgitt, baht and rupiah domestic currency bonds in the future.

ABP mainly offers two types of accounts - trading accounts for institutional investors and subscription accounts for groups and individuals who want to access to market analysis and information on the portal. ABP's income is mainly derived from the transaction fees charged to brokers/dealers for each trade and content subscriptions to the portal. As a multi-dealer system, ABP enables institutional investors to trade with various brokers/dealers through a single site, provided that they have sufficient credit lines. Institutional investors can execute trades on firm prices or solicit bids and offers from brokers/dealers and negotiate prices online. ABP provides a platform for secondary bond trading during Japan and Hong Kong trading hours and plans to support 24-hour trading across Asia, London and New York trading times in the future.

It is expected that ABP will enhance price discovery and transparency. More competitive prices might lead to tighter margins for brokers/dealers. The automation of the collection of pre-trade information (executable bids and offers) and post-trade information (trade details) leads to greater transparency and more timeliness of information flows. The accessibility of quotes from several brokers/dealers at the same time contributes to lower search costs. However, complete straight through processing is not possible with the current system, as clearing and settlement of trades remain the same as if the deals are done over the telephone. There is no anonymity in the trading process, as each counterparty in a transaction will know with whom they are dealing.

2. BondsInAsia

BondsInAsia (BIA), a joint venture of Barclays Capital, BNP Paribas, Citigroup, Credit Suisse First Boston, DBS Bank, Deutsche Bank, Hang Seng Bank, HSBC and BRIDGE eMarkets, was established in July 2000. BondsInAsia creates a multi-dealer trading platform for each Asian market, allowing local investors to trade Asian domestic and international fixed income securities, including government and corporate bonds. The platforms provide real-time firm and indicative prices, yield, deal analytics, research and news, and will be linked to offer trading in local and international Asian markets to both domestic and global market participants. BIA's multi-market model encompasses both dealer-to-client and dealer-to-dealer trading. Users can access the BIA system through the internet and other private networks; view and negotiate prices; and execute trades online. They can choose to view a country hub or a central page showing all the markets. The BIA trading system officially went live in November 2001, offering trades in Hong Kong dollar bonds via BondsInHong Kong, Singapore dollar bonds via BondsInSingapore and Asian credits via G3BondsInAsia.

BIA follows a franchise business model. While BIA provides infrastructure, security and operational services for the trading platform, local dealers participate in ownership and governance of the franchise in their market. The sources of BIA's income include the franchise fees from dealers who act as market-makers, and the transaction fees for each trade.

By providing a single point of access to multi-dealer pricing, execution and trade-related information about Asian domestic and international fixed income securities, BIA should help enhance price discovery and transparency of Asian bond markets. Liquidity of Asian fixed income securities will increase if the improved market access can attract more participants, including dealers and investors. BIA supports straight through processing, which should help reduce transaction cost and minimise transaction errors. Unlike ABP, which primarily focuses on the Asian international bond markets, BIA is expected to help internationalise the Asian local debt markets.

Box 2 (cont)

3. Bloomberg

Bloomberg announced in October 2000 that its ET platform, Bloomberg Electronic Trading System (BETS), was starting to offer trading in Asian fixed income securities. BETS were first launched in the United States in March 1999 and was subsequently introduced in Europe. In addition to US and Europe government, agency and corporate bonds, BETS currently offers Asian government bonds of the Philippines, Hong Kong, Japan and Singapore. The online trading of Hong Kong and Singapore government bonds is currently offered by JP Morgan eXpress (JPeX), which runs on BETS. JPeX focuses on sovereign bonds while ABP offers emerging market corporate bonds. BETS is available to Bloomberg Professional service subscribers to view real-time two-way prices from multiple dealers on a single screen and to execute transactions online with straight through processing capabilities. As a leverage network of current terminals, trading via BETS incurs no transaction fees, and participating dealers' revenue is mainly derived from BASs.

With a worldwide customer base of corporations, issuers, financial intermediaries and institutional investors, BETS allows extensive market access to the platform. BETS also supports straight through processing. BETS helps to enhance price discovery as clients can view and trade on real-time bid/offer prices provided by multi-dealers. BETS captures other trade-related information such as real-time positions, profit and loss results, and historical performance review.

Box 3

Major ET platforms in the foreign exchange market in Hong Kong

Among the different FX ET platforms, also including Atriax, Currenex, FX Connect, and STN Treasury, FXall is the only one that has a presence in Hong Kong and is approved as a money broker by the HKMA.[7] Other ET systems that are approved by the HKMA as money brokers include Reuters and EBS, which only serve the interbank trading community. Other institutional customers such as corporate treasurers and hedge funds cannot access these systems.

Reuters Dealing 2000-2 was launched in 1992, the first international computerised matching service for foreign exchange trading. The Electronic Brokering System (EBS) was established in September 1993 by a dozen leading banks in foreign exchange and Quotron, an electronic information screen competitor with Reuters. Before the introduction of these ET systems, banks had to rely on voice brokers or direct telephone dealing to execute trades, which are characterised by slow price formation and opaque market information.

FXall, a multibank ET platform for foreign exchange, including FX spots, forwards, swaps and options, was launched in May 2001 and established an office in Hong Kong in September 2001. Owned by 15 banks - Bank of America, Bank of New York, Bank of Tokyo-Mitsubishi, BNP Paribas, Credit Agricole Indosuez, Credit Suisse First Boston, Dresdner Kleinwort Benson, Goldman Sachs, HSBC, JP Morgan Chase, Morgan Stanley Dean Witter, Royal Bank of Canada, Royal Bank of Scotland, UBS Warburg and Westpac Banking Corporation FXall offers institutional clients foreign currency trade execution, access to research, straight through processing and 24-hour access to a multilingual support centre.

FXall can be accessed via the internet or private networks. With 50 global banks acting as liquidity providers, clients can trade on FXall and request executable quotes from several liquidity providers at once, provided that they have trading relationships with the specified liquidity providers. In addition, both clients and others can access indicative foreign exchange quotes, which are blended rates of the liquidity providers' quotes. Clients can also chat with liquidity providers online. Income of FXall is mainly derived from the price makers, as there is no fee for transactions or access to research for clients and others. FXall is the only fully automated multibank ET platform for foreign exchange in Hong Kong, with straight through processing capability. Price discovery and transparency should be enhanced as both clients and others are able to view indicative quotes aggregated from liquidity providers, though only clients are allowed to view real-time executable quotes from several individual liquidity providers at once.

7 A money broker refers to a person who acts as an intermediary between independent counterparties, one of which is an authorised institution, in foreign exchange and money market transactions. In Hong Kong, money brokers are required to be approved by the Monetary Authority under the Banking Ordinance.

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Foreign exchange markets in the 1990s: intraday market volatility and the growth of electronic trading

Alain Chaboud and Steven Weinberg,[1]
Board of Governors of the Federal Reserve System

Abstract

Foreign exchange markets experienced broad structural changes in the 1990s, including the gradual introduction of electronic trading platforms, which now process the majority of inter-dealer spot transactions. The changes have raised concerns that liquidity in foreign exchange markets may have deteriorated over time. We briefly survey the growth of electronic trading in foreign exchange markets over the decade, and discuss why it may have affected market liquidity and volatility. Using high-frequency data, we then examine several measures of foreign exchange market volatility from the period 1987 to 2001. We consider the evolution of variance ratios over time to examine whether intraday volatility has changed relative to daily volatility, and study the incidence of large intraday movements, a possible indicator of reduced liquidity. We find no evidence of a substantial change over time in the level of volatility or in the frequency of large movements in foreign exchange markets.

1. Introduction

The foreign exchange market has undergone several important structural changes in the past decade. At a macro level, the number of major participants in inter-dealer markets decreased considerably due to numerous mergers and acquisitions, particularly in the latter half of the decade, and the introduction of the euro in 1999 eliminated many trades. At the micro level, extensive changes in trading technology were evident. The adoption of electronic trading methods for inter-dealer transactions in the major currency pairs, though gradual, became widespread, particularly relative to fixed income and equity markets. The structure of foreign exchange markets at the beginning of this decade is therefore very different from that at the beginning of the 1990s.

These changes in the structure of foreign exchange markets have raised concerns about a possible decrease in market liquidity and an increase in market volatility in the past few years. In particular, some market analysts have voiced fears that a reported drop in the number of market-makers and in the total amount of capital dedicated to market-making may have had negative effects on the depth of foreign exchange markets. The increased presence of electronic trading is thought to be one of the factors contributing to this reported decrease in market-making activity. In this note, we first briefly review the growth of electronic trading in FX markets in the past few years and discuss how it may have affected the provision of market-making services. Using intraday high-frequency data from the period 1987 to 2001, we then study the evolution over time of several measures of volatility in the dollar-yen and dollar-mark (and euro-dollar) markets. We also examine the frequency of large exchange rate movements, a possible indicator of reduced liquidity.

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[1] The views in this note are solely the responsibility of the authors and should not be interpreted as reflecting the views of the Board of Governors of the Federal Reserve System or of any other person associated with the Federal Reserve System.

2. A very brief history of electronic trading in foreign exchange

The earliest ventures into electronic trading in foreign exchange markets were clearly just a better telephone. Reuters launched its Monitor Dealing Service in the early 1980s, and replaced it with Reuters Dealing 2000-1 in 1989. These early systems allowed communications between two foreign exchange dealers on the initiative of one of the counterparties, but did not perform the more complex matching function between a number of potential counterparties traditionally done by voice brokers. This changed in April 1992, when Reuters launched Dealing 2000-2, a true electronic broking system, automatically matching buy and sell quotes from ex ante anonymous (but pre-screened) dealers. The Minex Corporation, largely owned by Japanese foreign exchange brokers and banks, set up its own automated foreign exchange broking system in April 1993. Finally, in September 1993, EBS (Electronic Broking Service), formed by a group of large dealing banks which had pulled out of early tests of Reuters Dealing 2000-2, launched its trading system. Minex transferred its business rights to EBS in 1996, leaving us in 2001 with two major inter-dealer electronic broking systems, Reuters (now 3000) and EBS. Over time, each of the systems has gained an almost completely monopolistic role in the inter-dealer market for given currency pairs, with EBS dominant in dollar-yen and euro-dollar, and Reuters dominant in transactions involving sterling and emerging market currencies.

For inter-dealer transactions, these systems, first introduced in the early 1990s, had become the primary trading vehicles by the end of the 1990s. For customer-to-dealer transactions, however, the emergence of electronic trading has so far been much less widespread. Many financial institutions attempted late in the 1990s to launch single-dealer electronic trading platforms allowing them to transact foreign exchange electronically with their own customers. These platforms received little acceptance as customers appeared to value highly the ability to receive simultaneous quotes from several potential counterparties. A new generation of multidealer platforms is now being introduced, in part spurred by the success of Currenex, a reverse auction matching service developed independently of the banking community, which was launched in April 2000. Two large groups of banks have since launched their own multidealer trading platforms, Atriax and Fxall.

Because of the decentralised over-the-counter nature of foreign exchange markets, the exact share of global foreign exchange trading volume conducted through these electronic broking services is not easy to determine precisely. An estimate of the share of inter-dealer trading volume executed through electronic platforms puts the share at less than 5% in 1992, a bit more than 10% in 1995, about 40% in 1998, and about 60% in 2001. These data probably understate the true importance of electronic broking in these markets. First, the share of the number of transactions conducted through e-brokers is likely to be higher than the share of trading volume, as large transactions tend more often not to be conducted electronically, using instead direct personal contact between counterparties. And second, with most inter-dealer transactions routed through electronic brokers, this is clearly where the process of price discovery occurs. As far as customer-to-dealer transactions are concerned, it is generally thought that at present (2001) no more than 10% of these transactions are conducted through electronic platforms.

3. Electronic trading, market structure, liquidity and volatility

It is not immediately obvious that the adoption of electronic trading venues should necessarily have affected the liquidity and volatility of foreign exchange markets. The modern electronic trading platforms are, after all, simply a replacement for a system of telephones and voice brokers. They perform essentially the same functions, receiving large amounts of data from buyers and sellers, and arranging feasible matches. Most voice brokers have been forced into retirement since the mid-1990s, reportedly in great part due to the cost advantage of the electronic systems. There is little doubt, however, that the process of price discovery and the way the current price is disseminated among dealers and to the public have changed substantially with the spread of electronic trading. There is clearly much more price transparency now than in the days before electronic broking, in the sense that: (1) through centralisation there is greater clarity and precision of price; (2) most dealers have instant access to current prices; and (3) customers can also gain real-time access to these prices much more easily.

In the past, when the foreign exchange market was a conglomeration of two-way phone or e-mail conversations and of a number of voice brokers, the true market price was likely to be a bit fuzzy, potentially differing from dealer to dealer. In order to be continuously informed about the price, dealers tended to execute small trades regularly throughout the trading session, not just to look for profit opportunities, but also to attempt to gather information about the current price. Today, with price discovery automated and centralised, the over-the-counter foreign exchange market has taken on some of the characteristics of an exchange, including the existence of a widely broadcast single price at any one moment. In 2001, any dealing room with an EBS terminal instantly knows the current dollar price of the euro and yen, certainly for trades of the size typically dealt through EBS. As a consequence, the amount of trading activity designed primarily to gather information has greatly diminished. This new clarity and transparency of the price are very probably one of the factors explaining the dramatic drop in inter-dealer spot trading volume reported in the latest Triennial Central Bank Survey.

Table 1

Reported global daily FX trading volume

(USD billions)

Year	1992	1995	1998	2001
Total volume	394	494	568	387
With other dealers	282	325	348	218
With other financials	47	94	121	111
With non-financials	65	75	99	58

So, what could be the effects on the market of this increased clarity and access to price? On the one hand, the increased transparency could make it easier for new dealers to enter the trading arena, as the costs and the critical mass (of traders, analysts, market contacts, etc) required to run a foreign exchange operation with a reasonable chance of success have probably decreased. On the other hand, for the players who had previously established an information advantage, there may now be incentives to reduce their presence in the market, as the returns on their information gathering may not be as large as in the past. So, in theory at least, within the inter-dealer community, as these two forces compete, the net effect on the amount of market-making activity is uncertain.

The effect of the increased price clarity and transparency on the relationship between dealers and customers appears to be less ambiguous. The recent failures of many of the single-dealer dealer electronic platforms dedicated to dealer-to-customer trading testify to the increased price competition this has brought to the industry. Even before the actual birth of these business-to-consumer sites, the increased clarity in price at a given moment, combined with better information technology, made performing price comparisons much easier for customers. When these customers were first given instantaneous access to price information through single-dealer electronic platforms, they very quickly began to require simultaneous access to many price sources. The result has been a clear increase in price competition, and the market power of the industry as a whole over its customers appears to have eroded greatly. It is therefore generally believed that, in great part due to this increase in price transparency, industry profits from FX trading as a whole have declined on net in the last few years. It is also widely believed that, in part as a result of the scenario just described, the overall amount of capital assigned to market-making has fallen, as has the amount of proprietary trading done by dealers.

Due to the nature of the foreign exchange business, there is, however, no more than anecdotal evidence to back these “beliefs”. And it is, of course, impossible to untangle how much of this may be due primarily to the rise of electronic trading, and how much may be due to other structural changes in the industry, in particular the numerous mergers. Still, there are concerns among some market participants that these changes will soon adversely affect liquidity and volatility in foreign exchange markets if they have not done so already. The analysis in the next section attempts to uncover whether or not these concerns are currently warranted.

4. Data and analysis

We use intraday exchange rate data on dollar-yen and dollar-mark exchange rates (euro-dollar after 1999) covering the period from January 1987 to September 2001. The data, collected by Olsen and Associates, are based on Reuters indicative quotes, which have been shown to be an accurate source of high-frequency price data (but a poor source of bid-offer spread and transaction volume data). Using the midpoint of the bid and offer rates of the data, we construct time series of log differences of the exchange rates at 24-hour (at 21:00 GMT), 15-minute and five-minute intervals.

From these series of log differences, we compute three measures of volatility. The first is a standard measure of volatility based on squared daily returns. The second and third are "integrated volatility" measures based, respectively, on squared 15-minute and squared five-minute returns. Our volatility measures are not demeaned, and we express both as annualised standard deviations. We also calculate the ratios of the daily volatility to each of the integrated volatilities, presented in the right-hand columns. These variance ratios would be expected to be equal to exactly one if exchange rates behaved precisely as standard random walks. Values below one indicate a higher level of intraday price movement relative to the daily exchange rate movement, in other words the presence of mean reversion at higher frequencies than day-to-day. Table 2 presents these data per year for dollar-mark and euro-dollar, and Table 3 displays the data for dollar-yen. The mean value of each statistic and its standard deviation are presented in the last two rows of each table.

Table 2

DEM: annualised volatility and variance ratios

	1 day	15 min	5 min	1d/15min	1d/5min
1987	0.1165	0.1089	0.1090	1.0700	1.0684
1988	0.1098	0.0959	0.0955	1.1451	1.1501
1989	0.1202	0.1153	0.1155	1.0422	1.0405
1990	0.1028	0.1053	0.1094	0.9763	0.9393
1991	0.1388	0.1298	0.1340	1.0698	1.0363
1992	0.1401	0.1446	0.1503	0.9694	0.9324
1993	0.1093	0.1086	0.1153	1.0065	0.9478
1994	0.0954	0.0964	0.0994	0.9900	0.9597
1995	0.1297	0.1308	0.1324	0.9915	0.9797
1996	0.0704	0.0755	0.0814	0.9325	0.8649
1997	0.1018	0.0997	0.1013	1.0219	1.0049
1998	0.0903	0.0994	0.1011	0.9082	0.8932
1999	0.0971	0.1055	0.1107	0.9206	0.8778
2000	0.1233	0.1363	0.1405	0.9045	0.8777
2001	0.1101	0.1088	0.1145	1.0123	0.9620
mean	0.1103	0.1107	0.1140	0.9690	0.9708
sd	0.0187	0.0181	0.0184	0.0672	0.0800

Though daily volatility has varied substantially from year to year in both currencies, we see neither a clear trend over time nor an outsized movement in the last few years. Recent annual readings of daily volatility are, in fact, generally statistically close to the mean. It would also be difficult to find much of a trend in integrated volatility at 15- and five-minute intervals over the period in either of the currencies. Readings for 2001, for instance, are at or below their mean level over the sample period. The data therefore do not indicate that a wholesale change in market volatility, either daily or intraday, has occurred since the introduction of electronic trading. A look at the evolution of the two variance ratios over time in both tables also shows little substantial change. The two ratios remain close to one throughout the sample, though a bit more often below one than above. Recent values are either above their mean in our sample years, or statistically indistinguishable. If variance ratios had decreased in the later years, that would have been consistent with the story of a reduced presence of market-makers as electronic trading became widespread. In theory, one would then have expected customer trades to move the price more easily initially, only to be later reversed, yielding an increased short-term volatility not matched by larger movements in daily returns (a nice story, but clearly not in the data).

Table 3

JPY: annualised volatility and variance ratios

	1 day	**15 min**	**5 min**	**1d/15min**	**1d/5min**
1987	0.1203	0.1057	0.1067	1.1385	1.1276
1988	0.1118	0.0985	0.1001	1.1360	1.1178
1989	0.1193	0.1103	0.1130	1.0813	1.0558
1990	0.1189	0.1136	0.1191	1.0463	0.9976
1991	0.1035	0.1039	0.1108	0.9968	0.9345
1992	0.0929	0.0971	0.1036	0.9573	0.8975
1993	0.1196	0.1223	0.1296	0.9778	0.9229
1994	0.1045	0.1116	0.1187	0.9358	0.8797
1995	0.1464	0.1499	0.1556	0.9765	0.9410
1996	0.0759	0.0886	0.0967	0.8565	0.7842
1997	0.1275	0.1279	0.1322	0.9970	0.9645
1998	0.1687	0.1825	0.1798	0.9241	0.9379
1999	0.1339	0.1447	0.1467	0.9251	0.9125
2000	0.0982	0.1056	0.1081	0.9301	0.9085
2001	0.0984	0.0965	0.0995	1.0191	0.989
mean	0.1159	0.1172	0.1213	0.9581	0.96388
sd	0.0228	0.0250	0.0236	0.0801	0.0900

Next we briefly examine the frequency of large intraday movements at five and 15-minute intervals over the sample period. A reduced presence of market-makers in foreign exchange markets would be consistent with an increase in the frequency of “gapping”, sudden large movements in the price often interpreted as a sign of reduced market liquidity. We study the presence of gapping in these two markets by measuring, for each year in our sample, the frequency of movements of a given size relative to the volatility based on daily returns. Tables 4 and 5 show, by year, the frequency of absolute five-minute price movements within certain ranges, in units of standard deviations (expected standard deviations of five-minute movements based on yearly levels of volatility calculated from squared daily returns). The first column shows the frequency of absolute five-minute movements up to one standard deviation, the second between one and two standard deviations, and so forth. The rightmost column shows the frequency of movements exceeding six standard deviations.[2] Tables 6 and 7 display similar results for 15-minute intervals. The last two rows of each table show the mean and standard deviation of each column.

[2] For reference, a one-standard deviation five-minute movement in a year with a daily volatility near 0.12 (about average) represents about a 0.05% move in the exchange rate (so a 6σ move is about 0.3%). For 15-minute movements, a 6σ move is about 0.5%.

Table 4

DEM: distribution of five-minute movements

σ	0-1	1-2	2-3	3-4	4-5	5-6	6+
Year							
1987	0.8347	0.1261	0.0266	0.0077	0.0025	0.0012	0.0012
1988	0.8516	0.1176	0.0221	0.0052	0.0018	0.0006	0.0010
1989	0.8191	0.1383	0.0299	0.0075	0.0028	0.0012	0.0013
1990	0.7770	0.1652	0.0400	0.0113	0.0037	0.0013	0.0015
1991	0.8225	0.1357	0.0283	0.0083	0.0025	0.0010	0.0016
1992	0.8041	0.1460	0.0336	0.0091	0.0033	0.0017	0.0023
1993	0.7850	0.1611	0.0370	0.0108	0.0032	0.0011	0.0018
1994	0.8057	0.1463	0.0316	0.0092	0.0034	0.0015	0.0023
1995	0.8180	0.1352	0.0303	0.0094	0.0036	0.0014	0.0022
1996	0.7387	0.1938	0.0459	0.0134	0.0044	0.0019	0.0019
1997	0.7916	0.1615	0.0335	0.0084	0.0027	0.0010	0.0013
1998	0.7591	0.1769	0.0441	0.0115	0.0046	0.0018	0.0020
1999	0.7466	0.1853	0.0465	0.0134	0.0044	0.0018	0.0020
2000	0.7740	0.1641	0.0413	0.0118	0.0049	0.0021	0.0019
2001	0.7756	0.1662	0.0403	0.0112	0.0038	0.0013	0.0016
mean	0.7936	0.1546	0.0354	0.0099	0.0034	0.0014	0.0017
sd	0.0326	0.0219	0.0074	0.0023	0.0009	0.0004	0.0004

Table 5

JPY: distribution of five-minute movements

σ	0-1	1-2	2-3	3-4	4-5	5-6	6+
Year							
1987	0.8449	0.1203	0.0242	0.0064	0.0024	0.0007	0.0010
1988	0.8508	0.1158	0.0219	0.0069	0.0024	0.0011	0.0012
1989	0.8222	0.1352	0.0291	0.0088	0.0024	0.0011	0.0013
1990	0.8064	0.1440	0.0341	0.0098	0.0031	0.0012	0.0014
1991	0.7824	0.1633	0.0368	0.0105	0.0035	0.0018	0.0015
1992	0.7586	0.1784	0.0424	0.0132	0.0039	0.0017	0.0017
1993	0.7773	0.1641	0.0394	0.0110	0.0044	0.0018	0.0020
1994	0.7605	0.1764	0.0413	0.0128	0.0046	0.0020	0.0025
1995	0.7947	0.1510	0.0363	0.0104	0.0040	0.0018	0.0018
1996	0.7006	0.2098	0.0596	0.0176	0.0065	0.0030	0.0028
1997	0.7971	0.1535	0.0335	0.0094	0.0038	0.0013	0.0015
1998	0.8034	0.1460	0.0331	0.0102	0.0036	0.0013	0.0024
1999	0.7827	0.1613	0.0367	0.0112	0.0041	0.0018	0.0022
2000	0.7660	0.1741	0.0409	0.0115	0.0040	0.0016	0.0019
2001	0.7830	0.1663	0.0352	0.0098	0.0030	0.0014	0.0014
mean	0.7887	0.1573	0.0363	0.0106	0.0037	0.0016	0.0018
sd	0.0382	0.0246	0.0091	0.0028	0.0011	0.0006	0.0005

Table 6

DEM: distribution of 15-minute movements

σ	0-1	1-2	2-3	3-4	4-5	5-6	6+
Year							
1987	0.8450	0.1168	0.0253	0.0076	0.0027	0.0009	0.0018
1988	0.8649	0.1065	0.0195	0.0051	0.0018	0.0007	0.0015
1989	0.8276	0.1312	0.0281	0.0077	0.0031	0.0009	0.0015
1990	0.7890	0.1586	0.0360	0.0104	0.0034	0.0013	0.0013
1991	0.8280	0.1323	0.0277	0.0069	0.0028	0.0010	0.0015
1992	0.8153	0.1372	0.0313	0.0092	0.0039	0.0011	0.0020
1993	0.8033	0.1501	0.0319	0.0091	0.0030	0.0012	0.0015
1994	0.8203	0.1357	0.0281	0.0097	0.0029	0.0013	0.0021
1995	0.8233	0.1316	0.0288	0.0088	0.0035	0.0020	0.0021
1996	0.7693	0.1741	0.0395	0.0100	0.0040	0.0014	0.0016
1997	0.7951	0.1604	0.0316	0.0083	0.0029	0.0006	0.0010
1998	0.7644	0.1753	0.0408	0.0121	0.0040	0.0014	0.0020
1999	0.7710	0.1707	0.0402	0.0104	0.0043	0.0014	0.0021
2000	0.7863	0.1555	0.0375	0.0128	0.0045	0.0017	0.0017
2001	0.7951	0.1523	0.0369	0.0097	0.0036	0.0009	0.0015
mean	0.0806	0.1459	0.0322	0.0092	0.0034	0.0012	0.0017
sd	0.0290	0.0207	0.0062	0.0020	0.0007	0.0004	0.0003

Table 7

JPY: distribution of 15-minute movements

σ	0-1	1-2	2-3	3-4	4-5	5-6	6+
Year							
1987	0.8509	0.1169	0.0222	0.0059	0.0018	0.0010	0.0012
1988	0.8608	0.1085	0.0212	0.0051	0.0023	0.0010	0.0011
1989	0.8304	0.1310	0.0260	0.0075	0.0030	0.0007	0.0014
1990	0.8086	0.1475	0.0309	0.0081	0.0030	0.0007	0.0012
1991	0.8000	0.1520	0.0328	0.0096	0.0032	0.0009	0.0016
1992	0.7894	0.1577	0.0361	0.0109	0.0032	0.0015	0.0014
1993	0.7957	0.1533	0.0354	0.0093	0.0029	0.0014	0.0020
1994	0.7878	0.1570	0.0363	0.0110	0.0044	0.0014	0.0020
1995	0.8010	0.1501	0.0334	0.0091	0.0033	0.0015	0.0016
1996	0.7288	0.1986	0.0497	0.0143	0.0046	0.0019	0.0020
1997	0.7979	0.1578	0.0300	0.0082	0.0033	0.0013	0.0014
1998	0.7936	0.1556	0.0337	0.0100	0.0035	0.0013	0.0023
1999	0.7876	0.1587	0.0361	0.0100	0.0037	0.0018	0.0020
2000	0.7748	0.1689	0.0385	0.0101	0.0041	0.0018	0.0017
2001	0.7883	0.1632	0.0337	0.0102	0.0024	0.0014	0.0007
mean	0.7997	0.1518	0.0331	0.0093	0.0032	0.0013	0.0016
sd	0.0322	0.0218	0.0071	0.0023	0.0008	0.0004	0.0004

Note first that the distribution of high-frequency exchange rate movements is, as is expected, leptokurtic (too much mass within one standard deviation, for instance, and too much also in the tails). Small changes from year to year in the distribution of these high-frequency movements are evident, but again one would be hard pressed to conclude from these data that the frequency of large movements has increased substantially in the last few years, either for dollar-mark or dollar-yen. Aggregating some of the data, Figures 1 and 2 present the frequency of five-minute movements larger than three standard deviations and larger than five standard deviations by year for both currencies. Figures 3 and 4 show similar data for 15-minute movements. If one disregards the increases of the late 1980s, which we suspect may be due in part to the price reporting behaviour of the dealers at the time, the frequency of relatively large movements has not increased in recent years. In other words, the incidence of “gapping”, a common symptom of illiquidity, does not appear to have risen in a substantial way with the advent of electronic trading.

5. Conclusion

Despite our best efforts to look for trouble, we have been unable to uncover evidence that the recent changes in the structure of foreign exchange markets, including the adoption of electronic trading, have had a negative effect on market liquidity and volatility. Daily and intraday volatilities have not changed appreciably, ratios of daily to intraday volatilities have remained within past ranges, and the frequency of large intraday movements has not risen substantially in the past few years. To the optimist, this is evidence that these markets are resilient to wholesale changes, and that new sources of liquidity may have emerged as old ones dropped out. It also perhaps suggests that the cost savings associated with electronic trading have been sufficient to counteract, in great part, the loss of information advantage suffered by large dealers. If one insists on being pessimistic, one could perhaps argue that the deepest changes in the structure of foreign exchange markets are yet to come, as the various multidealer-to-customer platforms gain further acceptance and further erode the dealers’ information advantage. Whether or not trouble is brewing in the future, the price data we have examined do not indicate that foreign exchange markets have experienced a noteworthy increase in volatility in the past few years.

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Figure 1
Cumulative frequency of large five-minute movements
(three standard deviations and larger)

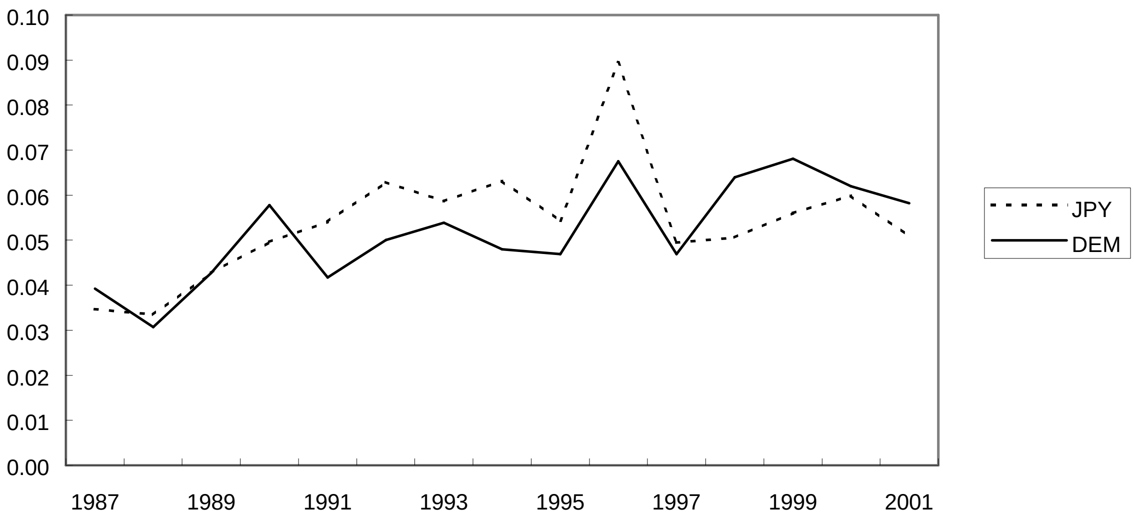


Figure 2
Cumulative frequency of large five-minute movements
(five standard deviations and larger)

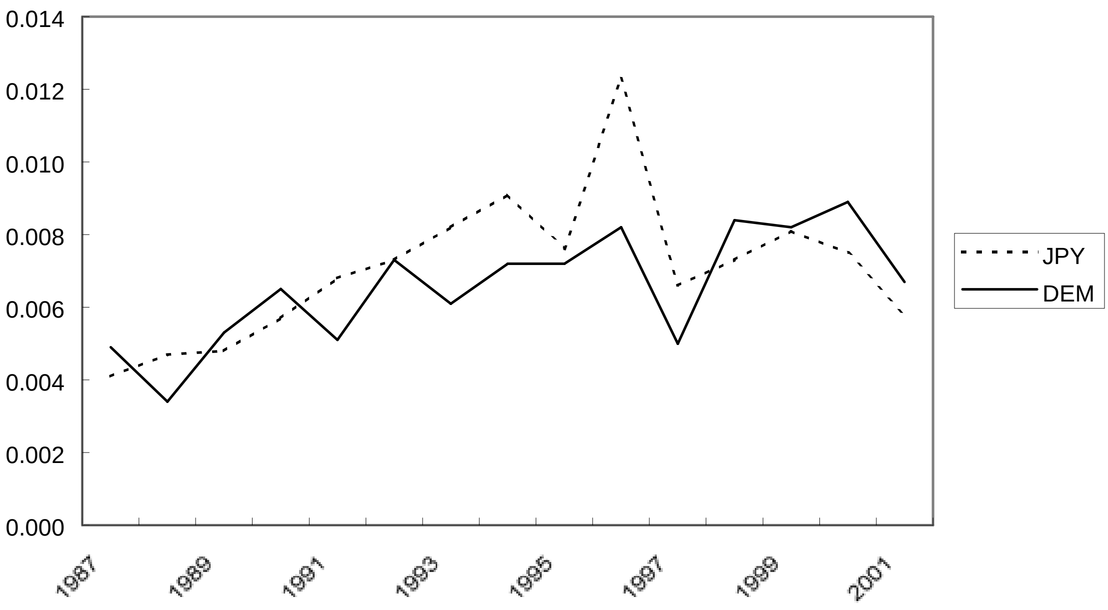


Figure 3

Cumulative frequency of large 15-minute movements

(three standard deviations and larger)

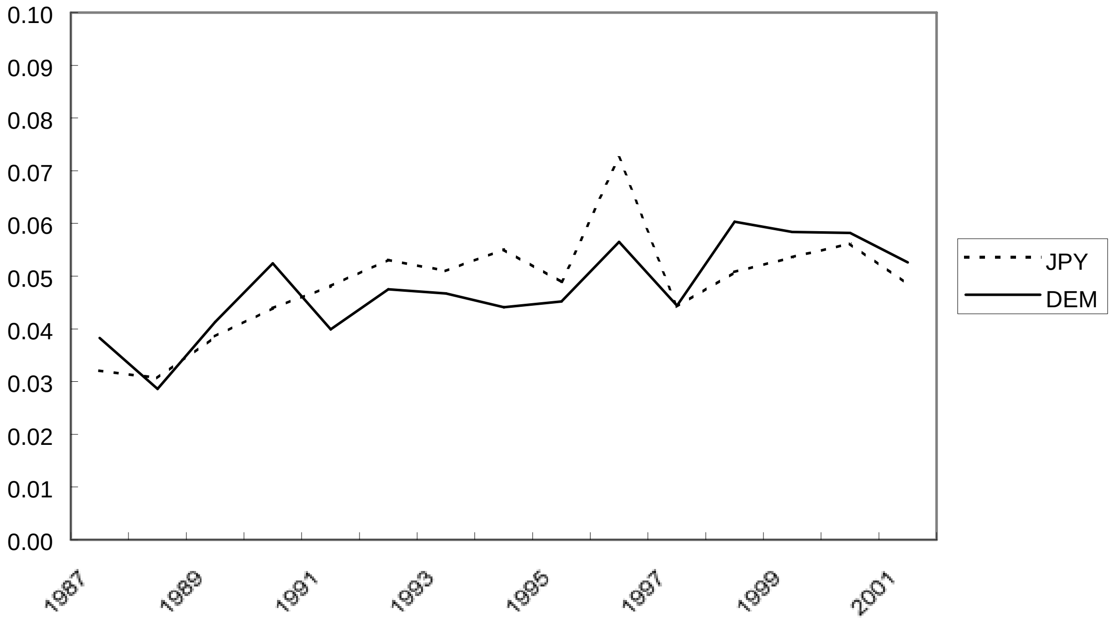
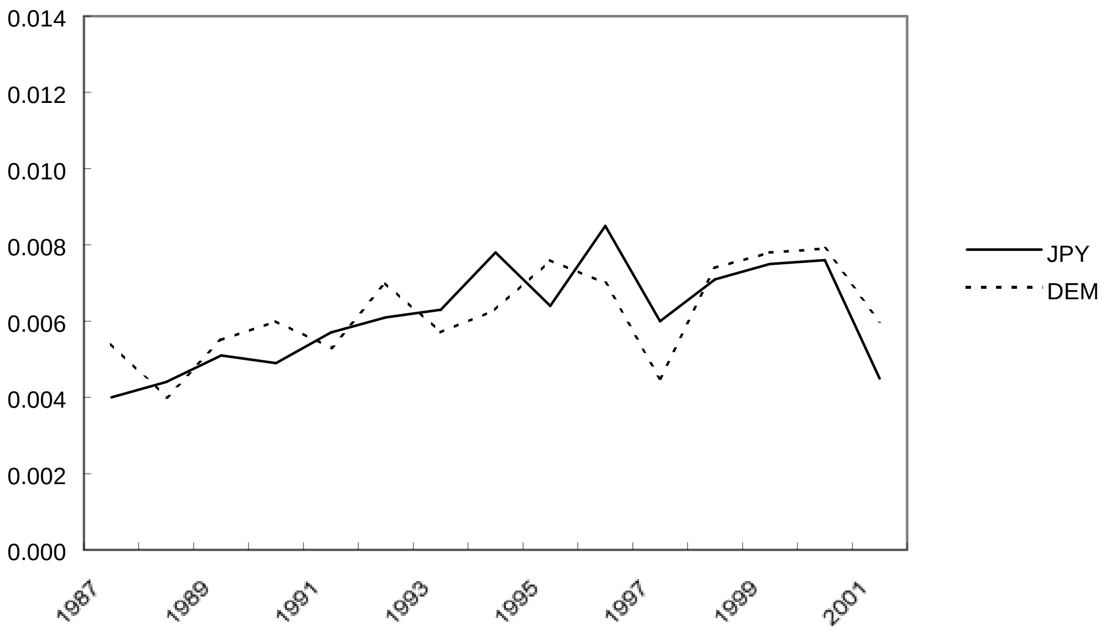


Figure 4

Cumulative frequency of large 15-minute movements

(five standard deviations and larger)



Positive feedback trading under stress: evidence from the US Treasury securities market

Benjamin H Cohen, Bank for International Settlements
and Hyun Song Shin, London School of Economics[1]

Abstract

A vector autoregression is estimated on tick-by-tick data for quote changes and signed trades of two-year, five-year and 10-year on-the-run US Treasury notes. Confirming the results found by Hasbrouck (1991) and others for the stock market, signed order flow tends to exert a strong effect on prices. More interestingly, however, there is often - but not always - a strong effect in the opposite direction, particularly at times of volatile trading. An examination of tick-by-tick trading on an especially volatile day confirms this finding. At least in the US Treasury market, trades and price movements appear likely to exhibit positive feedback at short horizons, particularly during periods of market stress. This suggests that the standard analytical approach to the microstructure of financial markets, which focuses on the ways in which the information possessed by informed traders becomes incorporated into market prices through order flow, should be complemented by an account of how price changes affect trading decisions.

1. Introduction

A principal conclusion of the theoretical literature on market microstructure holds that order flow - the sequential arrival of the buy and sell decisions of active traders - plays a vital role in price discovery. In the most influential papers, such as Glosten and Milgrom (1985) and Kyle (1985), order flow plays this role because of the presence of information asymmetries across traders, resulting in adverse selection effects. In Glosten and Milgrom (1985), for example, market-makers do not know whether an incoming order is from an informed or an uninformed trader, and quoted bid and ask prices reflect a trade-off between losses to trading with informed traders and profits to trading with uninformed traders.

By means of a vector autoregression (VAR) analysis of the time series properties of equity price changes and order flows, Hasbrouck (1991) documents a number of apparently robust empirical findings that support the adverse selection approach. Notably, order flow influences prices in the way predicted by the theory. Buy orders raise prices and sell orders lower prices, and there is a component of the price change that may be regarded as the permanent price impact of a trade that remains even after time has elapsed to smooth away transitory effects.

Another robust finding in Hasbrouck's study, however - and one which is relevant for our paper - is that there is also a strong relationship in the opposite direction: from price changes to order flows. Specifically, Hasbrouck finds a strongly *negative* relationship between current order flow and past price changes. In other words, price increases are followed by sales, and price falls are followed by purchases. Given the strong positive effect of past order flow on prices, this relationship between prices and subsequent order flow therefore has a mildly dampening effect on price behaviour.

One of the goals of the present paper is to examine how well the intuitions and models motivated by the stock market and the associated empirical findings translate into another important class of assets: that of fixed income government securities. The market for government securities is important in its own right given its size and benchmark status in the financial market, but we believe that it may in addition offer some valuable lessons in our understanding of market dynamics that differ from the

[1] We are grateful to Marvin Barth, Michael Fleming, Craig Furfine, Richard Payne and Eli Remolona for comments and discussions on an earlier draft and to Gert Schnabel for research assistance. All errors and opinions are our own.

stock market. It is likely that the models motivated by the stock market would fit in less well in those markets, such as for foreign exchange or government bonds, where it is less clear how the theoretical categories can be mapped onto real world variables. The analogue of the “fundamentals” for stocks in the case of Treasury securities corresponds to broadly macroeconomic considerations, and it seems less easy to tell a plausible story of a subset of (private sector) traders having strictly better information about these fundamentals than the others.

To a significantly greater extent than for equities, the fixed income (and foreign exchange) pages of the financial press as well as the commentary from traders themselves abound in strategic trading terms such as overhangs of leveraged positions, short covering and the like. This suggests that these strategic interactions between traders may result in market dynamics that differ from those in markets, such as equities, that conform to the adverse selection-based models of market microstructure.

Our objective in this paper is to investigate whether this intuition can be substantiated from the market data. We take the VAR methods used by Hasbrouck (1991) and apply them to the US Treasury securities market. Our conclusions point to some interesting and revealing differences from Hasbrouck’s original results for the stock market. To anticipate our main findings, we find that:

– Under tranquil market conditions, when trading is orderly and trading frequency is low, most of the qualitative conclusions in Hasbrouck (1991) for the stock market are replicated. The key difference is that, whereas Hasbrouck found that past price changes generally have a negative effect on order flow, we find this only to be the case when price volatility and trading frequency are at their lowest. For most of the sample period, the effect is either zero or slightly positive.

– However, during periods of high price volatility and active trading, there appears to be a structural shift in the market dynamics. In such periods, the positive effects of past order flow on current prices, *and vice versa*, are reinforced. In other words, not only do buy orders elicit higher prices, but price increases in turn elicit more buy orders. As a result, price movements become more positively autocorrelated (or less negatively autocorrelated) at short horizons.

The structural shift in market dynamics to positive feedback trading is detectable even during a single day’s trading, and coincides with bursts of intense trading activity. The onset of frenetic trading is accompanied by rapid price changes and a heavily one-sided order flow. We illustrate this effect by examining in some detail the particularly volatile trading on 3 February 2000, when markets were unsettled following the US Treasury’s announcements on debt management policy and rumours about large losses at certain institutions.

Positive feedback trading is consistent with the market adage that one should not try to “catch a falling knife” - that is, one should not trade against a strong trend in price. Some recent empirical studies are also consistent with such behaviour. Hasbrouck (2000) finds that a flow of new market orders for a stock are accompanied by the withdrawal of limit orders on the opposite side. Daníelsson and Payne’s (1999) study of foreign exchange trading on the Reuters 2000 trading system shows how the demand or supply curve disappears from the market when the price is moving against it, only to reappear when the market has regained composure.

The next section describes the data set used and applies the VAR methodology to intraday trading in on-the-run US Treasury notes over the period 1999-2000. Section 3 examines trading on an especially volatile day in some detail, as a way of illustrating how price and transaction behaviour can shift suddenly in volatile trading conditions in ways that cannot be fully explained by an approach based on adverse selection and order flow.

Providing a theoretical basis for an explanation of this kind of positive feedback trading is an important unresolved task. It is not our objective in this paper to tackle this issue, but we will identify the possible ingredients of such a theory in Section 4. We suggest an alternative (and to some degree complementary) theoretical approach that relies on the strategic interactions among traders. Section 5 concludes.

2. Testing for strategic interaction among traders

2.1 The data

The data are provided by GovPX, Inc. GovPX provides subscribers with real-time quotes and transaction data on US Treasury and agency securities and related instruments compiled by a group of inter-dealer brokers, including all but one of the major brokers in this market. For each issue, GovPX records the best bid and offer quotes submitted by primary bond dealers, the associated quote sizes, the price and size of the most recent trade, whether the trade was buyer- or seller-initiated, the aggregate volume traded in a given issue during the day, and a time stamp. Dealers are committed to execute the desired trade at the price and size that they have quoted. However, counterparties can often negotiate a larger trade size than the quoted one through a "work-up" process. Boni and Leach (2001) describe this process. Fleming (2001), who provides an extensive description of this data set, estimates that the trades recorded by GovPX covered about 42% of daily market volume in the first quarter of 2000.

We examine quotes and trades in two-year, five-year and 10-year on-the-run (ie recently issued) Treasury notes over the period January 1999 to December 2000. Although GovPX provides round-the-clock data, we restrict the series to quotes and trades that take place between 07:00 and 17:00, when trading is most frequent. The quotes used are the midpoint of the prevailing bid and ask quotes. When a new issue becomes "on the run", the GovPX code indicating on-the-run status switches to the new issue starting at 18:00; this means that a given set of *intraday* quotes and trades will always refer to the same issue. Trade volumes are calculated as the difference in the aggregate daily volume recorded for the corresponding security. Because these figures are provided in chronological order, the result is an ordered data set in which each observation is either a quote change, a trade or both.

Table 1a summarises the data used for the three securities. Our observations are in "event time" rather than chronological time. One issue is whether the tick-by-tick returns should be normalised so that they are comparable to calendar returns over a fixed time interval. Our main qualitative results turn out to be insensitive to whether we normalise or not, but for the results to be reported below, returns (r_t) are defined as the difference in the log of the quoted price (more precisely, the midpoint between the prevailing bid and ask quotes) at t and $t-1$, divided by the time difference between t and $t-1$ in minutes.

The number of observations increases with maturity, while the number and size of transactions falls. In other words, the data set includes more quote changes and fewer transactions as maturity rises. As suggested by Fleming (2001), this may reflect differences in coverage by GovPX rather than differences in the actual relative liquidity of two-, five- and 10-year issues, since the excluded broker (Cantor Fitzgerald) is relatively more active in longer-term issues.

The mean absolute value of the return from one observation to the next rises with maturity.[2] This may suggest that, although bond market price movements are traditionally reported in price terms, the underlying factor driving them is yield changes, since a given yield change produces greater price changes as the duration (the weighted average maturity of the payments underlying the note) rises.

Table 1a also gives the average duration (the time between observations) for the full sample of each bond and for four subsamples. This is about one minute for the two-year note, and about 45 seconds for the five- and 10-year notes. For the 50 trading days where average duration is highest, the time gap was slightly less than two minutes, while for the 50 trading days with the lowest average duration, this gap is about 40 seconds for the two-year note and 30 seconds for the five- and 10-year notes. This suggests that, while there are clearly more active and less active trading days in the sample, divergences in the frequency with which quotes and/or trades are observed are not great.

Average durations are also presented for the 50 days where the difference between the daily high and low price for the specified bond is highest, and for the 50 days where this difference is lowest. We

[2] In terms of 32nds, which are the usual quote convention for Treasury notes, and assuming a price close to 100, the mean absolute returns shown correspond to price changes of 0.29 32nds for the two-year, 0.67 32nds for the five-year and 1.26 32nds for the 10-year note.

would expect days in the former sample to correspond to relatively volatile trading conditions, while days in the latter are relatively quiet. Again, a clear difference between the two samples in terms of average duration can be observed. Days with wide price swings tended to see more frequent trades and/or quote changes, with observations coming in every 40 to 45 seconds, than quieter days, when the time between observations averaged between 56 and 92 seconds. However, this difference in duration is not great enough to suggest that we should expect to observe differences in the time series properties of the data stemming merely from a substantially longer gap between measured observations.

Confirmation of the relationship between the frequency of trading and various volatility measures is presented in Table 1b for the two-year note. The average duration of a given day tends to be negatively correlated with the range (high-low) of prices observed during the day, the standard deviation of tick-by-tick returns during the day, and the change (open-close) in prices that occurred during the day. The latter three variables tend to be positively correlated with one another.

2.2 Testing for the cross-effects of trades and quote revisions

2.2.1 A two-variable VAR of signed trades and returns

GovPX records the pricing and trading decisions of bond dealers, rather than those of speculative traders or investors. A reasonable assumption is that the dealers participating in the system attempt to minimise their open exposures to bond yields as far as possible, and do not attempt to "take a view" on likely yield movements.[3] Under this assumption, when a dealer accepts a bid or offer that has been posted on the system, he could be following one of two possible behavioural rules. One is that, whenever a dealer executes a trade with a customer, either by selling him a bond out of inventory or by buying a bond from him, the dealer immediately submits a countervailing trade to an inter-dealer broker in order to remain balanced. The other is that the dealer only rebalances his exposure periodically. Under the first rule, a transaction observed in the GovPX data closely tracks the transaction decision of a position-taker in the market. Under the second, an observed transaction primarily reflects inventory control operations and not a position-taking decision, except in the sense that position changes lead to inventory adjustments over a relatively long horizon. To the extent that both of these motivations are in action, the dealer-submitted transactions compiled by GovPX are likely to reflect a combination of the speculative strategies of traders and the inventory-control strategies of dealers.

The quotes posted on the system are also likely to reflect a combination of speculative and inventory-control motives. At certain times, a dealer may adjust his posted bid and ask quotes because of the information that he has gleaned from customer order flow. At other times, he may "shade" posted bid and ask quotes in order to induce a sufficient number of buy or sell orders to bring inventory back into line with its desired level. Both categories of motives are likely to influence the posted quotes that we observe on GovPX.

A primary aim of the analysis of intraday financial market data is to understand how the microstructure characteristics of a given market affect the time series characteristics of price quotes, signed transactions, and the interactions between them. If the dealers whose quotes and trades are recorded by GovPX are primarily mimicking customer orders, then this would allow us to test for the informational interaction between prices and trades. Specifically, we could test the result in the theoretical literature on market microstructure noted above, namely that signed order flow should have a measurable impact on price formation. We could also test whether, for reasons that will be discussed in more detail in Section 4, lagged price movements have an impact on trading under certain conditions.

Further, there are reasons to believe that the time series of both order flow and returns themselves exhibit serial dependence. Among the factors that might produce such dependence are inventory

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[3] Some dealers, however, execute trades on behalf of proprietary trading desks under the umbrella of the same financial institution. For the purposes of this discussion, a proprietary trading desk would be thought of as a "customer" of its affiliated dealer. During the time period covered by this study, January 1999-December 2000, many of the major government bond dealers had either closed or seriously curtailed their proprietary trading operations.

control motives, lagged adjustment to incoming information and minimum tick sizes. Some of these factors would result if dealers followed a customer-driven rule, while others would imply the primacy of inventory adjustment in short-run dealer behaviour.

At a short enough time horizon - data observed in intervals of minutes and seconds, rather than days or months - one might expect these factors to exert an impact on observed quotes and trades that can be measured statistically, even if at longer time horizons price changes are thought of as being driven more or less exclusively by the arrival of new information. This would allow us to determine which rules are being followed by the dealers in the market and, if we think the mimicking of customer orders is important, to learn more about customer behaviours as well.

The following VAR should capture many of these short-horizon effects:

$$\begin{aligned} r_t &= \sum_{i=1}^{10} \alpha_i r_{t-i} + \sum_{i=0}^{10} \beta_i trade_{t-i} + \varepsilon_{1,t} \\ trade_t &= \sum_{i=1}^{10} \gamma_i r_{t-i} + \sum_{i=1}^{10} \delta_i trade_{t-i} + \varepsilon_{2,t} \end{aligned} \tag{1}$$

Here r_t is the return variable cited above, while $trade_t$ is a signed trade variable. Two variables are used for $trade_t$:

x_t, an indicator variable equalling 1 for a buyer-initiated transaction, –1 for a seller-initiated transaction, and zero where there is a change in the price quote without a transaction; and

v_t, the size of the trade in millions of dollars, multiplied by 1 for a buyer-initiated transaction and –1 for a seller-initiated transaction.

The version using x_t is essentially identical to the VAR computed by Hasbrouck (1991). Like Hasbrouck we estimate the contemporaneous impact of trades on prices. That is, we include a term $\beta_0 trade_t$ on the right-hand side of the first equation. This allows for the possibility that trades are "observed" slightly before quote revisions through the work-up process.[4] Although the estimate of β_0 is positive and significant in all versions of the VAR that we examine, excluding $trade_t$ from the estimation of the first equation produces qualitatively similar results.

Results from the estimation of equation (1) on the full two-year sample are presented in Table 2 for $trade_t = x_t$, and in Table 3 for $trade_t = v_t$. For each trading day, the calculation of the VAR starts with the 11th observation of the day as the dependent variable. This eliminates the above-mentioned effect of the switch from one on-the-run issue to the next, the influence of overnight price changes and the inclusion of the effects of the last few observations in one day on the first few observations in the next.

For three of the four "quadrants" of coefficients - the effects of lags of r_t on r_t; the effects of lags of $trade_t$ on r_t; and the effects of lags of $trade_t$ on $trade_t$ - there is a remarkable degree of consistency across the three maturities (two-year, five-year and 10-year) and across the two trade variables (x_t and v_t). The results for all three quadrants conform to those found by Hasbrouck (1991) for the US equity market:

- Lagged returns tend to exert a negative effect on present returns, though this effect is partially reversed in later lags. In other words, returns are negatively autocorrelated at very short time intervals.
- Current and lagged trades tend to exert a positive effect on present returns. In other words, price movements follow order flow. Besides Hasbrouck's findings for the equity market, similar effects have been found for the Treasury market by Fleming (2001) and for the foreign exchange market by Evans and Lyons (forthcoming).
- Lagged trades tend to exert a small but significantly positive effect on current trades. In other words, trades are positively autocorrelated. This may suggest that traders tend to adjust their

[4] In January 2000, the average length of the work-up process was 20.97 seconds for the on-the-run two-year note, 16.12 seconds for the five-year note and 17.86 seconds for the 10-year. These are all less than the average tick lengths, which were 59, 46 and 44 seconds respectively. Boni and Leach (2001) describe and analyse the work-up process in the US Treasury market.

positions in a series of trades, rather than all at once. It may also imply that inventory adjustment effects (which might suggest negative autocorrelation in signed trades) are weak or absent. Within the very short time horizon covered by the VARs, dealers are apparently content to accommodate these sequential adjustments in traders' positions by running inventory imbalances rather than aggressively moving to restore desired inventory levels.

It is in the "upper right" quadrant - the effect of lagged returns on current signed trades - where the consistency breaks down somewhat across maturities, and where the results are generally different from Hasbrouck's. This set of effects will be the focus of Sections 3 and 4 of the paper.

For the two-year and five-year notes in the VARs using x_t, and for all three maturities in the VARs using v_t, the coefficients on lagged returns (sometimes with the exception of the first lag) tend to be *positive* for current trades. In other words, price increases tend to be followed by buy orders, at short horizons, while price decreases are followed by sell orders. For 10-year notes in the VARs using x_t, the coefficients are negative. This corresponds more closely to Hasbrouck's results for the equity market.

2.2.2 Estimating cumulative effects

A standard tool for analysing the results of VARs is the impulse-response function. In the present case, however, we are not interested in the usual impulse-response function - the effect on the level of one of the variables at some future point from a shock to a variable in the system - but in the *cumulative* effects of shocks to the included variables. Thus, for example, we want to know the impact of a new buy order on the overall return over the next several minutes, rather than on the level of the observed return at a specific point in the future. Similarly, we want to know the total number of net buys or sells that happen in the aftermath of a new buy or sell.

To do this, we can cumulate the output of the usual impulse-response function, taking account of the presence of the contemporaneous signed trade as an explanatory variable in the return equation. To construct the orthogonalised shocks to signed trades and returns, we need to make a prior assumption about the direction of causality between the variables. In this case, we assume that signed trades "cause" returns.

Graphs 1a to 4c show the cumulative effects of a one-unit increase in returns and buys on the cumulative return and number of net buys over the following 20 periods for active two-, five- and 10-year Treasury notes. The results using the coefficients estimated over the full two-year sample are given by the line indicated as "Full sample" in each graph.

The graphs largely confirm the results identified in our earlier review of the signs of the respective raw coefficients. Roughly 82% of a given shock to the return of the two-year note is still contained in the price level 20 periods later; this proportion falls to 76% for the five-year and 67% for the 10-year (Graphs 1a-1c). A buy order has a strong positive effect on returns in the short term; a buy causes a cumulative positive return of about 1.1 hundredths of a percentage point for the two-year note, 2.7 hundredths of a percentage point for the five-year note and 4.5 hundredths of a percentage point for the 10-year note (Graphs 2a-2c). In the 20 observations after a net buy order is recorded, a further 0.74 net buys result for the two-year note, 0.60 net buys for the five-year, and 0.37 for the 10-year (Graphs 4a-4c). As maturity increases, there seems to be a greater reversal of shocks to returns, a greater impact of trades on returns and less positive autocorrelation of trades.

The cumulative impact of returns on trades, which as already noted differs strikingly from Hasbrouck's results, is illustrated in Graphs 3a-3c. The graphs show the impact of a one-unit increase in the return. When one considers the typical size of these returns, it becomes clear that the magnitude of the effect is not large. For the two-year note, for example, an increase of one standard deviation in the return (a return of 2.05×10^4 from one tick to the next, or about 2 hundredths of a percentage point) leads to the occurrence of 1.2% more net buys than would otherwise take place over the subsequent 20 periods, or roughly 19.6 minutes.[5] For the five-year note, there are 3.4% more net buys. However, the

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[5] More precisely, the fraction of total transactions in the next 20 periods that are buys is 0.012 higher than it otherwise would have been.

coefficients are significant, suggesting that this is more than a statistical artefact. For the 10-year note, the cumulative effect on x_t is negative, with net sells rising by 1.3%.

2.3 Estimation results for duration-based subsamples

More interesting than the size of these effects is the way they change over different subsamples. The lines in Graphs 1-4 labelled “High duration” show the cumulative effects when the VAR in equation (1) is estimated using the 50 days (10% of the sample) for which the average time between new observations (trades and/or quote change is highest.[6] These should be the days of relatively “quiet” trading (and indeed, as already noted, price volatility and the differential between the daily high and low tend to be highest on these days). Similarly, the “Low duration” lines show the estimated cumulative effects on the 50 days when the time between observations is lowest. These should be days when trading and changes in quotes are relatively rapid, suggesting volatile trading conditions.

For all three maturities, the cross-effects between trades and returns on the low-duration days tend to be higher than the effects estimated over the full sample, and are substantially higher than the effects estimated for the high-duration days (Graphs 2a-3c). For the two-year note, the autocorrelations of both trades and returns are higher on low-duration days than on high-duration days, while for the five- and 10-year notes the difference is small or absent (Graphs 1a-c and 4a-c).

The effects of trades on subsequent returns increase strongly and consistently for all three maturities when trading ranges are high, and decline (but remain positive) when trading ranges are low (Graphs 2a-2c). For the two-year note, for example, the impact of a trade on the cumulative return over 20 periods rises from 1.1 hundredths of a percentage point in normal times to 1.4 hundredths on low-duration days, while falling to 0.9 hundredths on high-duration days. The economic significance of this effect can be gauged by comparing these figures to the standard deviation of the tick-by-tick returns, which is 2.1 hundredths of a percentage point.

Effects in the opposite direction - from returns to subsequent trading behaviour - also shift on high- and low-duration days relative to the rest of the sample (Graphs 3a to 3c). For the two-year note, these effects are more strongly positive on low-duration days than in normal times (that is, they lead to more net buys), and become strongly negative on high-duration days (that is, rather than leading to net buys, they lead to net sells). The net number of new buys following on a one standard deviation rise in the return rises from 1.2% to 4.1% on low-duration days, while on high-duration days net sells increase by 8.2%. For the five-year note, the effects are similar. For the 10-year note, positive price movements cause an increase in net selling in the sample as a whole, but cause increased buying on low-duration days, with net buys rising by 1.1%. On high-duration days, net sells are relatively higher.

Given that, as was shown above, order flow tends to have a strong positive effect on returns in this market, that returns have a positive effect on order flow (at least for the two- and five-year notes) and that these effects tend to be stronger on low-duration days, an important consequence of this finding should be that price movements exhibit stronger positive autocorrelation on such days. This prediction is confirmed by Graphs 1a-1c, which show the cumulative effect on r_t of a one standard deviation increase in r_t. For the two-year note, over the full sample period 82% of a positive return is still incorporated into the price quote after 20 observation periods - ie, negative autocorrelation results in 18% of a given return having been reversed 20 minutes later. During high-duration days, however, the proportion that remains in subsequent prices is only 68%. During low-duration days, the return is virtually not eliminated at all, with 98% of a shock to the return still evident after 20 observations. Similar, if weaker, results hold for the five- and 10-year notes.

Trades also become more positively autocorrelated on low-duration days (Graphs 4a-4c). It was noted above that, for the two-year note, a net buy tends to be followed by an additional 0.74 of a net buy over the next 20 observations during the sample period. For the low-duration days, however, 0.83 of a net buy results, while for the high-duration days this figure falls to 0.49. The same pattern can be seen for the five-year note, though the shift is less strong. For the 10-year note, no change in the autocorrelation pattern of signed trades is observed.

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6 To save space, the coefficients from this and the other VARs based on subsamples are not given. Coefficients from these VARs are available from the authors.

3. A case study: 3 February 2000

The results in Section 2 suggest that, on days of relatively volatile trading activity, traders tend to reinforce price movements (at least at short time horizons) rather than dampening them. This section explores the dynamics of this shift on a particular, very volatile trading day that occurred during the sample period.

3.1 Events of 3 February

3 February 2000 witnessed the sixth highest daily trading range for the on-the-run two-year note in the sample period (Graph 5). The price quoted on GovPX (using the average of the prevailing bid and ask quotes) opened at 99.551 at 07:04, reached a low of 99.523 at 10:03, rose to a high of nearly 99.977 at 12:36, and finished at 99.727 at 17:00. The range of the price from its lowest to its highest point, 0.45% of par, is very large in comparison with the sample median daily price range of 0.12%, the mean absolute value of the daily price change (open to close), 0.07%, and the standard deviation of the daily price change, 0.09%. This price range corresponds to 85 basis points in yield, in comparison with a median daily yield range of 23 basis points.

News accounts of the trading on 3 February, a Thursday, do not point to a specific new piece of public information digested by the market. The market was reported to be unsettled by the US Treasury's plans to change its auction practices and repurchase selected issues as part of a broader policy of using budget surpluses to reduce the debt held by the public. A key piece of public information relevant to that policy had been released on 2 February when the Treasury outlined plans to reduce the amounts of specific maturities to be issued in future auctions, including the popular 30-year bond. This announcement came during trading hours on the 2nd, so it was no longer fresh news to the market on the 3rd. Nevertheless, market commentary focused on the uncertain environment created by the announcement. In its daily report on the US Treasury market, The Associated Press emphasised the uncertain implications of the new Treasury programme for the liquidity of the 30-year bond, and the effects this uncertainty had had on market trading. According to one fund manager:

> *Folks are kind of shocked. Treasuries have become a scarce commodity. … It's 'wild, wild stuff', as Johnny Carson used to say. It's definitely a new environment for everybody. We're all trying to figure out what this means for the future* (AP Online (2000)).

In the same article, The Associated Press noted another series of events which may have influenced trading on 3 February:

> *Adding to Thursday's mayhem was a widespread rumour that the dramatic decline in bond yields had wiped out a large unnamed financial institution and that a rescue meeting was being held at the Federal Reserve Bank of New York. The rumour prompted a statement from the New York Fed denying there was a meeting to discuss market volatility* (AP Online (2000)).

An item released on the Market News International Wire at 12:14 that day reads in its entirety:

> NEW YORK (MktNews) - *A spokesman for the Federal Reserve Bank of New York Thursday declined all comment on a rumor widespread in financial markets that there would be an emergency meeting at the Fed to address big losses at a financial firm.*
>
> *The spokesman said it is Fed policy not to comment on such rumors.*
>
> *The completely unsubstantiated rumor circulated all morning Thursday, and appeared related to the market dislocations triggered by the Treasury's plans to cut back on supply of long-term securities. That has resulted in an inversion in the Treasury yield curve in recent days and a huge rally in Treasury long bonds Wednesday and Thursday.*[7]

3 February thus seems to offer an excellent opportunity for a case study of patterns of trading in the US Treasury market under conditions of uncertainty. With the exception of the Fed's announcement denying the rumour, there was no occasion when a piece of price-relevant information simultaneously

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[7] We are grateful to Michael Fleming for calling our attention to this news story.

became known to all participants. Instead, there was uncertainty as to how markets themselves would be expected to behave in the new environment of shrinking supply. The rumours of an institution in trouble added to the uncertainty, but undoubtedly, as tends to happen in these situations, the main area of uncertainty for market participants was the nature and extent of the knowledge possessed by *other* participants.

Examination of Graph 5 suggests that the day can be divided into four periods in terms of trading behaviour. Characteristics of these periods, and comparable figures for the full two-year sample, are presented in Table 4. From 07:00 to 11:00, prices were flat or slightly higher, bid-ask spreads were wider than usual but steady, and there was a roughly even balance between buys and sells. From 11:00 to 12:15, prices rose sharply, accompanied by an imbalance of buys over sells. This is presumably the time when rumours about a troubled institution dominated market trading, with prices at first bid up on the expectation that the institution would have to liquidate a large short position. From 12:15 to 14:00 prices fell about as sharply, with sells outnumbering buys. This followed the New York Fed announcement. In both the second and third periods, quoted bid-ask spreads were wide and volatile, and occasionally negative.[8] Finally, from 14:00 to 17:00, prices rose gradually amid relatively calm conditions, though bid-ask spreads remained elevated.

Two points are worth noting with regard to Table 4, both of which suggest that the bond market on 3 February behaved in a more complex way than would be implied by a simple adverse selection model in which information is incorporated in order flow.

First, while it is clear that an imbalance of buy orders over sell orders was associated with rising prices and vice versa, it is interesting that a virtually identical share of buys (66%) led to a sharp price increase between 11:00 and 12:15, but to only a relatively mild price increase between 14:00 and 17:00.

Second, the bid-ask spread was at its highest between 12:15 and 14:00 - even though, as noted above, the Fed announcement was probably the day's most influential piece of *public* information. If wide bid-ask spreads indicate a high degree of information asymmetry, as the adverse selection model would predict, one would expect that when an important item of news, with a direct and immediate bearing on market prices, becomes known simultaneously to all market participants, this would contribute to a significant *narrowing* of bid-ask spreads.

3.2 Comparing price movements and order arrival

A closer examination of trading patterns throughout the day presents further puzzles (Graphs 6a-6d). It is worthwhile, first, to consider what the different theoretical frameworks used in market microstructure would predict about the patterns of price movements and orders. A pure neoclassical view would suggest that the price moves automatically to adjust to new information, and that buys and sells should be essentially balanced whatever the price level is and in whatever direction it is moving. If orders primarily reflect inventory adjustment, then groups of buys and sells should alternate, with a large number of buys leading to price increases (as dealers rebuild inventory) and sells leading to price decreases (as they lay off inventory) in an essentially predictable rhythm. According to an adverse selection-based view, we would expect to see an exogenous build-up of purchases to be followed more or less immediately by information-driven price increases, and a build-up of sales to be followed by price declines.

During the 07:00-11:30 period (Graph 6a), buys and sells appear to be balanced over the period as a whole, but do not seem to follow any of these predictions closely. Rising prices are associated with buys (eg just after 10:04) and declines with sells (eg just before 8:18). But the order flows and price movements appear to be simultaneous; the price graph does not wait for a build-up of orders before it starts moving. And periods of persistent one-sidedness in the market (eg the buying activity from 10:17 until around 10:40) are not followed by price movements that would be sustained enough to return inventories to balance; instead, on this occasion, the price hovers for a while, then turns downwards - and only then (around 10:44) do we see clusters of sales.

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8 Both the very wide and the negative bid-ask spreads are probably the result of "stale" quotes that dealers did not have time to update.

As the rumours of a troubled institution begin to take hold (Graph 6b), the price rose amid heavy buying. But sometimes the price rose with little or no buying, as in the phase just after 11:46, and again around 12:12. At the very top of the market, from around 12:15 onward, traders appeared to be buying at peaks, and selling at valleys. Again, neither the neoclassical, nor the inventory adjustment, nor the adverse selection view appears to explain the interaction between price and order behaviour.

The period after the Fed announcement (Graph 6c) is virtually the mirror image of the hour or so that preceded it - this despite the very different nature of the information that was driving the market in the two periods, with rumours replaced by credibly stated facts. Prices sometimes fell without any order flows, at other times accompanied by heavy selling. Prices seemed to stabilise around 13:05, even though traders continued to sell. A cluster of buys eventually emerged just before 13:16, but the market seemed happy with its new level - even when the buys were followed by further sales.

During the last three hours of the trading day, the market rose slowly and without much volatility (Graph 6d). A heavy series of buy orders did little to move the price. These may have derived from traders covering short positions entered into during the previous phase, or they may represent the rebuilding of inventory by dealers (though an examination of *cumulative* order flow, not shown here, would cast doubt on this).

For an example of a distinct kind of price volatility, consider the trading pattern for the two-year note on the morning of 28 January 2000 (Graph 7). In this case new information - an unexpectedly strong non-farm payroll figure - became instantaneously available to virtually all market participants when the data were released at 08:30. Trading appears to have reflected first the anticipation of, then the accommodation to, this new information, while virtually no trades took place when the announcement was being made. While some position-taking in anticipation of the announcement moved the price somewhat, in the aftermath of the announcement trades tended to have little or no impact on the price, perhaps because participants understood that this represented the squaring of speculative positions and the rebalancing of portfolios. Trading volume was much higher after the announcement than before, as can be seen in the shorter time intervals between the times indicated on the x-axis (which are spaced 50 ticks apart). This pattern of the adjustment of Treasury prices to information releases conforms to similar findings by Fleming and Remolona (1999) and Huang et al (2001).

3.3 VAR analysis

Graphs 8a-8d illustrate estimations of the cumulative effects of returns and signed trades on one another, and of returns on subsequent returns, when the VAR in equation (1) is applied to prices and trades recorded for the two-year note on 3 February 2000. Because there are fewer data points, five lags are used in each equation instead of 10. Cross-effects between trades and returns seem to have been stronger on 3 February than they were during the full two-year sample period. The impact of trades on returns was about twice as strong on 3 February as it was during the full sample, with a new buy order leading, on average, to an increase of 2.23 hundredths of a percentage point return (Graph 8b). The effect of returns on trades is also substantially higher than normal on 3 February: a one standard deviation positive return now leads to a 3.8% increase in the likelihood of a purchase after 10 periods, more than three times the effect estimated for the sample as a whole (Graph 8c). However, the effects of the variables on themselves - the persistence of shocks to returns and the positive feedback of trades - were weaker. Only 69% of an increase in the return remains in the bond price 10 periods later, compared with 81% for the sample as a whole (Graph 8a). A new buy order is followed by an additional 0.57 of a net buy over subsequent periods, in contrast to the usual effect of 0.74 (Graph 8d).

These patterns shifted in the course of the day. During the most turbulent period, 11:00-14:00, trades had a relatively stronger effect on returns and were relatively more persistent than was the case either before 07:00 or after 14:00. In the 07:00-11:00 and 11:00-14:00 periods, returns had strong positive effects on the direction of trades, while after 14:00 this relationship became negative. The effects of returns on subsequent returns were more or less the same as for the full sample, and did not change much during the day. The persistence of returns did not alter very much throughout 3 February.

3.4 Trading in volatile conditions: a summary

Combining the evidence from the duration-based subsamples and from 3 February 2000, it appears that the interactions between price movements and trade behaviour change in at least two ways at times when trading is volatile and uncertainty is high. First, the impact of trades on price movements (the conventional adverse selection effect) is stronger. Second, however, effects in the other direction - from price movements to trades - become stronger as well. It is also clear that markets can sometimes shift suddenly from one regime to another in terms of the absolute and relative strengths of these different effects. In the case of 3 February 2000, for example, it appears that positive feedback effects diminished substantially as price movements stabilised in the afternoon, and information-driven price dynamics were replaced with a greater role for inventory adjustments.

4. Discussion

The results presented in Sections 2 and 3 suggest that the traditional approach to market microstructure, which is focused on the ways in which information gets incorporated into market prices through order flow, needs to be augmented by a deeper understanding of the strategic interactions among market participants.

When market participants pursue their individual goals in the face of uncertainty in the market, there are several ways in which they may affect each others' interests. As well as the direct interaction between the two counterparties to a transaction, there are other indirect interactions that occur through the impact of trades on price and other characteristics of the market. These interactions affect the incentives of market participants, and may also have a direct bearing on their payoffs, and hence their conduct in the market.

Take the example of a market in which two traders face a market-maker who attempts to smooth his inventory position across trades. When the market-maker receives a sell order from one of the traders, he may subsequently set a price that is relatively low in order to attract a buy order from the other trader. The trader who then purchases at this low price has benefited from the sell order from the first trader, even though the interaction is indirect, through the market-maker. This example is one where the actions of the two traders are *offsetting* in the sense that a sale by the first leads to a purchase by the second. The larger the sale, the greater is the incentive to buy, and vice versa. When viewed over the two trading periods, the actions of the two traders can be seen as *strategic substitutes*, in which the greater incidence of one action leads to a greater incentive (via prices) to adopt the reverse action. In terms of price dynamics, the payoff interactions between the two traders have a stabilising effect in which any deviation of price from its fair value elicits a trade that dampens this deviation.

We may contrast this with modes of interaction where traders' actions are mutually reinforcing and short-term fluctuations are amplified. For instance, let us modify the above example so that both traders are portfolio managers whose respective mandates dictate that they engage in portfolio insurance by using trading techniques that replicate a synthetic call option through delta-hedging. This entails selling the asset when its price falls and buying it when its price rises. In this scenario, when the price of the asset falls because of an exogenous shock, both traders will attempt to sell it to the market-maker. But if the market-maker then marks down the price for inventory reasons, the rigid trading rule of both traders dictates a further round of selling, which may feed into even lower prices. This is an instance where the strategic interaction between the traders is *mutually reinforcing*, rather than offsetting. The greater the sale by one trader, the greater is the sale by the other trader. In other words, the actions of the traders are *strategic complements*.

The example of strict portfolio insurance is admittedly extreme, although accounts of the 1987 stock market crash attribute some blame to such practices (see Gennotte and Leland (1990)). More generally, however, mutually reinforcing interactions are characteristic of markets where traders have short decision horizons, or where they operate under external constraints on their decisions. The short horizon may be due to internally imposed trading limits that arise as a response to agency problems within an organisation, or when traders operate under a risk management system which circumscribes their actions. In those markets where traders are highly leveraged, the short horizon can be attributed to bankruptcy constraints, which may require positions to be sold for cash when net asset values are low or when a margin call dictates liquidation of trading positions.

The distinction between stabilising and amplifying interactions between traders suggests an important dimension along which we can classify the interaction between market participants. Mutually reinforcing actions are a distinctive characteristic of markets under stress. We have witnessed its disruptive effects on several occasions in the recent episodes of market distress following the Asian crisis of 1997 and the Russian/LTCM crisis of 1998. Financial commentators, central bankers and other regulators have consequently devoted a great deal of attention to understanding the nature of positive feedback trading and its implications for supervision and policy execution.

In contrast to the concerns expressed by central bankers and other regulators about the effects of feedback trading, the literature on market microstructure has placed relatively little weight on the possible payoff interaction between traders through mutually reinforcing actions.[9] In part, this is explained by the prevailing theoretical approach to microstructure issues, which emphasises the adverse selection problem faced by a market-maker who faces possibly better informed traders. The task of the market-maker is to anticipate his losses to better informed insiders. This is typically done by quoting prices that incorporate an actuarially fair safety margin so that losses to insiders are compensated by gains from uninformed traders. The direction of causality runs from order flows to price changes.

In such an environment, the intensity of trading is related to the arrival rate of new information, although the theory admits a wide variety of empirical manifestations of this process. Easley and O'Hara (1992) propose a framework in which trading activity is positively related to the arrival rate of new information. When information flow is slow, trading activity itself is slow, while when information flow is fast, this is reflected in high trading activity. In this view, a burst of market activity is due to the exogenous arrival of new information. Easley and O'Hara coined the term "event uncertainty" to describe the fluctuations in the arrival rate of new information. The term refers to the uncertainty concerning this exogenous process. In contrast, Lyons (1996) proposes an alternative "hot potato" hypothesis for the foreign exchange market in which dealer inventory adjustment takes centre stage, and hence higher levels of trading activity are associated with lower arrival rates of new information. In both cases, however, the direction of causality runs from order flows to price changes.

The results presented in Sections 2 and 3 above suggest that, while the order flow effect on prices is undoubtedly present and important in the US government securities market, under certain circumstances the direction of causality is reversed, so that price changes influence order flow. The effect seems particularly strong in situations where trading is rapid and volatile.

These features are reminiscent of economic models where agents' actions are mutually reinforcing, such as during currency attacks or bank runs. Such contexts are usually fertile territory for multiple equilibria, where there is more than one set of self-fulfilling beliefs. For instance, in the currency attack context, when the agents believe that a currency peg will fail, their actions in anticipation of this precipitate the crisis itself, while if they believe that a currency is not in danger of imminent attack, their inaction spares the currency from attack, thereby vindicating their initial beliefs. The global game method advocated by Morris and Shin (2000) may be one way to introduce elements of concerted shifts in trading positions as a function of the underlying fundamental. Consider the following sketch of a model of short-term traders who operate in a market with limited liquidity. Traders face the choice of taking a long position in an asset, or taking a short position (both up to some fixed bound). They are assumed to have short horizons, so that their payoffs are determined by the price of the asset at the next date. The traders operate in a market with limited liquidity, in the following sense. When the net demand for the asset among the traders is non-zero, the market clears by means of a residual demand/supply function which is imperfectly elastic. The greater the net demand from the set of traders, the higher is the market-clearing price. Conversely, the greater the net supply, the lower is the market-clearing price.

This framework gives rise to strategic complementarities in which the actions of the traders are mutually reinforcing. If a large proportion of the traders decide to switch from being short to taking a long position, the market-clearing price is raised accordingly, and hence the incentive for any individual trader to take a long position is increased. Conversely, the larger the proportion of the traders who switch to a short position, the lower will be the market-clearing price, and hence the greater is the incentive for an individual trader to take a short position. Notice the importance of the short horizon assumption here, and the absence of players with deep pockets that stand ready to provide an infinitely elastic demand/supply function. The uncertainty in the return from date $t-1$ to date t thus has two components. As well as any exogenous uncertainty in the fundamental value of the

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9 Among the few exceptions is the literature on momentum trading in the stock market. See DeLong et al (1990), Grinblatt et al (1995) and Jegadeesh and Titman (1993).

asset, there is the endogenous price response arising from the trading decisions of the traders themselves and the imperfectly elastic residual demand/supply function. When each trader has a noisy signal concerning the exogenous uncertainty, the traders follow a switching strategy around a threshold point for the signal realisation in which a trader goes long if his signal lies above this threshold, but goes short if it lies below it.

One consequence of this equilibrium is that the short-run demand curve for the asset is upward-sloping. The traders buy the asset when the fundamentals are good, which is precisely when the fundamental value of the asset is high. But the traders' actions exacerbate the price response, sending the price higher. This price response validates the action to buy. In terms of the observables, this equilibrium entails that the traders tend to buy the asset (or keep to a long position) precisely when the price of the asset is high. Conversely, if the fundamentals are bad, the traders as a group tend to sell the asset, which brings about a low price for the asset. The demand curve for the group as a whole is therefore upward-sloping.

Since the degree of strategic interaction depends on the initial holdings of the traders, so will the return density. The price response seen for 3 February 2000 may be better understood by reference to the fact that many active traders had short positions on US Treasury securities before the Federal Reserve's announcement.

The "Duke of York" price pattern for the trading on 3 February 2000 is suggestive of the following scenario. An initial frenzy of buying is triggered when the traders are caught short in a rising market. The exaggerated price response pushes the price up to a sharp peak at around 12:30, by which time we may conjecture that some of the net short positions of the traders had been unwound, and some may have taken on long positions. The unwinding of the net short positions reduces the probability of continued upward movement in prices. The actual price response in the afternoon of 3 February is sharply downwards, reversing much of the price increase seen in the morning. The market recovers some of its composure by 14:00, from which time the market trades in relatively tranquil mode until the close.

We believe this line of investigation may yield theoretical models that do a better job of capturing strategic notions such as overhangs of leveraged positions, short-covering and the like.

5. Conclusions

We have found that the interactions between trades and quote changes in the US Treasury securities market tend to change in important ways when trading conditions are volatile. The impact of trades on prices tends to become stronger, confirming a common theoretical result in the market microstructure literature. The impact of prices on trades tends to change as well on more volatile days, generally in a positive direction. As a consequence of these two effects, price changes tend to be more highly autocorrelated on days when conditions are more volatile. This pattern can be seen for the two-year, five-year and 10-year on-the-run Treasury notes over the period January 1999-December 2000. It also emerges from a close analysis of quotes and trades from 3 February 2000, which was a particularly volatile trading day during this period.

The models commonly used in the analysis of market microstructure emphasise adverse selection effects resulting from the present of informed and uninformed traders in the market. This helps to explain the impact of trades on prices, but a richer theoretical approach is necessary to capture the impact of prices on trades. Such effects might come out of a model where traders face uncertainty, not just about the fundamental value of an asset, but also about the precision of the signals observed by them and by other traders. In such an environment, a price movement in a given direction could lead a trader to revalue the asset in the same direction, at least for a short period of time. This would lead to positive feedback in trading behaviour and, as a result, in returns over short horizons.

Tables

Table 1a

Statistics on returns, trades and trading volumes (1999-2000)

	Two-year	**Five-year**	**10-year**
Number of observations	358,361	494,437	506,880
of which:			
% trades only	*39.7*	*22.5*	*18.9*
% quote changes only	*49.5*	*64.7*	*70.9*
% trades and quote changes	*10.8*	*12.8*	*10.2*
Tick-by-tick returns[1]			
Mean	-1.29×10^{-6}	-1.50×10^{-6}	-2.19×10^{-6}
Mean abs value	0.000090	0.000209	0.000394
Std deviation	0.000205	0.000436	0.000824
Daily returns			
Mean	3.68×10^{-6}	7.07×10^{-7}	-7.20×10^{-6}
Mean abs value	0.000667	0.001750	0.003065
Std deviation	0.000882	0.002325	0.004017
Trades			
Number of trades	180,967	174,406	147,546
% buys	52.9	51.1	50.6
Volume per trade ($m)			
Mean	12.96	7.28	5.45
Std deviation	22.65	9.03	7.41
Trading days	501	501	501
Transactions per day	361.21	348.12	294.50
Volume per day ($m)	4,622	2,534	1,604
Time between ticks (minutes)			
Full sample	0.98	0.76	0.74
High duration days (top 50)	1.96	1.93	1.81
Low duration days (bottom 50)	0.67	0.48	0.51
Low trading range days (bottom 50)	1.53	1.00	0.93
High trading range days (top 50)	0.73	0.59	0.61
Low volatility days (bottom 50)	1.18	1.15	1.06
High volatility days (top 50)	0.78	0.62	0.62

[1] Log change in midpoint between bid and ask quotes.

Table 1b

Correlations among daily price range, price change, volatility and average duration: two-year note

	Price range	Volatility	Price change[1]
Duration[2]	– 0.443	– 0.211	– 0.257
Price range[3]		0.654	0.717
Volatility[4]			0.323

[1] Difference between daily closing and opening prices. [2] Daily average time between observations, in minutes. [3] Difference between daily high and low prices. [4] Daily standard deviation of tick-by-tick returns.

Table 2

Vector autoregression results: signed trades
Two-year, full sample

This table gives the estimated coefficients from the following vector autoregression:

$$r_t = \sum_{i=1}^{10} \alpha_i r_{t-i} + \sum_{i=0}^{10} \beta_i x_{t-i} + \varepsilon_{1,t}$$

$$x_t = \sum_{i=1}^{10} \gamma_i r_{t-i} + \sum_{i=1}^{10} \delta_i x_{t-i} + \varepsilon_{2,t}$$

r_t is defined as the change from *t-1* to *t* in the log of the midpoint between the prevailing bid and ask quotes, divided by the time (in minutes) between observations. The variable x_t takes the value one for a buyer-initiated trade, minus one for a seller-initiated trade and zero for a quote revision without a trade. The VAR is estimated over the period from 4 January 1999 to 29 December 2000, and includes only the transactions and quote changes taking place between 07:00 and 17:00. On each day, the estimation starts with the eleventh observation after 07:00.

[a] Coefficient estimates for the r_t equation are multiplied by 100,000.

	Dept variable: r_t		Dept variable: x_t	
	Coef	**t-stat**	**Coef**	**t-stat**
Lags of r_t				
1	– 0.228	– 8.85	– 10.692	– 2.34
2	– 0.070	– 5.93	24.111	4.52
3	– 0.019	– 2.29	16.445	3.15
4	0.024	2.65	5.173	1.01
5	0.016	2.24	– 0.828	– 0.15
6	0.011	1.61	– 4.384	– 0.80
7	0.011	1.64	– 1.658	– 0.31
8	0.022	1.49	3.178	0.59
9	0.007	0.97	1.814	0.32
10	0.001	0.17	7.368	1.33
Lags of x_t[a]				
0	1.355	45.00		
1	4.029	70.58	0.260	164.32
2	2.190	19.23	0.115	64.16
3	0.625	7.86	0.026	14.64
4	0.196	3.00	0.007	3.86
5	– 0.130	– 2.04	– 0.001	– 0.67
6	– 0.244	– 4.00	0.002	1.03
7	– 0.195	– 3.38	0.003	1.72
8	– 0.157	– 2.58	0.005	2.78
9	0.023	0.29	0.003	1.80
10	– 0.039	– 0.55	0.003	1.55
$\overline{R}^2$	0.08			

Table 2 (cont)

Five-year, full sample

	Dept variable: r_t		Dept variable: x_t	
	Coef	**t-stat**	**Coef**	**t-stat**
Lags of r_t				
1	– 0.283	– 24.66	17.078	10.30
2	– 0.087	– 8.95	5.797	3.11
3	– 0.029	– 3.45	13.028	6.98
4	0.007	0.72	10.600	5.56
5	0.005	0.91	8.084	4.15
6	0.021	4.13	8.309	4.33
7	0.008	1.98	0.111	0.06
8	0.016	4.25	1.525	0.79
9	0.012	3.68	– 0.529	– 0.27
10	0.008	2.40	1.162	0.63
Lags of x_t[a]				
0	7.452	110.26		
1	7.866	61.82	0.166	124.66
2	4.918	32.95	0.107	71.08
3	1.944	13.08	0.049	31.68
4	0.652	4.24	0.021	13.93
5	0.198	1.41	0.009	5.84
6	– 0.192	– 1.52	0.001	0.95
7	– 0.141	– 1.23	0.003	1.69
8	– 0.254	– 2.30	0.003	1.93
9	– 0.037	– 0.35	0.002	1.58
10	– 0.101	– 0.97	0.003	2.28
$\overline{R}^2$	0.10		0.06	

[a] Coefficient estimates for the r_t equation are multiplied by 100,000.

Table 2 (cont)

10-year, full sample

	Dept variable: r_t		Dept variable: x_t	
	Coef	**t-stat**	**Coef**	**t-stat**
Lags of r_t				
1	– 0.279	– 23.95	2.232	2.92
2	– 0.107	– 10.64	– 7.714	– 9.34
3	– 0.069	– 9.62	– 3.833	– 4.44
4	– 0.027	– 4.89	– 1.992	– 2.22
5	– 0.012	– 2.37	– 1.724	– 1.94
6	– 0.003	– 0.56	– 1.494	– 1.64
7	– 0.001	– 0.24	– 0.942	– 1.04
8	0.002	0.60	– 0.311	– 0.34
9	0.004	0.84	– 0.514	– 0.56
10	0.009	2.46	– 0.238	– 0.27
Lags of x_t[a]				
0	13.003	104.39		
1	15.125	61.18	0.130	100.35
2	9.359	34.68	0.079	53.03
3	5.382	19.70	0.035	22.57
4	2.812	11.19	0.014	8.91
5	1.109	4.61	0.005	3.48
6	0.758	3.32	0.004	2.33
7	0.076	0.34	0.003	2.14
8	0.001	0.00	0.004	2.89
9	– 0.016	– 0.07	0.004	2.78
10	0.088	0.40	0.004	2.57
$\bar{R}^2$	0.09		0.03	

[a] Coefficient estimates for the r_t equation are multiplied by 100,000.

Table 3

Vector autoregression results: signed order flow
Two-year, full sample

This table gives the estimated coefficients from the following vector autoregression:

$$r_t = \sum_{i=1}^{10} \alpha_i r_{t-i} + \sum_{i=0}^{10} \beta_i v_{t-i} + \varepsilon_{1,t}$$

$$v_t = \sum_{i=1}^{10} \gamma_i r_{t-i} + \sum_{i=1}^{10} \delta_i v_{t-i} + \varepsilon_{2,t}$$

r_t is defined as the change from *t-1* to *t* in the log of the midpoint between the prevailing bid and ask quotes. The variable v_t is the size of the trade in millions of dollars, multiplied by the directional indicator x_t defined above. The VAR is estimated over the period from 4 January 1999 to 29 December 2000, and includes only the transactions and quote changes taking place between 07:00 and 17:00. On each day, the estimation starts with the eleventh observation after 07:00.

[a] Coefficient estimates for the r_t equation are multiplied by 100,000.

	Dept variable: r_t		**Dept variable: v_t**	
	Coef	**t-stat**	**Coef**	**t-stat**
Lags of r_t				
1	– 0.202	– 7.93	793.723	4.89
2	– 0.050	– 4.52	877.265	4.49
3	– 0.006	– 0.76	306.628	1.39
4	0.031	3.65	– 102.586	– 0.51
5	0.018	2.72	107.892	0.59
6	0.011	1.72	– 108.072	– 0.58
7	0.010	1.61	36.596	0.19
8	0.021	1.57	90.123	0.56
9	0.007	1.00	245.149	1.44
10	0.001	0.12	211.914	1.40
Lags of v_t[a]				
0	0.050	15.18		
1	0.068	15.56	0.053	2.43
2	0.048	12.87	0.075	5.71
3	0.020	7.43	0.043	2.51
4	0.004	1.93	0.075	3.64
5	– 0.004	– 1.08	0.002	0.13
6	– 0.012	– 3.32	0.017	1.05
7	– 0.006	– 2.13	0.009	0.52
8	– 0.007	– 3.28	0.015	0.82
9	– 0.005	– 1.64	0.007	0.41
10	– 0.001	– 0.33	– 0.006	– 0.50
$\overline{R}^2$	0.05		0.02	

Table 3 (cont)

Five-year, full sample

	Dept variable: r_t		Dept variable: v_t	
	Coef	**t-stat**	**Coef**	**t-stat**
Lags of r_t				
1	– 0.261	– 23.06	370.143	18.32
2	– 0.068	– 7.18	355.989	16.75
3	– 0.016	– 2.00	324.818	15.09
4	0.015	1.71	231.494	10.67
5	0.010	1.78	161.104	7.19
6	0.023	4.91	120.218	5.66
7	0.008	2.30	62.606	2.83
8	0.016	4.50	60.668	2.89
9	0.012	3.62	50.043	1.75
10	0.007	2.26	24.166	1.16
Lags of v_t[a]				
0	0.410	41.53		
1	0.410	34.24	0.082	32.69
2	0.279	23.88	0.055	26.23
3	0.138	13.46	0.034	17.98
4	0.051	5.19	0.019	9.04
5	0.027	2.83	0.009	4.76
6	– 0.008	– 0.79	0.004	2.32
7	0.003	0.31	0.007	4.43
8	– 0.024	– 2.78	0.002	1.43
9	– 0.002	– 0.26	0.005	2.77
10	0.002	0.26	0.001	0.47
$\overline{R}^2$	0.07		0.02	

[a] Coefficient estimates for the r_t equation are multiplied by 100,000.

Table 3 (cont)

10-year, full sample

	Dept variable: r_t		Dept variable: v_t	
	Coef	**t-stat**	**Coef**	**t-stat**
Lags of r_t				
1	– 0.260	– 22.61	61.921	10.12
2	– 0.090	– 9.13	32.092	4.85
3	– 0.057	– 8.35	40.767	5.51
4	– 0.020	– 3.73	38.354	5.41
5	– 0.008	– 1.63	28.502	4.08
6	– 0.001	– 0.15	19.427	2.17
7	0.000	– 0.09	13.393	1.80
8	0.003	0.63	17.261	2.30
9	0.003	0.80	17.918	2.43
10	0.009	2.38	20.015	2.80
Lags of v_t[a]				
0	0.937	28.82		
1	0.792	22.82	0.054	18.76
2	0.575	19.10	0.045	18.74
3	0.367	14.52	0.030	13.05
4	0.177	8.28	0.016	6.10
5	0.036	1.72	0.009	5.06
6	0.053	2.56	0.005	2.17
7	– 0.033	– 1.64	0.006	3.25
8	0.014	0.68	0.007	3.48
9	– 0.004	– 0.22	0.004	2.18
10	0.031	1.58	0.007	2.61
$\overline{R}^2$	0.07		0.01	

[a] Coefficient estimates for the r_t equation are multiplied by 100,000.

Table 4

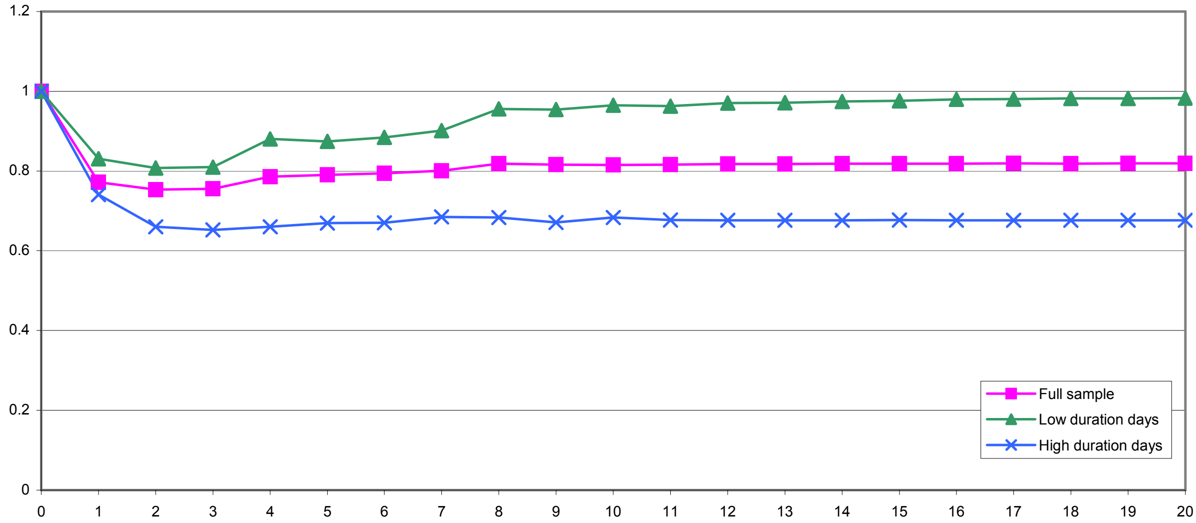
Trading epochs for the two-year note on 3 February 2000

	Price change	% buys	Mean bid-ask spread[1]
07:00-11:00	0.063	52.6	0.0097
11:00-12:15	0.340	65.9	0.0102
12:15-14:00	– 0.316	40.9	0.0181
14:00-17:00	0.090	66.7	0.0120
Memo item: Full sample (1/99-12/00)	0.067[2]	52.9	0.0065

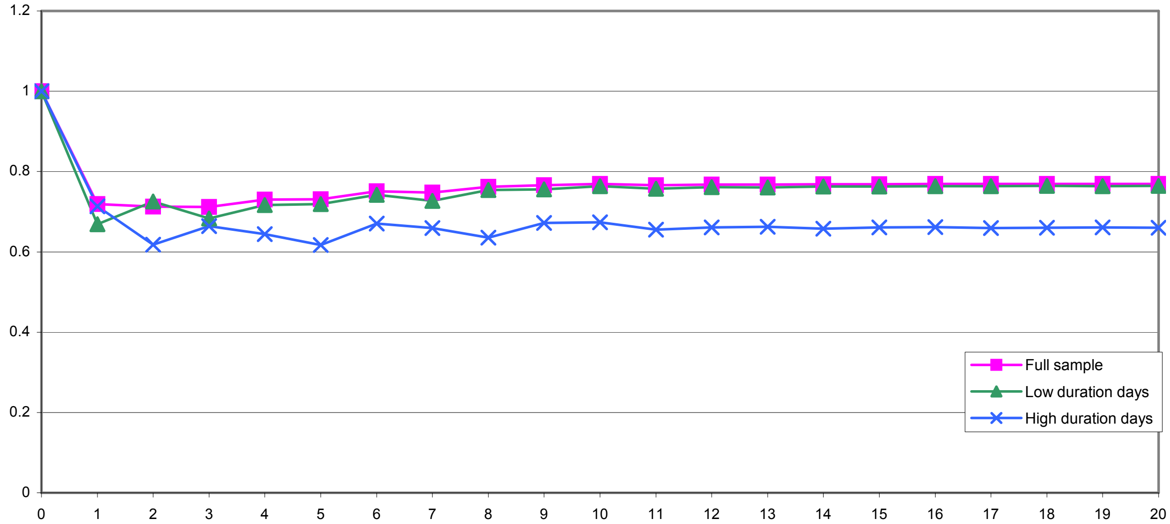
[1] Difference between prevailing ask and bid prices. [2] Average of absolute values of daily price changes.

Graphs

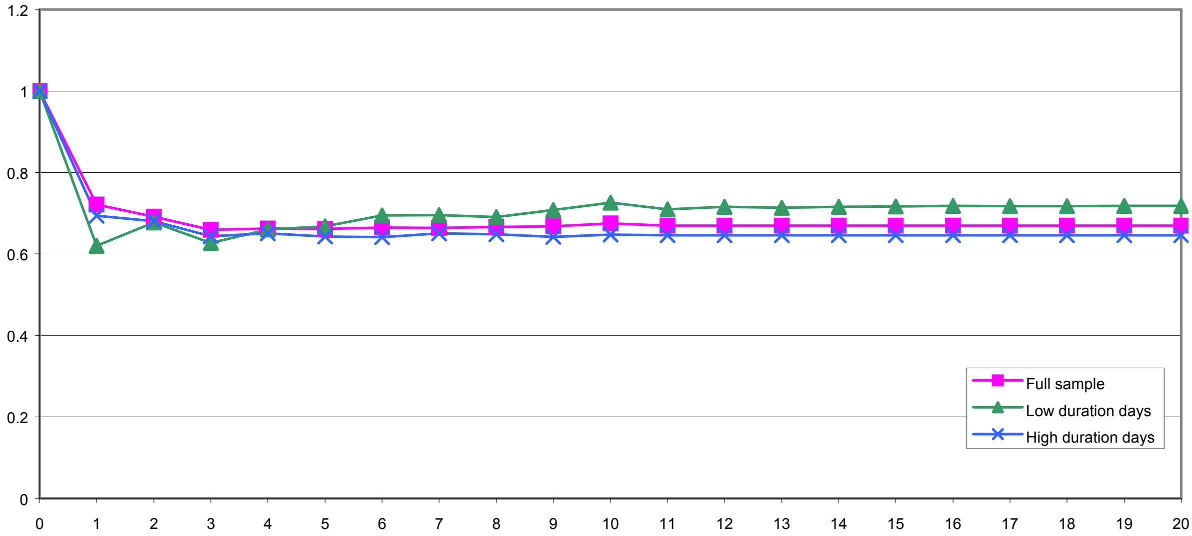
Graph 1a
Cumulative effect on net returns of an additional one unit return: two-year note



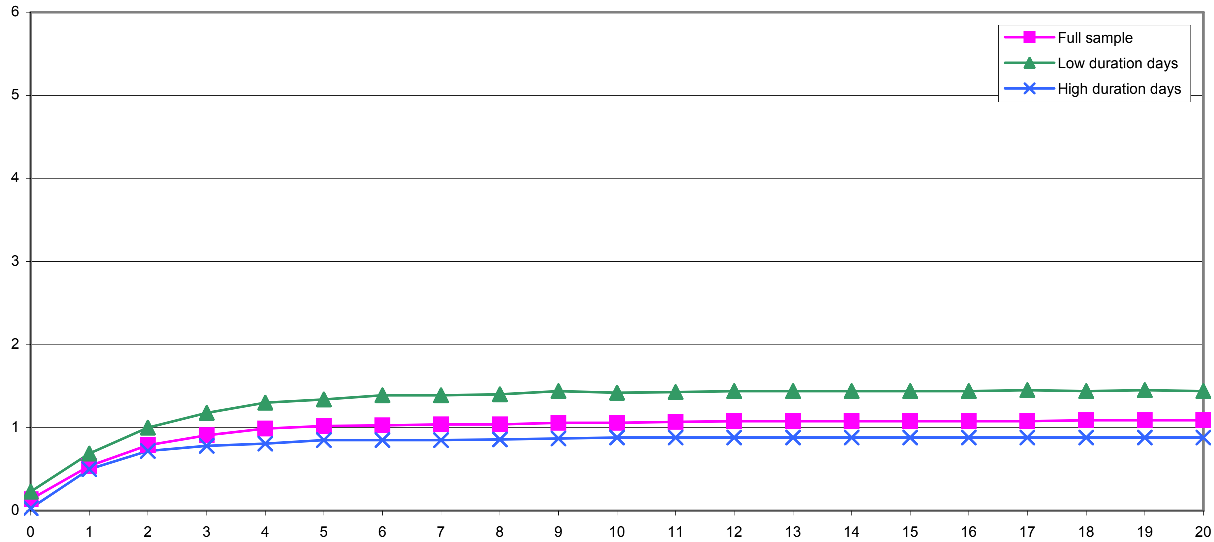
Graph 1b
Cumulative effect on net returns of an additional one unit return: five-year note



Graph 1c
Cumulative effect on net returns of an additional one unit return: 10-year note



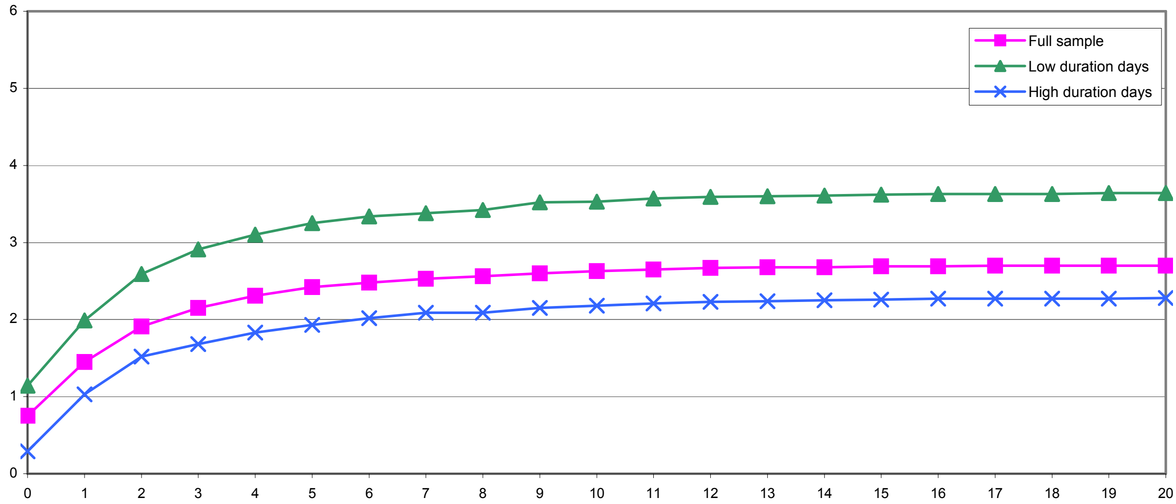
Graph 2a
Cumulative effect on return of an additional net buy: two-year note



Note: Return figures multiplied by 10,000.

Graph 2b

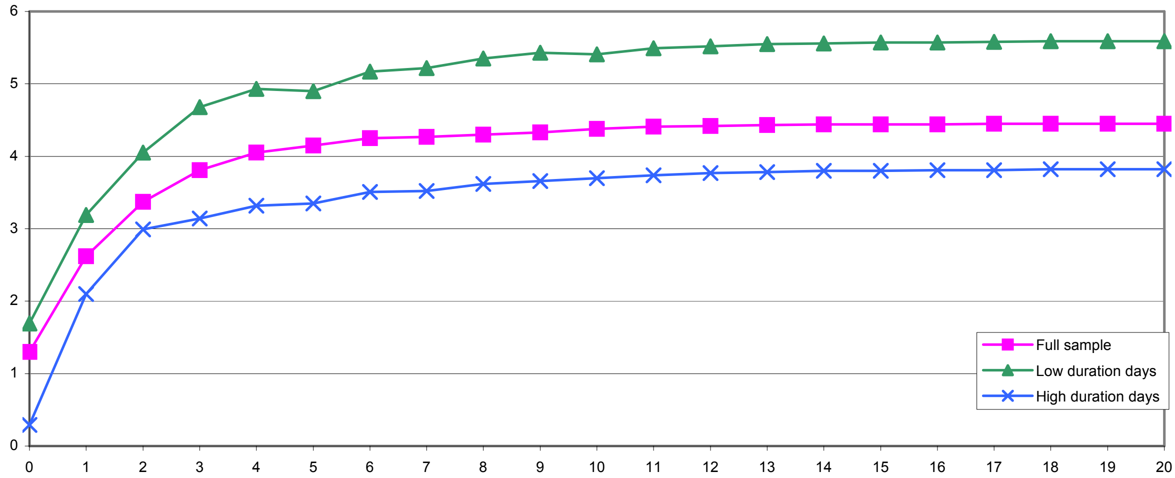
Cumulative effect on return of an additional net buy: five-year note



Note: Return figures multiplied by 10,000.

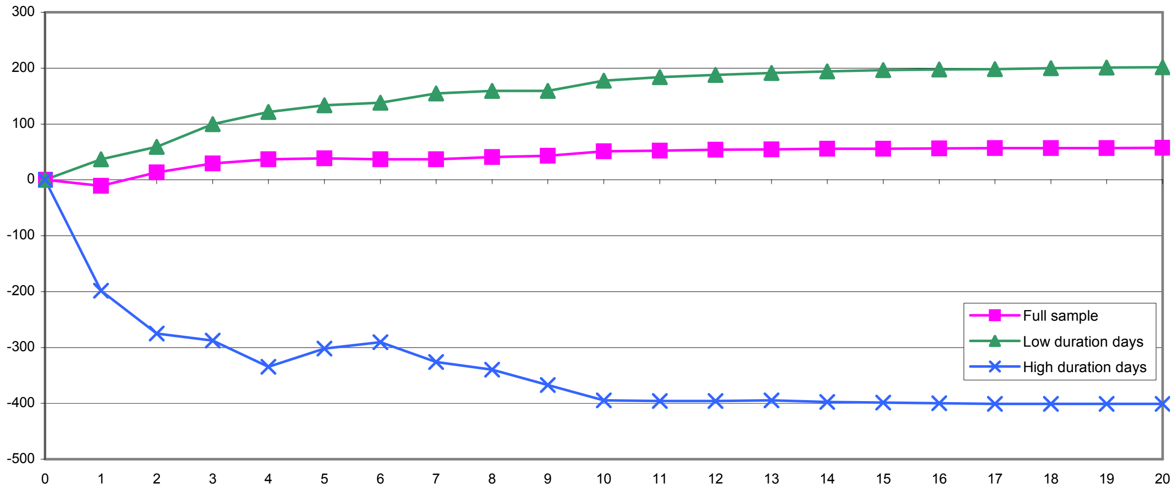
Graph 2c

Cumulative effect on return of an additional net buy: 10-year note

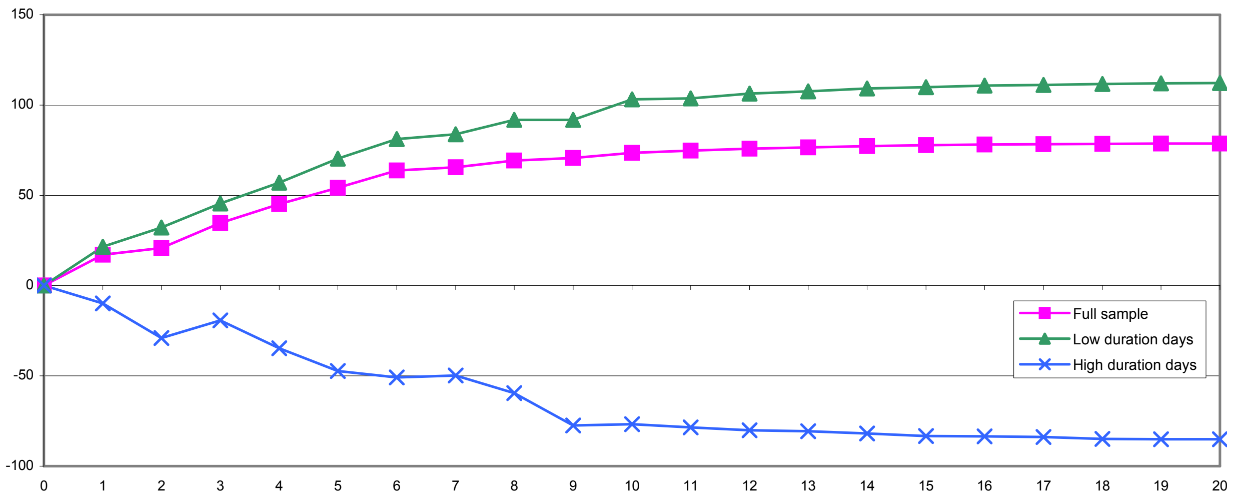


Note: Return figures multiplied by 10,000.

Graph 3a
Cumulative effect on net buys of an additional one unit return: two-year note

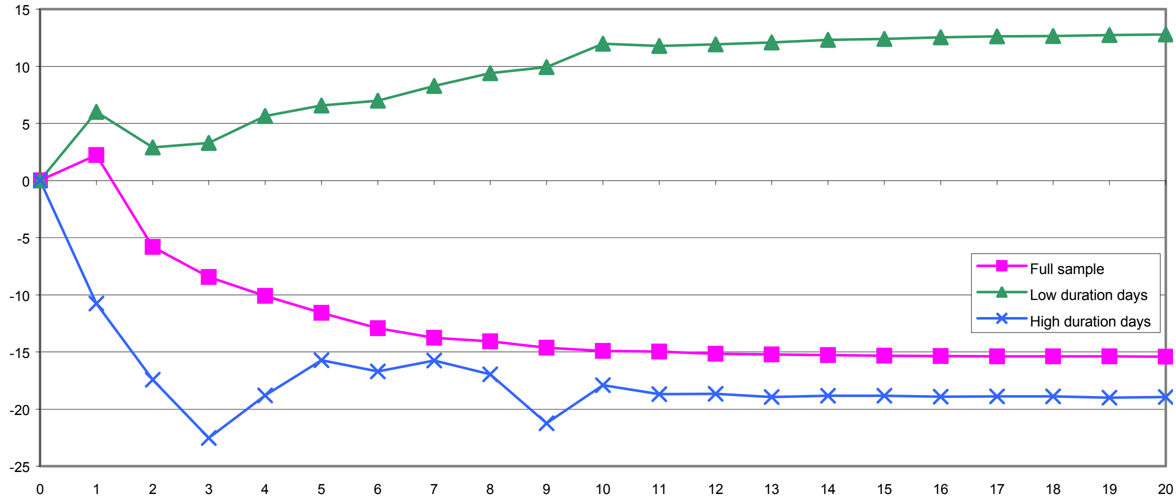


Graph 3b
Cumulative effect on net buys of an additional one unit return: five-year note



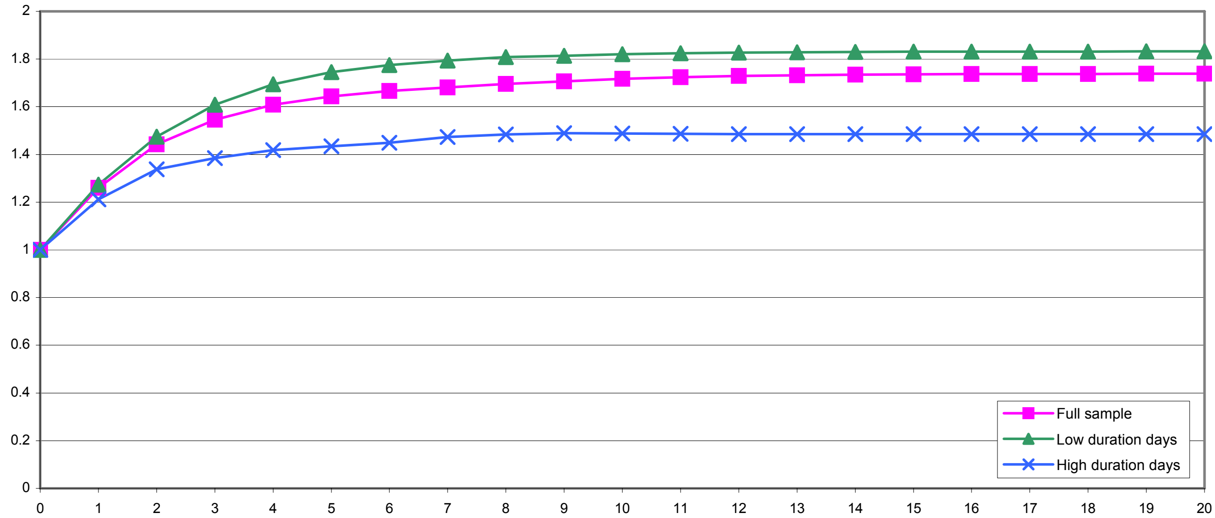
Graph 3c

Cumulative effect on net buys of an additional one unit return:
10-year note



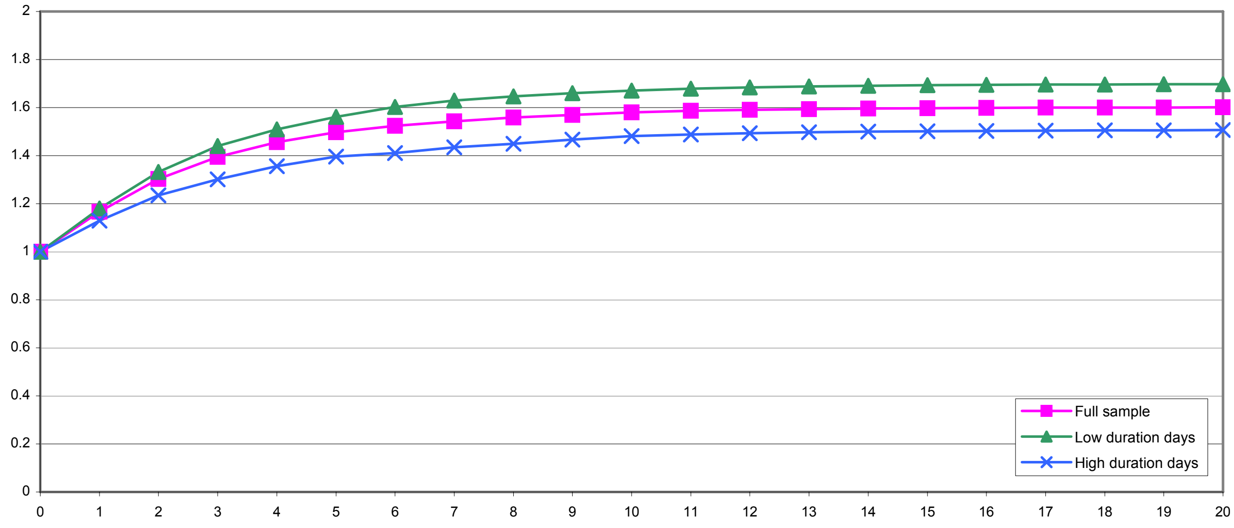
Graph 4a

Cumulative effect on net buys of an additional net buy:
two-year note



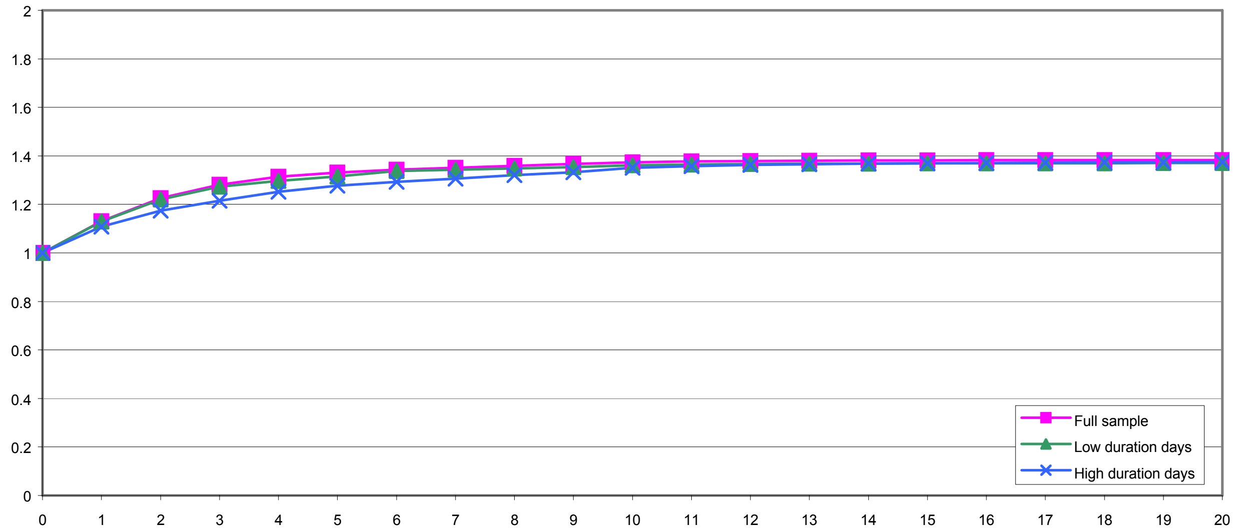
Graph 4b

Cumulative effect on net buys of an additional net buy: five-year note



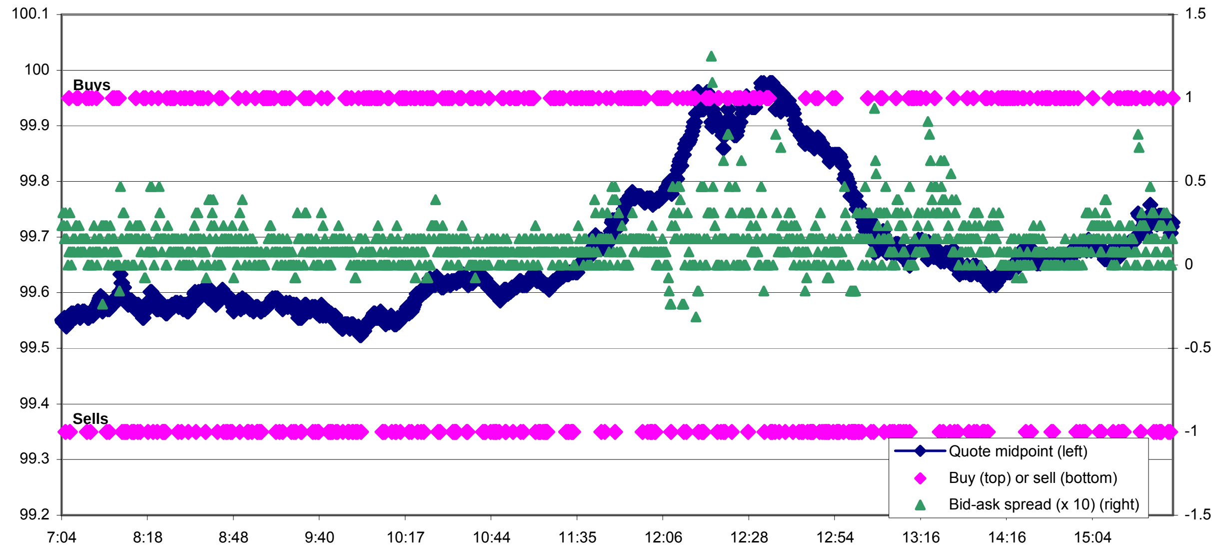
Graph 4c

Cumulative effect on net buys of an additional net buy: 10-year note



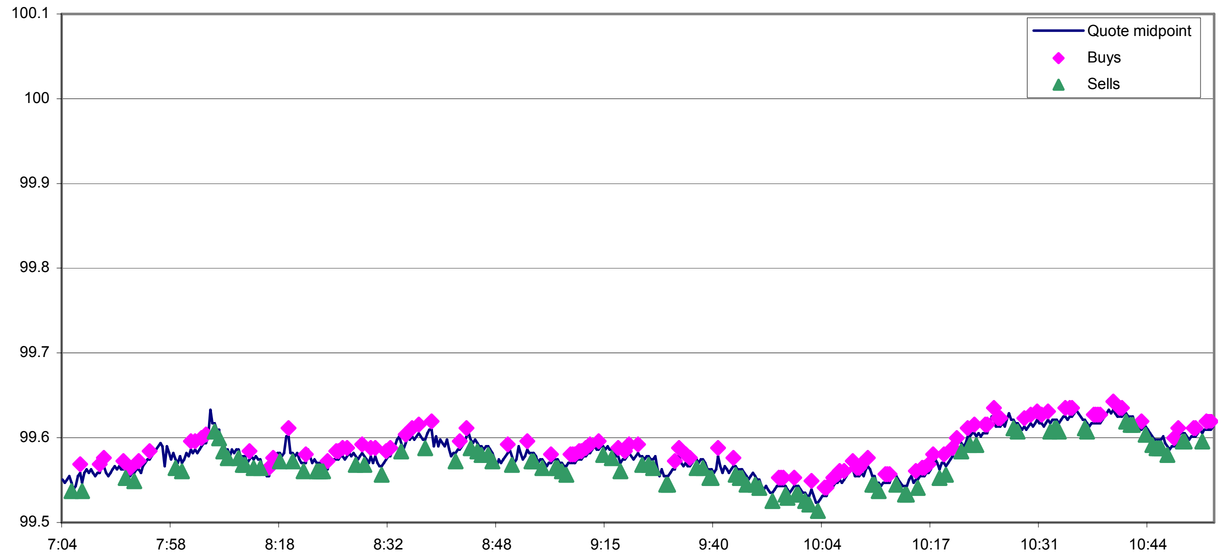
Graph 5

Quotes, trades and bid-ask spreads for the two-year Treasury note
3 February 2000



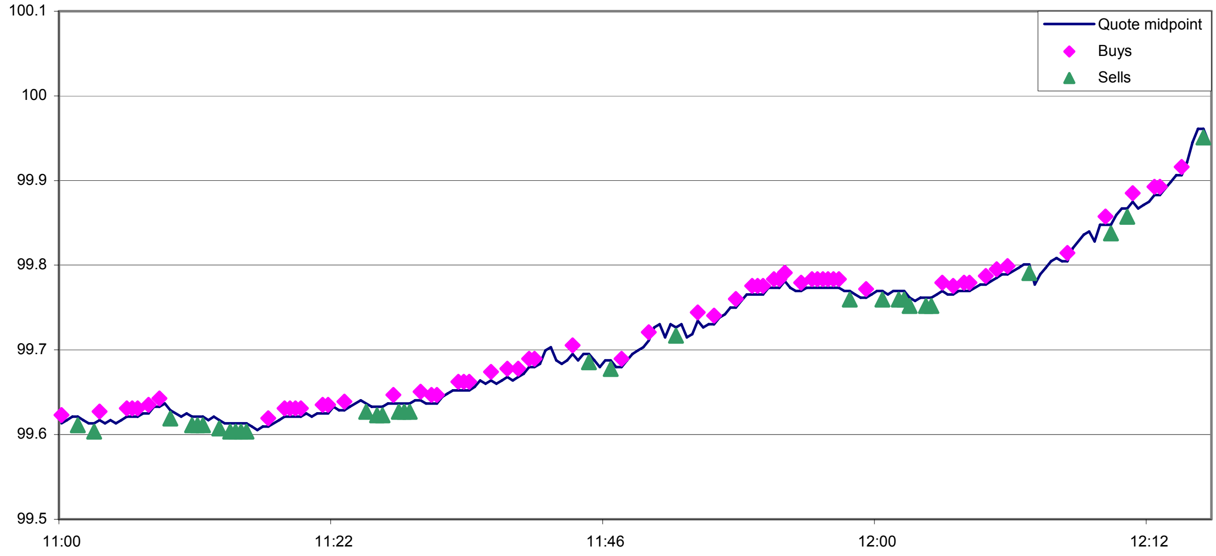
Graph 6a

Quotes and transactions in the two-year note:
3 February 2000, 07:00-11:00



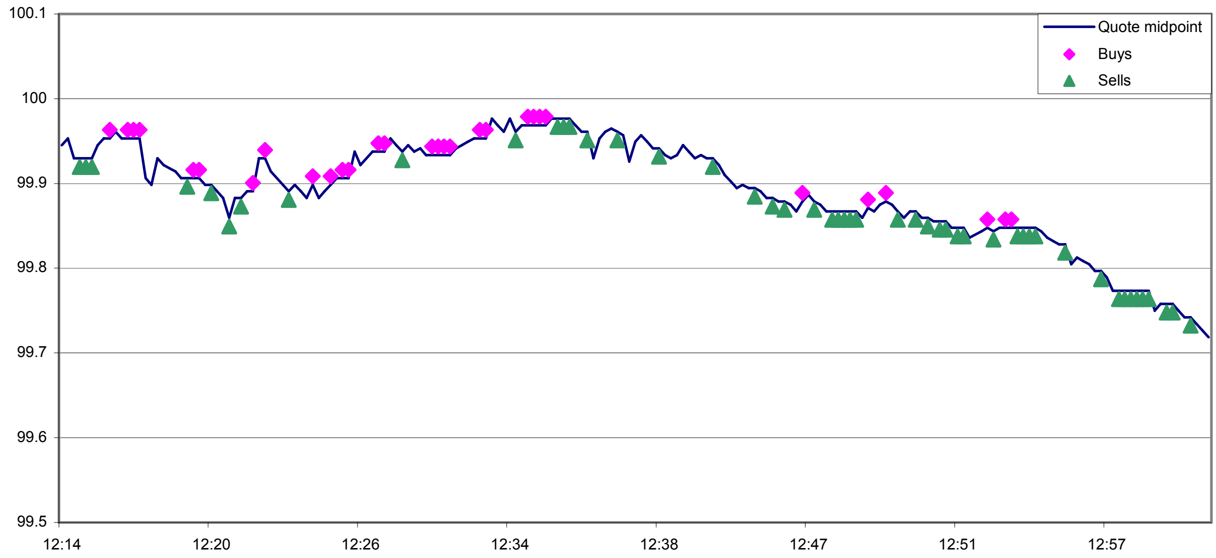
Graph 6b

Quotes and transactions in the two-year note:
3 February 2000, 11:00-12:15



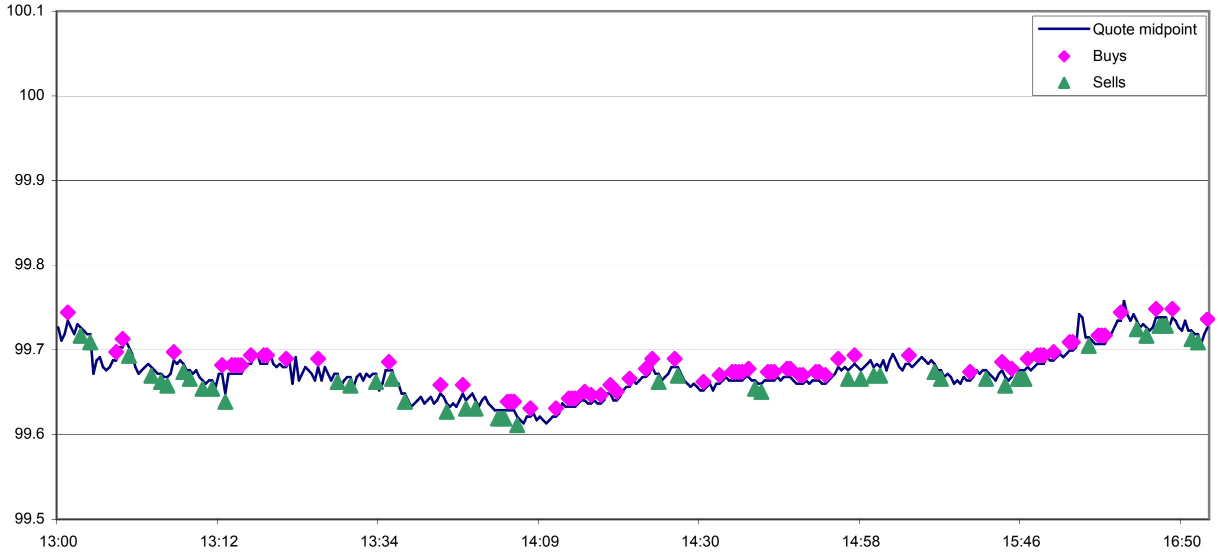
Graph 6c

Quotes and transactions in the two-year note:
3 February 2000, 12:15-13:00



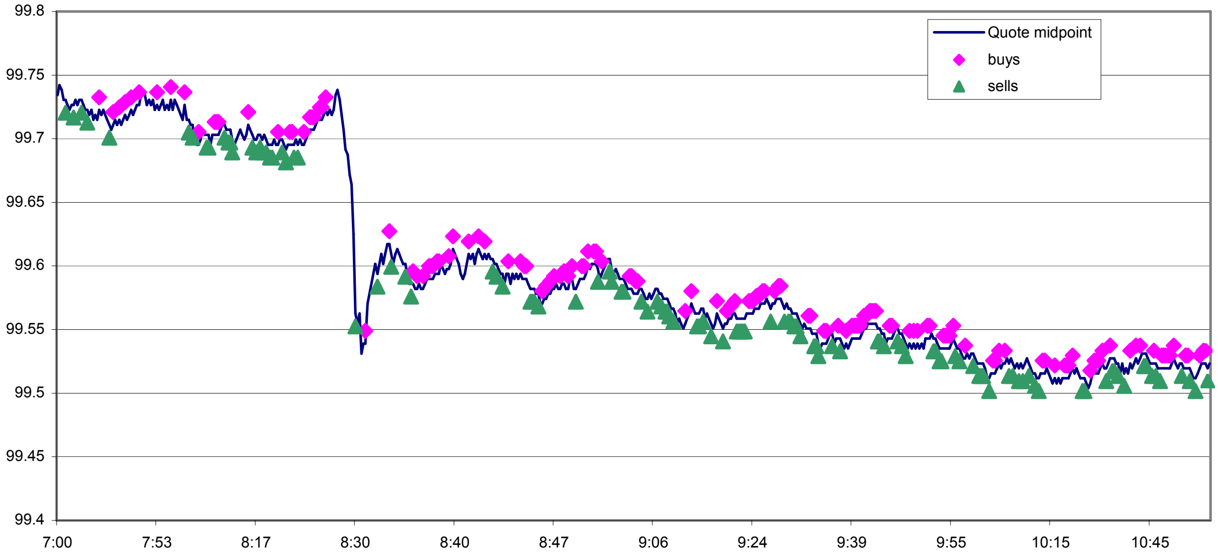
Graph 6d

Quotes and transactions in the two-year note:
3 February 2000, 13:00-17:00



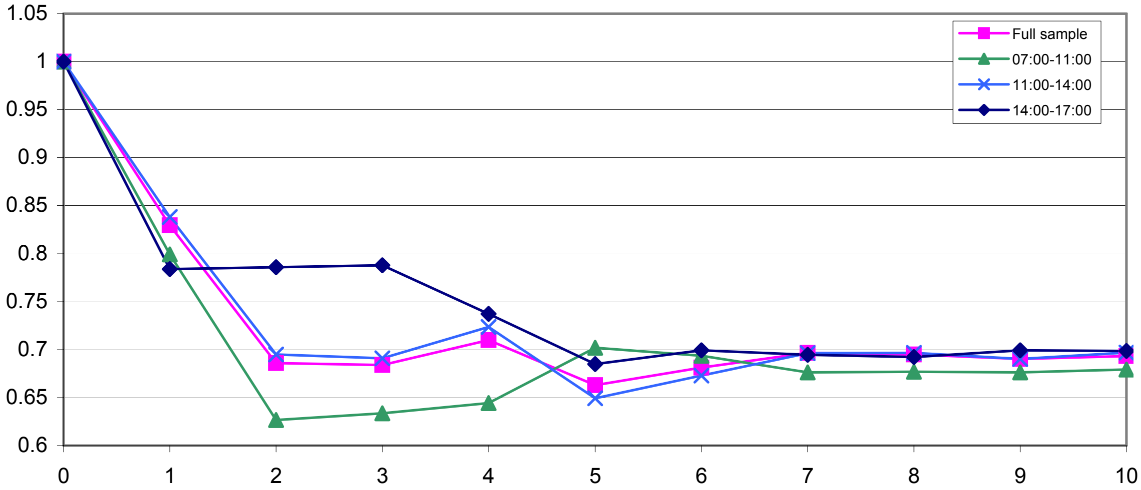
Graph 7

Quotes and transactions in the two-year note:
28 January 2000, 07:00-11:00



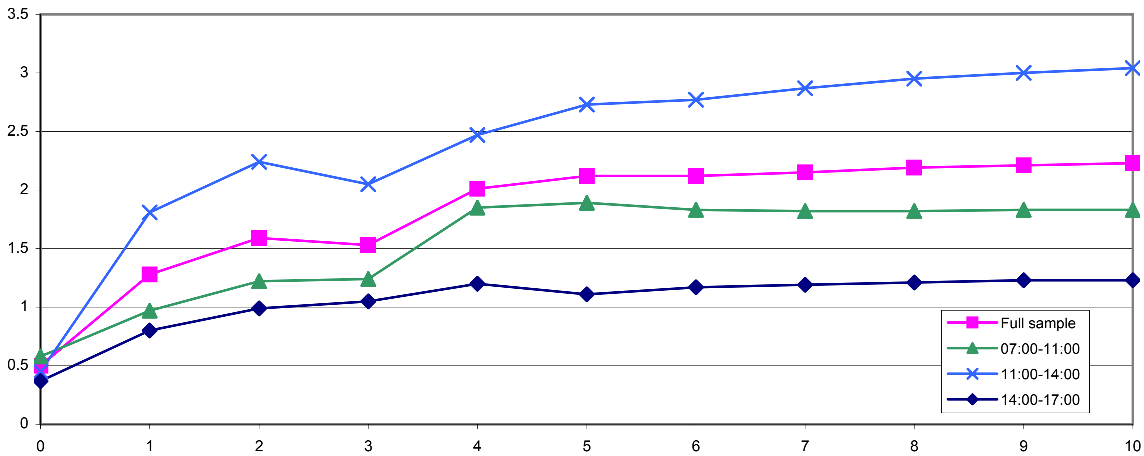
Graph 8a

Cumulative effect on net returns of an additional one unit return: two-year note, 3 February 2000



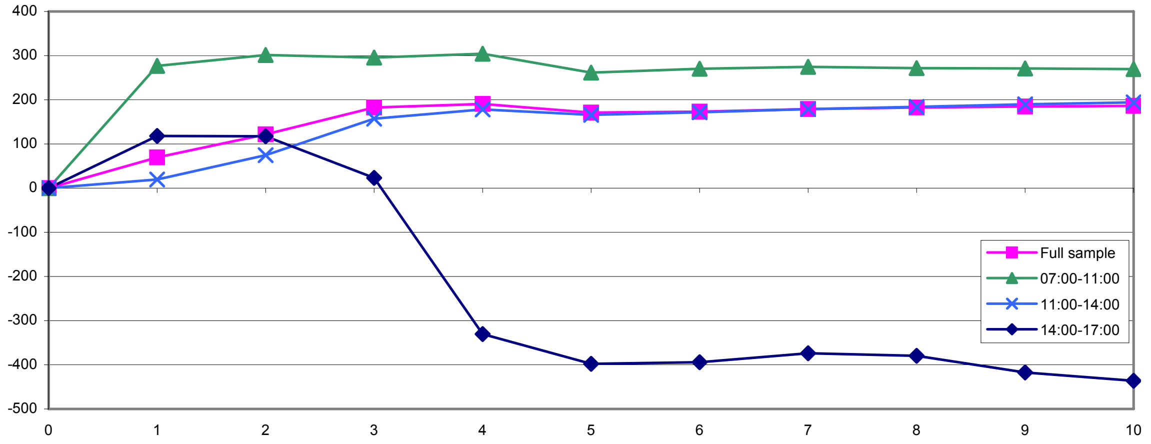
Graph 8b

Cumulative effect on return of an additional net buy: two-year note, 3 February 2000

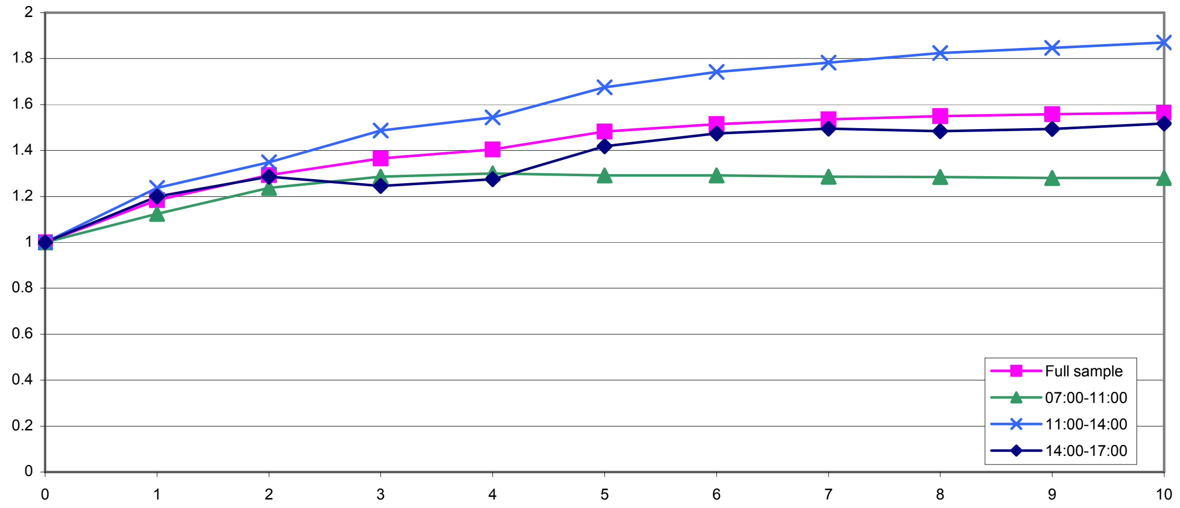


Note: Return figures multiplied by 10,000.

Graph 8c
Cumulative effect on net buys of an additional one unit return: two-year note, 3 February 2000



Graph 8d
Cumulative effect on net buys of an additional net buy: two-year note, 3 February 2000



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The determinants of credit spread changes in the euro area

Michael Boss[1] and Martin Scheicher[2]
Austrian National Bank

1. Introduction

In recent years investors, central bankers, regulators and academics have been studying the markets in default-risky instruments such as corporate bonds, loans or credit derivatives with growing attention. The interest in credit products has increased for a number of reasons. First, credit markets are representative of important structural developments in financial markets. In the United States the shrinking supply of government bonds due to the fiscal surplus has motivated investors to consider alternative assets among fixed income products. In Europe the process of monetary union has increased the pace of integration in the capital markets. Credit markets in the euro area have grown quickly, as the increasing euro-denominated issuance by non-sovereign borrowers indicates. These developments have widened the investment universe and therefore reinforced the importance of analysing corporate bond markets. Furthermore, the changing regulatory framework and the development of new products have generally strengthened the focus on modelling default-risky assets. In particular, the ongoing Basel II process and the rapid development of credit derivatives have motivated researchers to undertake theoretical as well as empirical work on instruments with credit risk.

For a central bank, there are three perspectives on credit markets, based on its activities in setting monetary policy, conserving financial stability and asset management. In the context of monetary stability, credits are studied due to their role in the transmission mechanism. In order to understand the functioning of monetary policy measures, monetary authorities analyse the interdependence between corporate bonds, government bonds and money markets. Thus, they can obtain an insight into how the impulses of monetary policy action are transmitted across financial markets and on towards the real economy. Furthermore, there is evidence that corporate bonds possess leading indicator properties for the economic climate in aggregate. So, the information content of credit spreads makes them useful as indicators for monetary policy. Since the crisis in August 1998, central banks have been increasing their monitoring of potential sources of instability in financial markets. In this context, the systemic risk in the banking sector is regularly observed. This key risk category is heavily influenced by the development of aggregate credit risk among banks and financial institutions. Despite the increasing importance of financial markets, credit risk is still the major component of most banks' activities. Here, corporate bond markets are an important data source, because data on bank loans are difficult to collect. Finally, central banks are active as asset managers, for example when they invest foreign exchange reserves. So, from a treasury perspective, central bankers are interested in determinants of risk factors for portfolio management and hedging.

The purpose of our paper is to study the functioning and the determinants of the pricing process in corporate bond markets. Our study focuses on the euro area. Due to monetary union, the importance of the markets for default-risky assets has grown relative to the historically dominating government bonds. For comparative purposes we include US bond markets, which have been studied in some detail. The markets in the euro area are still at an early stage of development and therefore evidence from the more mature markets in the United States can complement the European perspective.

[1] Austrian National Bank, Otto-Wagner-Platz 3, A-1011 Vienna, Austria; tel: +43+1 40420 3243; e-mail: Michael.boss@oenb.co.at

[2] Austrian National Bank, Otto-Wagner-Platz 3, A-1011 Vienna, Austria; tel: +43+1 40420 7418; e-mail: martin.scheicher@oenb.co.at.
The opinions in this paper do not necessarily reflect those of the Austrian National Bank.

As regards related literature, a number of studies are of interest. The comprehensive theoretical literature on the valuation of default-risky assets is surveyed by Nandi (1998), Saunders (1999) and Crouhy et al (2000). Evidence for European credit markets is so far rather limited. Düllmann et al (1998) study DM-denominated debt of a variety of issuers. They analyse the term structures of the spreads and observe a significant influence of interest rates on the spreads. Annaert and De Ceuster (1999) analyse spreads of euro area bond indices with a focus on the behaviour of spreads in different credit quality or maturity categories. Finally, Houweling et al (2001) focus on constructing credit curves. In contrast to the euro area, the US markets for investment grade and high yield debt have been analysed by a number of authors. Closely related to our methodology is the study by Collin-Dufresne et al (2001). This paper studies which factors determine the first differences of credit spreads of individual industrial bonds. Their main finding is that the spreads are mostly determined by a single common factor, which is not related to pricing theory. Another recent study on US credits is Elton et al (2001). The market for US high-yield debt is studied by Cooper et al (2001) or Barnhill et al (2000).

In order to shed some light on the mechanisms in the euro credit market, we analyse three time series of credit spreads. The spreads which we study are the distances between yields of corporate bonds from industrials, financials and plain vanilla interest rate swaps and default-free yields, ie from government bonds. The difference between two categories of yields is a key variable, because it reflects the market's assessment of default risk. Hence, differences between the spreads of different borrowers can indicate the relative riskiness of various categories of debt. In this context, an important caveat is that the spread is not a pure measure of credit risk, because liquidity risk is a potential additional component. By means of econometric techniques we model the determinants of these three spreads and so we can examine the importance of a variety of risk factors. Our approach is to model the spreads in linear regressions with a comprehensive set of variables. We include variables based on theoretical valuation models, a variety of variables related to default-free interest rates and proxies for market liquidity. We distinguish between statistical and economic significance of the estimates. The results provide some insight into the pricing process of default-risky instruments. Hence we can illustrate to what extent spreads are influenced by eg other interest rates, measures of market liquidity or stock prices. Our framework for the interpretation of the econometric results consists of the three central bank perspectives outlined above.

Our principal results are as follows. First, we observe that factors based on yields of German government bonds play an important role in explaining the movements of euro credit spreads. Second, we find a sizeable unobserved component, which may be linked to market-specific factors that are not captured by our model. The comparison of the estimates for the euro area with the US bond markets documents some differences, though overall the results are quite similar, supporting the robustness of our findings.

The rest of this paper is organised as follows. Section 2 describes the methodology and Section 3 our sample. Section 4 summarises our empirical results. Section 5 concludes.

2. Methodology

Our analysis of European credit markets is based on three time series, namely the yields on the Euro Credit Index Industrials and Euro Credit Index Financials, both provided by JP Morgan (JPM), and the 10-year swap rate, which we obtain from Datastream. By means of Ordinary Least Squares (OLS) regression we try to extract the factors that determine the weekly changes in spreads between the yields on the credit indices, or the swap rate, and the yield on risk-free debt, for which we use the yield on 10-year German government benchmark bond (Bunds). For purposes of comparison we investigate the weekly changes in credit spread according to the difference between the yield on the Merrill Lynch Bond Index for US industrials and the yield on the 10-year US Treasury benchmark bond. The following table summarises the variables which we try to explain by means of linear regressions.

Table 1

Dependent variables

Var	Description
Δs_{eu}^{i}	Weekly changes in the spread between the yield on the JPM Euro Credit Index Industrials and the yield on the 10-year German government benchmark bond.
Δs_{eu}^{f}	Weekly changes in the spread between the yield on the JPM Euro Credit Index Financials and the yield on the 10-year German government benchmark bond.
Δs_{eu}^{s}	Weekly changes in the spread between the 10-year swap rate according to Datastream and the yield on the 10-year German government benchmark bond.
Δs_{us}^{i}	Weekly changes in the spread between the yield on the Merrill Lynch Bond Index for US industrials and the yield on the 10-year US Treasury benchmark bond.

The factors which we include in our regression equations are partly motivated by theoretical arguments according to the class of structural models of credit risk. In addition, we include factors which are based on empirical observations and economic reasoning. In the following - after a brief introduction to structural models of default risk - the factors that we use in our estimations will be described in detail.

2.1 Structural models of default risk

The class of structural models of default risk was introduced by Merton as early as 1974 and since then numerous extensions and refinements of Merton's basic formulation have been presented.[3] It has been pointed out by Merton (1974) that issuing a default-risky (zero coupon) bond has the same payoff structure as a risk-free bond plus writing a put option on the firm's value with strike price equal to the face value of the debt. Structural models of the default risk specify a continuous stochastic process for the value of the bond-issuing firm, where default is assumed to occur when the firm's value falls below some threshold, which in the simplest case equals the face value of the outstanding debt. This framework permits the application of standard option pricing theory - like the well known Black-Scholes equation in the basic framework presented by Merton (1974) - to the pricing of a default-risky bond. Its price is simply the price of a risk-free bond with the same face value as the risky debt minus the price of - or plus the value of a short position in - a put option on the firm's value with strike price equal to the face value of the risky bond .

The factors affecting the price of a default-risky bond in a structural model differ for the various variants and extensions of Merton's basic model. They are determined by the respective specification of the firm value process, the definition of the threshold for the default event and other modelling issues like consideration of bankruptcy costs or stochastic interest rates.[4] However, the set of factors which determine the price of a default-risky bond according to Merton's basic specification is common to all of its variants. In Merton's model the price of the put option on the firm's value is given by the well known Black-Scholes formula and hence the factors are the ratio of debt to the value of the firm, ie the leverage ratio, the volatility of the firm value and the risk-free interest rate.

If structural models of the default risk are of empirical relevance, we would expect that the price-determining factors used in this class of models can be used to explain the changes in credit spreads we observe in the corporate bond market. Hence, we include those variables which represent the firm-specific factors on an aggregate level. This is necessary because our estimations do not rely on firm-

[3] Shimko et al (1993), Leland (1994) and Longstaff and Schwartz (1995) are some of the more prominent examples.

[4] A good introduction to Merton's model and its various extensions and variations can be found in Cossin and Pirotte (2001).

specific data as we try to explain credit spreads implied by the JP Morgan Euro Credit Indices and the 10-year swap rate.

Besides the factors implied by Merton's model, we include additional factors which are motivated by extensions of the basic framework, like the structural model of default risk with stochastic interest rates by Longstaff and Schwartz (1995), as well as variables motivated by empirical evidence such as measures for liquidity risk.

The factors which we use as explanatory variables in our estimations can be divided into three categories: interest rate sensitive variables, variables measuring market liquidity and equity related variables. To some extent, these three categories correspond to the different types of risk which account for the spreads between the yield of corporate bonds, on swap rates, and the yield on government bonds, namely interest rate risk, liquidity risk and credit risk.[5] While the first two of these types of risk apply to all bonds and swaps, government bonds are usually considered to be free of credit risk, and therefore they are called (default)[6] risk-free bonds. In contrast, corporate bonds and swaps are also subject to credit risk and hence they are named (default-) risky assets. However, it should be noted that the sensitivities of corporate bond and swap prices with respect to interest rate and liquidity risk may be different to that of government bonds. Taking this into account, we do not only include variables which refer to credit risk, but consider also interest rate and liquidity risk relevant factors when we try to explain the spread between the yields of default-risky and default risk-free assets. In the following the set of variables which we use in our estimations is described. All changes, returns and volatilities are relative to the frequency on which we base our estimations, namely one week.

2.2 Interest rate sensitive variables

(a) Changes in the 10-year government benchmark bond yield

According to structural models of the credit risk the risk-free spot rate is a relevant factor for the pricing of risky debt. In accordance with Collin-Dufresne et al (2001), who examined the determinants of credit spread changes for the US market, we use changes in the yield of the 10-year government benchmark bond as a proxy for the risk-free spot rate. As has been pointed out above, in Merton's basic framework the price of the put option on the firm value, which determines the price of the risky debt, equals the well known Black-Scholes formula. The risk-free rate enters the Black-Scholes formula as the rate at which the expected payoff of the option at maturity is discounted to the present value. Under the assumption that the average maturity of the corporate bonds in the indices under consideration is about 10 years, it is reasonable to use the 10-year government bond yield as a proxy for the risk-free spot rate.

Changes in the risk-free rate have an inverse effect on the credit spread, ie an increase in the risk-free spot rate leads to a decrease in the credit spread. The reasoning behind this is less obvious than with the other factors that affect the credit spread within Merton's framework: First, if the interest rate increases, the present value of the expected future cash flows, ie the price of the option, decreases. Second, increasing interest rates tend to raise the expected growth rate of the firm value[7] and hence a higher firm value becomes more likely. As has been pointed out above, this implies a lower price of the put option on the firm value. Hence both effects of increasing interest rates decrease the costs of insurance against default, ie the price of the put option on the firm value, which implies a smaller credit spread.

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5 The correspondence between the different categories of variables and the three types of risk that account for the spread between risky and risk less debt is not an exact one. For example, potential changes in the risk-free interest rate will usually be interpreted as interest rate risk, but the risk-free rate is also a relevant factor in structural models for the credit risk.

6 Note that in this context the term "default" is sometimes omitted, which can be somewhat misleading in the case of government bonds, because they are still exposed to interest rate and liquidity risk and hence are not entirely risk-free.

7 A higher interest rate leads to an higher expected growth rate of the firm value because in Merton's setup the drift of the risk-neutral process (ie the expected growth rate) of the firm value is equal to the risk-free interest rate.

For the euro market the time series of weekly changes in the yield of the 10-year benchmark bond was constructed on the basis of the most recent issues of German 10-year bonds (bunds), and for the US market the latest issues of 10-year Treasury bonds were used. The yields of the individual on-the-run benchmark bonds were obtained from Datastream on a weekly basis and linked in order to get a continuous series of benchmark bond yields, from which weekly changes were calculated.[8]

(b) Changes in the volatility of the 10-year government benchmark bond yield

Apart from changes in the level of the risk-free interest rate, we also include its volatility. From a theoretical perspective this factor is motivated by Longstaff and Schwartz (1995), who introduced stochastic interest rates to Merton's basic setup. Furthermore, Collin-Dufresne et al (2001) report that squared changes of the yields of 10-year government bonds add significant explanatory power to their models of credit spread changes in the US market. As we do not have data available on the implied volatility of the risk-free rate, we estimate the historical volatility on the basis of a GARCH(1,1) model. In order to do this, for both markets we first construct a time series of relative weekly changes of 10-year benchmark yields.[9] Then we fit a GARCH(1,1) process to these data, which in turn we use to calculate a time series of weekly volatilities. Finally we take the first differences of this time series and obtain weekly changes of weekly volatilities of the relative changes of the 10-year government benchmark yields.

The influence of volatility can be interpreted as a quantification of convexity, ie the curvature in the interdependence between bond yields and bond prices. Concerning the sign of the respective coefficient, it is not a priori clear if it should be positive or negative, ie if the credit spread falls or rises as the yield volatility increases. Collin-Dufresne et al (2001) report with regard to the squared yield of the 10-year government bonds negative coefficients for high-rated corporate bonds with short maturities and positive coefficients for low-rated short term and all long-term bonds. This result is consistent with respect to the structural model of default risk with stochastic interest rates by Longstaff and Schwartz, where the impact of a change in the yield volatility on the credit spread can be positive or negative.

2.3 Changes in the slope of the government yield curve

The third variable in the category of interest rate related factors is the weekly change in the slope of the term structure. We define the slope as the difference between the yields of 10-year and two-year benchmark government bonds. The continuous time series of benchmark bond yields was constructed as described above on the basis of the yields of individual bund and US Treasury benchmark bonds, which we obtained from Datastream.

The interpretation of the slope of the riskless term structure is twofold: first, in the context of the Longstaff and Schwartz (1995) structural model with stochastic interest rate, in the long run the short rate is expected to converge to the long interest rate. Hence an increase in the slope of the term structure should lead to an increase in the expected future spot rate. This in turn will decrease the credit spread, as has been pointed out above. Second, from a more general perspective, a decreasing slope of the term structure may imply a weakening economy, which in turn may lower the expected growth rate of the firm value and hence lead to higher credit spreads. Thus both arguments predict an inverse effect of changes in the slope of the yield curve on changes in the credit spread.

(a) Liquidity-measuring variables

Liquidity is without doubt an important source of risk, but its measurement is not an easy task. Theobald et al (1999) argue that measuring liquidity by traditional means like bid/ask spreads and traded volumes may not be adequate in all situations. We will therefore use two different measures of

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[8] Although Datastream provides a continuous time series for the yield of the 10-year government benchmark bond, we constructed the time series by ourselves, because Datastream updates the used benchmark bonds only once a month and hence it can happen that an off-the-run benchmark bond is included in the time series instead of the latest issued benchmark bond.

[9] We calculate the volatility of relative yield changes, because this makes the bond volatility comparable to equity volatility.

liquidity, which are both based on the spread between more and less actively traded securities in the government bond market. The liquidity measures can be based on the government bond market, because the liquidity premium is highly correlated across markets as has been found by Theobald et al (1999) in their study on valuing market liquidity in US, German and UK bond and swap markets. They conclude that the liquidity conditions in the government markets proxy for the liquidity premia reflected in the pricing of corporate bonds and swaps. In our estimations we use the following variables to account for the liquidity risk:

(b) Changes of the liquidity spread of 30-year government benchmark bonds

A measure of liquidity which has become quite common in recent years is the spread between the yields of on-the-run and off-the-run government benchmark bonds for a certain maturity. The actual benchmark bond for a certain maturity, which is usually the most recent issue with this maturity, is called the on-the-run benchmark, while the previous benchmark, which has been substituted by a newer issue, is called the off-the-run benchmark. If the difference in the remaining time to maturity for both bonds is small and other characteristics, like the coupon payments, are the same, the two bonds should trade approximately at the same price. However, the on-the run-benchmark bond is the most actively traded and hence the most liquid bond for the respective maturity and therefore it is subject to less liquidity risk than the off-the-run benchmark bond. In order to compensate for the higher liquidity risk, the latter trades at a yield which is usually a few basis points above the yield of the on-the-run benchmark bond. Thus, if the characteristics of the two bonds are about the same, the spread between the yields of the two bonds can be interpreted as the liquidity premium.

In times when liquidity is high, the liquidity risk accounts only for a few basis points. But as liquidity dries up, liquidity risk increases and traders are willing to pay a higher price for avoiding this risk. Hence the gap between the yield of on-the-run and off-the run benchmark bonds widens, ie the liquidity premium becomes higher. In crisis situations, the “flight to quality” appears in parallel with a “flight to liquidity”, where an increase of the liquidity premium by more than 20 basis points can be observed. As corporate bonds are usually less liquid than the government bond market we would expect that such a “flight to liquidity” weakens demand in the corporate bond market. Hence, the credit spread should increase with the liquidity spread, all else equal.

We use the liquidity spread calculated on the basis of the yields of 30-year bunds and US Treasuries as a proxy for liquidity in the corporate bond and swap markets we investigate. Again, yields of the on-the-run and off-the-run benchmark bonds are taken from Datastream and the respective time series are constructed analogously to the time series of yields of 10-year benchmark bonds. Finally we calculate the weekly changes of the liquidity spread for the respective markets.

(c) Changes in the liquidity spread of the government bond market

The idea on which our second measure of liquidity is based, is taken from Theobald et al (1999) and it is somehow connected to the liquidity spread. However, it does not measure liquidity on the basis of the on-the-run and off-the-run benchmark bonds for a single maturity, but uses the information of the whole term structure by measuring the relative pricing of government bonds versus a model of the government term structure. Such a model uses observed prices of government bonds in order to estimate the discount function, which is implied by these prices. In order to do this, the discount function defined as a function of some free parameters, which are chosen in a way such that the observed prices, or alternatively the corresponding yields, are approximated as closely as possible[10] by the “theoretical” prices, or yields, ie those which are implied by the estimated discount function. For bonds which have the same characteristics, clearly the theoretical yields are the same. For yields implied by observed prices, this is not always the case, but as there is no relevant default risk, differences in observed yields should be due to liquidity risk.[11] Hence the difference between observed

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[10] In this context “as closely as possible” means that the free parameters of the discount function are set such that the summed squared differences between observed prices (yields) and the prices (yields) which are implied by the discount function, are minimised ie the parameters are estimated by Non-linear Least Squares (NLS).

[11] Another source of differences in observed prices could be the so-called coupon effect driven by coupon taxes or considerations related to accounting.

and theoretical yields - the "yield error" - can be interpreted as a measure of liquidity risk related to the individual bonds. The liquidity risk with respect to the whole market is measured by the average absolute deviation from the mean yield error.[12] We call this statistic the liquidity spread of the government bond market and, as with the other measure of liquidity risk, it increases as liquidity worsens and we hence expect that the credit spread increases with it.

The daily estimation of the term structure is based on Svensson's method with Datastream prices for German and US government bonds. For each estimate we calculate the liquidity spread of the respective government bond market and finally produce the time series of weekly changes.

2.4 Equity-related variables

(a) Stock returns

As has been outlined above, in structural models of default risk the firm's leverage ratio is a key variable in determining the price of the debt issued by the firm. The leverage is defined as the ratio of the firm's debt to the value of its assets, or the firm value. Within the framework of structural models default is triggered as this ratio approaches unity. Hence the higher the leverage ratio is, the higher is the risk of default and thus the lower is the price of debt. Therefore the credit spread should increase as the leverage ratio increases, all else equal.

With respect to the put option which determines the price of the risky debt, leverage is the ratio of the strike price (the face value of debt) to the price of the underlying (the firm value). This ratio is the inverse of the moneyness of an option. If leverage is high, the put option is said to be in the money, and if it is low, the option is said to be out of the money. The more the option is in the money, the higher is its price and consequently the higher is the credit spread.[13] More intuitively speaking, the higher the leverage ratio is, or the lower the value of the firm - given a fixed level of debt - is, the more likely it is that the firm will default and hence the more costly the insurance against default should be. The cost of this insurance, which is simply the price of the put option, is reflected by a higher credit spread.

However, in this study we do not analyse credit spreads on a firm-specific level but on the basis of indices for corporate bonds and hence we cannot use the leverage ratio itself as a factor in our estimations. In practice it is quite common to examine the relationship between credit spreads and leverage in terms of changes in equity level, or equity returns. Given a certain level of debt leverage increases as the firm value decreases, this leads to an inverse relationship between firm value and credit spread: the less the firm is worth, the higher the credit spread should be. In the reverse case, we expect that a positive return on the equity index decreases the credit spread.

Besides the theoretical reasoning according to the structural approach, there is another motivation for using the equity return as an explanatory factor of credit spreads. Collin-Dufresne et al (2001) argue that changes in the business climate can have an effect on credit spreads even if the probability of default remains constant over time through changes in the expected recovery rate. One would expect that recovery rates are higher when the economy expands than in times of recession. The return on a representative equity index is commonly used as a proxy for the overall state of the economy, and therefore - analogously to the theoretical argument - we would expect that a positive return on the equity index leads to a decrease in the credit spread.

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[12] Note that Theobald et al (1999) use a different statistic, namely the standard deviation of the yield errors, in order to measure liquidity risk. We prefer to base the summary statistic on absolute deviations, because this seems to be a more natural measure of liquidity risk. In fact it is quite similar to the liquidity spread for a single benchmark bond with a certain maturity. There are two differences: first, liquidity risk is measured with respect to the whole term structure instead of a single maturity, and second, this measure is based on the spread to an average yield, which is given by the theoretical yield implied by the estimated term structure, and not on the spread to the on-the-run benchmark bond. A possible improvement of the presented method could perhaps be achieved if the term structure estimation were based on benchmark bonds only instead of all bonds.

[13] The price of a default-risky bond equals the price of a risk-free bond minus the value of a put option on the firm value and hence a lower absolute price of the put option leads to a higher overall price of the risky bond, which in turn corresponds to a lower yield and a lower credit spread.

The equity index used in the estimations should be in a way representative of the firms that are included in the respective JP Morgan Credit Index. We decided to calculate the weekly returns for the euro area on the basis of the Dow Jones (DJ) STOXX Index family for European equities,[14] because these indices are based on a wide range of liquid European equities and sub-indices are available for various regions and market sectors. In order to account for the different market sectors, to which the three credit spreads under consideration refer, the estimations for the JPM Credit Index Financials, and the swap rates, and those for the JPM Credit Index Industrials are based on different sub-indices of the DJ EURO STOXX Total Market Index (TMI). This index covers 95% of the free floating market capitalisation in the euro area and it is calculated as a price and as a total return index on the basis of US dollars and on the basis of the euro, where we choose the euro denominated price indices[15] of the respective sub-indices for 18 different market sectors.

In particular, we use the DJ EURO STOXX TMI Banks to calculate equity returns for the JPM Credit Index Financials and the swap rates, because most bonds included in this credit index are issued by banks and swaps are usually traded by banks too. In the following we refer to this index as the EURO STOXX JPM Banks Index. Regarding the JPM Credit Index Industrials there is no DJ EURO STOXX Index which is representative for the respective bond issuers. Hence we had to calculate a representative equity index, which was done in the following way. First we calculated weights for the market sectors according to the firms in the JPM Credit Index Industrials on the basis of the overall nominal volume issued by the firms in the respective sectors. Second, these weights were used to construct a new index on the basis of the DJ EURO STOXX Sub-Indices for the respective market sectors. The resulting index will be called the EURO STOXX JPM Industrials Index in the following and should be a representative index for the composition of the JPM Credit Index Industrials.

For the United States we use the Wilshire 5000 Index, which is a much broader index than the Standard & Poor's and should therefore be more representative of the composition of the Merrill Lynch Bond Index for US industrials.

Returns are calculated from the indices by taking the difference of the logarithm of the current index value and the logarithm of the last period's (previous week's) index value. Additionally, we include the equity returns on these indices lagged by one week in the respective estimations, as for US markets it has been reported that lagged values of equity returns do have an impact on changes in bond yields and credit spreads.[16]

(b) Changes in the implied volatility of the return on the equity index

Another factor that affects the credit spread according to the structural approach is the volatility of the firm value. The price of an option increases with the volatility of the underlying, because increasing volatility makes it more likely that the put option will be exercised. In the present context a higher volatility implies that large changes of the leverage become more likely. Hence the probability that the leverage ratio approaches unity, or that the firm value falls below the face value of the debt and the firm defaults, increases. Again, the analysis is not done on the basis of the leverage ratio, but we use the volatility of an appropriate equity index, where we expect that a rise leads to an increase of the credit spread.

In order to obtain the market expectation of variance, we use the volatility, which is extracted from option prices. Unfortunately we do not have data for the implied volatility based on the EURO STOXX and the Wilshire 5000 indices, which we use to calculate equity returns. Instead we use the best substitutes available, namely the VDAX for the euro area and VIX for the US. The VDAX is a DAX-based constant maturity volatility index calculated on the basis of near the money DAX options traded at the Eurex, while the VIX is a volatility index of near the money options on the S&P 100 equity index and is provided by the Chicago Board of Exchange on a daily basis.

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14 See STOXX Limited (2001) for a detailed description of this index family. The data are available on the internet at http://www.stoxx.com.

15 The price index includes only dividend payments larger than 10% of the equity price and special dividends from non-operating income, in contrast to the total return index, which includes all dividend payments.

16 See for example Kwan (1996).

Table 2 summarises the factors which we use in our estimations and the corresponding signs that we expect for the respective estimates of the parameters.

Table 2

Explanatory variables and expected signs for parameter estimates

Var	Description	Sign
Δy_c^{10}	Weekly change in the yield of 10-year government benchmark bond	-
$\Delta\sigma_c^y$	Weekly change in the one-week volatility of the 10-year government benchmark bond yield obtained from estimated GARCH(1,1) model	~
Δsl_c	Weekly change in the slope of the government yield curve according to the spread between the 10 and the two-year government benchmark yield	-
$\Delta\ell_c^{30}$	Weekly change in the liquidity spread of the 30-year government benchmark bonds according to the difference between the respective on-the-run and off-the-run bonds	+
$\Delta\ell_c$	Weekly change in the liquidity spread of the government bond market according to the average absolute deviation from the mean yield error obtained from daily term structure estimates using Svensson's model	+
$r_{c,e}$	Weekly equity return based on the EURO STOXX JPM Banks Index (*e* = *b*) for *c* = *eu* and estimation of Δs_{eu}^f, Δs_{eu}^s, based on the EURO STOXX JPM Industrials Index (*e* = *i*) for *c* = *eu* and estimation of Δs_{eu}^i and based on the Wilshire 5000 Index (*e* = *i*) for *c* = *us*	-
$r_{c,e}^{t-1}$	Weekly return as defined by $r_{c,s}$ in the previous period/week	-
$\Delta\sigma_c$	Weekly change in the one-week implied volatility according to the VDAX for *c* = *eu*, and according to the VIX for *c* = *us*	+

Note: The interest sensitive variables and those measuring liquidity are all based on German bunds for *c* = *eu* and on US Treasuries for *c* = *us*. The equity returns for *c* = *eu* are calculated on the basis of the EURO STOXX TMI Sub-Indices for different market sectors in order to match the composition of the credit spreads regarding the market sectors of the respective firms.

2.5 Description of the data

Before outlining our sample, we provide a brief overview on the corporate bond markets in the euro area. The market size at the end of 2000 was $4 trillion for non-government bonds in the euro area and $13.2 trillion for US dollar credits.[17] In contrast to these considerable differences in market capitalisation, the levels of new issuance were quite similar in both regions in 1999 and 2000. For the bond markets of the euro area JP Morgan offers the representative JP Morgan Aggregate Index Euro.[18] The volume in this index separates into 64.5% for governments, 11.6% Pfandbriefe, 6.3% financial institutions, 9.4% corporates and 8.2% supranational or sovereign non-EMU borrowers.

[17] See ECB (2001) and BIS (2001).

[18] See JP Morgan (2001).

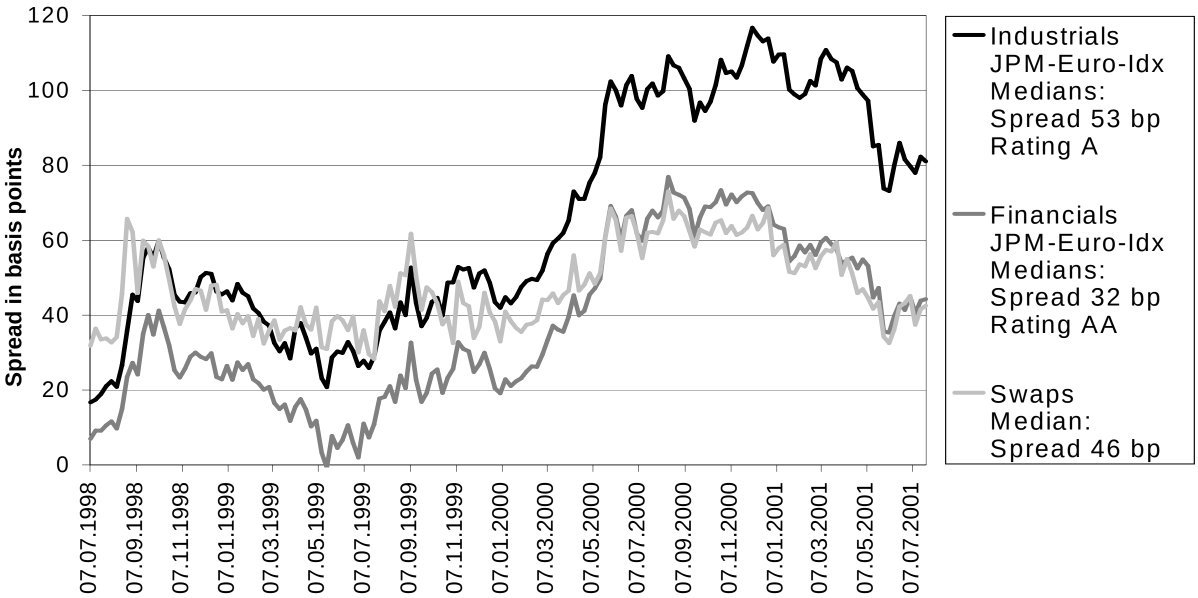
Our study is based on the Euro Credit Index Industrials and Euro Credit Index Financials. In addition to these two categories of corporate debt, we include the spread relative to 10-year interest rate swaps. This distance is frequently interpreted as an indicator of default risk on the interbank market and is therefore used for monetary policy analysis (ECB, (2000)). We compute three spreads relative to the yield on the 10-year bund benchmark.

Our sample comprises the period from 14 July 1998 to 24 July 2001. In order to obtain a reasonably large sample, we begin before the official start of EMU. However, in July 1998 uncertainty about the process was already quite low and therefore we can assume this period to be homogeneous.

Graph 1 depicts the three spread series and Table 3 summarises some details. As regards the credit quality of the issuers in the two index series, median Industrials are rated A and median Financials are rated AA.[19] The median spread is 53 bp (Industrials), 32 bp (Financials) and 45 bp (Swaps). In general, spreads fluctuate with a weekly standard deviation of 10-30 basis points. In the graph, the rise of the swap spread during the LTCM crisis in August 1998 is notable. The maximum was achieved for all spreads in the second half of 2000, namely for Industrials on 12 December 2000 with 120 bp, for Financials on 15 August 2000 with 80 bp and for Swaps on 15 August 2000 with 73 bp. The second half of 2000 was characterised by two major developments. Market participants focused with growing concern on the financial situation of debtors from the telecommunications sector and, simultaneously, the economic climate in the United States began to deteriorate.

Graph 1

Time series of euro credit spreads



Sources: JP Morgan, Datastream.

Given that the levels of dependent and independent variables possess unit roots, the first differences form the basis for our estimations. Our sample comprises 159 data points. Table 4 in the Appendix presents some descriptive statistics about the weekly changes of the spreads and the explanatory variables, measured in percentage points. The mean of the weekly changes of our variables is close to zero in most cases. For the interest rate variables in particular, the Jarque-Bera statistics indicate that the empirical distribution deviates strongly from the normal. In the lower half of Table 4 in the Appendix, the correlations between dependent and independent variables are provided. We observe correlations of more than 0.7 between the three spread changes. Given our common set of

[19] Average cumulative default rates for 10-years (Crouhy et al, (2000)): AA (1.29), A (2.17), BBB (4.34).

explanatory variables, we would expect that, to some degree, the correlations are accounted for by these factors. When we evaluate the interaction between independent and dependent variables, the first differences of government yields and the slope show the highest correlations. Among the set of independent variables, the strongest linkage exists between stock returns and volatility, with a value of around –0.6. Furthermore, the three variables based on bund yields are correlated with values below 0.3. The remaining correlations are all less than 0.15 and hence evidence for multicollinearity is weak.

Table 3

Euro credit spreads

	Number of bonds	**Distribution according to rating in %**						**Descriptive statistics of credit spread in %**			
		AAA	AA	A	BBB	High-yield	Not rated	Median	Max	Min	Std Dev
Industrials	473	7.3	14.9	41.6	25.1	3.2	7.9	0.53	1.17	0.17	0.30
Financials	505	19.5	43.8	31.3	0.8	0.8	3.8	0.32	0.77	-0.01	0.21
Swaps								0.46	0.73	0.28	0.11

Sources: JP Morgan, Datastream.

2.6 Model estimation and model selection

As has been mentioned already, we use OLS regressions to explain the three credit spreads for the euro area and the spread for the US corporate bond market. For each series we perform two regressions. First we estimate an equation in which all explaining factors according to Table 2 are included; formally we estimate

$$\Delta s_c^m = \beta_1 \Delta y_c^{10} + \beta_2 \Delta \sigma_c^y + \beta_3 \Delta sl_c + \beta_4 \Delta \ell_c^{30} + \beta_5 \Delta \ell_c + \beta_6 \Delta r_{c,e} + \beta_7 \Delta r_{c,e}^{t-1} + \beta_8 \Delta \sigma_c^r + \varepsilon_c^m ,$$

with $e = b$ and $m = f, s$, $e = i$ and $m = i$ for $c = eu$ respectively $m = i$ and $e = i$ for $c = us$. This results in four equations, three for the spreads $s_{eu}^i, s_{eu}^f, s_{eu}^s$ which we analyse for the euro area and one spread s_{us}^i for the US corporate bond market. The residuals are assumed to have an expected value $E(\varepsilon_c^m) = 0$, variance $Var(\varepsilon_c^m) = \sigma_{c,m}^2$ and to be uncorrelated $E(\varepsilon_{c_1}^{m_1} \varepsilon_{c_2}^{m_2}) = 0$ for $m_1 \neq m_2$ and $c_1 \neq c_2$.

Typically, not all of the estimated parameters are statistically significant. However, the objective of our analysis is not only to determine the factors which explain the various credit spreads under consideration, but in addition we want to analyse how - in particular large - changes in the explanatory variables affect the credit spreads. Because a model that contains insignificant variables would not be very helpful with respect to this task, a second model is estimated for each credit spread.

In order to find an appropriate model for each credit spread, we do not simply remove the variables with statistically insignificant parameter estimates, because this can affect the estimates for the parameters of the other factors and the respective statistical significance. Instead we use a heuristic model selection procedure in order to find a model, which will be referred to as the "parsimonious model" in contrast to the "complete model" which includes all factors listed in Table 2. This procedure works as follows: first, for every possible combination of factors to be included in the regression equation we estimate the respective parameters by OLS.[20] From this set of models, we select those

[20] For the Euro spreads an additional moving average term is included in the regression equation due to serial correlation in the residuals.

which have statistically significant parameter estimates given a significance level of 90% and for which the signs correspond to what we expect from theory, as summarised in Table 2. The remaining models are then sorted according to the Akaike Information Criterion (AIC) and the model with the lowest AIC is selected as the "parsimonious model". Hence, in the following for each credit spread we describe two estimated models, namely the complete and the parsimonious model.

3. Results

In the following we first present the estimates regarding the European credit spreads. We discuss our estimation results using the entire set of explanatory variables and the results from our model selection procedure, where we evaluate the explanatory value of the individual variables. In this context we also evaluate the economic significance of our results, which means that we also look at the size of changes in the credit spreads as a result of changes in a specific factor, given a statistically significant parameter estimate for this factor. We continue by comparing the regressions for the US and euro series. Finally, the results for the inclusion of some additional variables in our regression equations will be discussed.

3.1 Results for European credit markets

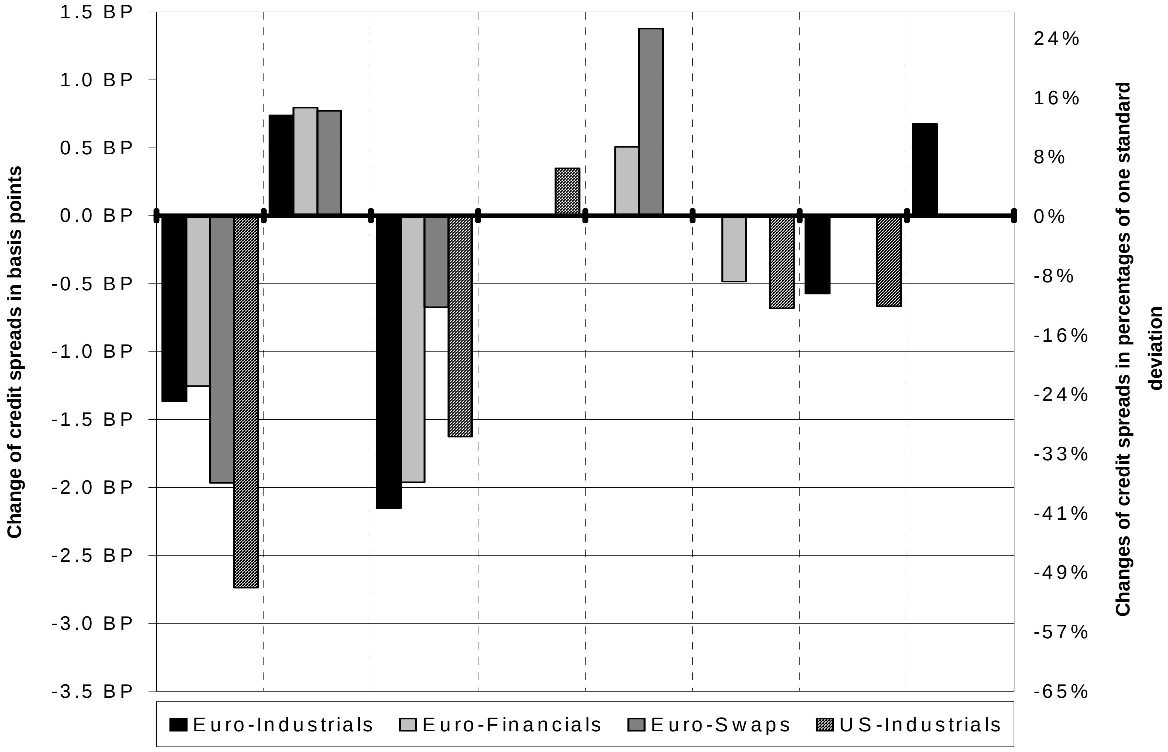
Table 6 in the Appendix shows the estimates for Industrials, Financials and Swaps with the common set of explanatory variables. Our first observation is that variables based on bund yields play a very important role as determinants of credit spreads. With respect to the European credit markets, with one exception all interest rate sensitive variables show statistical significance and all of them are included in the models which were found by our model selection procedure. The exception refers to the volatility of the bund yields, which is not significant in the model for the swap spread with all factors included. However, concerning the parsimonious model, there is some statistical evidence that the bond yield volatility might affect the swap spread, although with a p-value of 0.05 this evidence is not very strong.

The benchmark yield and the slope of the yield curve have a statistically significant influence on all three spreads, with coefficients around 0.1 for the yield and up to -0.28 for the slope. The signs are in accordance with bond pricing theory. As has been pointed out in Section 2.2, according to the Merton model the changes of yields affect spreads in a negative form, ie when the general level of interest rates rises, the spread falls. The negative sign of the parameter for the slope of the term structure is also in line with what we expected. From the theoretical point of view a decrease in the slope should lead to a higher expected future spot rate and hence a rising credit spread. The same is true, when the slope is interpreted as an indicator for future economic growth. The estimated coefficients are large enough for economic significance to be present. Among interest rate variables, apart from the exception mentioned above, the yield volatility to be statistically significant, but its coefficients are rather small in the three series and hence economic significance is ambiguous.

In the literature on determinants of the yields on government bonds (eg Bliss (1997)), three factors are frequently documented: the level, slope and curvature of the yield curve. For the distance between yields on default-risky and default-free assets, we find that the key factors are the level and the slope of the term structure. This result is also confirmed by Graph 2, which shows the impact of a change of one standard deviation on the credit spreads. According to this graph a change of one standard deviation in the yield, or the slope, results in a change of 1.5 to 2.0 basis points in the respective credit spreads, which corresponds to 30-50% of a standard deviation of credit spread changes. Therefore, our first result is that there are considerable similarities between the credit markets and the markets for government securities. With respect to theoretical models this result gives support to extensions of Merton's basic model which explicitly model stochastic interest rates, like the model by Longstaff and Schwartz (1995).

Graph 2

Changes in credit spreads in response to changes in factors by one standard deviation according estimates of parsimonious model



Note: The left-hand scale shows the change of credit spreads in response to a change of one standard deviation in the factors in basis points. The right-hand scale shows this change as a percentage of the average standard deviation of all time series of credit spread changes. As the standard deviations are more or less the same for all credit spreads, this scale measures the responses as (approximate) percentages of credit spread standard deviations.

Besides interest rate risk, the behaviour of market liquidity is a potentially important determinant of the spreads between risky and risk-free debt. As mentioned before, we use two measures, namely the liquidity spread of 30-year government benchmark bonds, ie the difference between the on-the-run and the off-the-run 30-year benchmark bund, and the liquidity spread of the government bond market, which is the average absolute deviation from the mean yield error derived from a term structure estimation according to Svensson's (1994) model. The regression results show that the second measure has a strong impact on the changes of credit spreads. Statistical significance is found only for Financials and Swaps, but not for Industrials. Hence the liquidity spread of the government bond market was included by our model selection procedure in the parsimonious model for the swap and the financial credit spread. However, it should be noted that, while the estimate is highly significant with respect to the first two spreads, this is not the case for the Industrials. In addition economic significance is only evident for the swap market, because a change of one standard deviation in the liquidity spread leads to a change of merely half a basis point in the Financials spread - in contrast to 1.5 basis points with respect to the swap spread, which can be seen in Graph 2. Therefore, we conclude that liquidity risk is priced only in some segments of the credit markets, as there is no evidence for a significant impact of our respective measures on the credit spreads of Industrials and as regards Financials significance is at least doubtful from the economic point of view. However, the impact is positive for all credit spreads, so, based on our construction of the measure, an increase in the average absolute deviation from the mean yield error, ie rising liquidity risk, raises the spread. Again, this is in accordance with what we expected, as a "flight to liquidity" raises demand for highly liquid government securities relative to less liquid corporate bonds.

When we turn to the impact of the equity-related variables on spreads, we can evaluate whether the predictions of the Merton model are validated in European credit markets. We observe that our proxy for equity volatility is significant only for the Industrials spread in the reduced model. Our model selection procedure includes equity volatility in the parsimonious model and with a p-value of 0.02 there is quite strong evidence for statistical significance. According to Graph 2, the impact of a change in volatility by one standard deviation is quite small, but equity volatility can be subject to large changes during a crisis situation. Hence, if there is a change in volatility by several standard deviations, the effect on the credit spread would indeed be economically significant. But, in the case of the yield differential for Financials and Swaps, the VDAX has no measurable impact at all. The positive signs - which we observe for the significant as well as for the insignificant estimates - are in accordance with Merton's model, namely increasing volatility has a positive effect on the spread of default-risky assets. The reason behind this mechanism is that rising variability of future stock returns means more uncertainty about the development of asset values and so the risk premium moves up. One interpretation for the differential impact of volatility comes from the differences in credit quality. From the option pricing perspective, lower credit quality means that the bond is more at the money, ie the strike price of the corresponding option is close to the current price. In this case, the volatility of stock returns has a larger impact on the value of the option. Table 3 shows that the debtors included in the Industrials index on average have a lower credit quality and so the volatility has a stronger impact.

The second equity-related factor with a possibly large influence on spreads is the level of stock prices, or the stock return. According to theory, the stock price has a key role in the financial strength of a firm, because it drives its leverage ratio. The behaviour of stock prices is also frequently used as an indicator of economic sentiment in general. According to Table 6 we find an impact of the current return on Financials and a significant influence of last week's return on the Industrials for both the parsimonious and the reduced models. The negative sign is in accordance with theory: as stock prices rise, risk premia in credit markets fall, because the financial strength of the debtors improves. As with volatility, the size of the respective coefficient is quite small and therefore we find only statistical significance. According to Graph 2, the impact of a change of the current or lagged equity return by one standard deviation on the credit spread of Industrials and Financials is similar to that for for volatility. But again, as equity returns are known to be fat-tailed, large changes with a significant influence on the credit spread are likely to happen sometimes. An explanation for the impact of lagged stock prices on Industrials is based on the fact that some of the information is already captured by equity volatility. The reason for this interdependence is the sizeable leverage effect. The negative correlation between returns and volatility is known as the leverage effect, because of the empirical observation that the standard deviation of a stock increases with the leverage of a firm. For our sample, Table 3 shows that the correlation between stock returns and VDAX is –0.62 for the EURO STOXX JPM Industrials Index and –0.67 for the EURO STOXX JPM Banks Index. Therefore, it seems plausible that the current stock price does not have a strong effect. Instead, the lagged stock price matters in the case of Industrials. As the autocorrelation in index returns is -0.1 at lag one and the effect of the contemporaneous stock price should be negative, the positive sign on last week's return is plausible.

Among the summary statistics of the regressions, all Durbin-Watson statistics are close to two, when we include a moving average with lag one. To judge the overall fit of our set of proxies for interest rate risk, liquidity risk and stock market developments, the R^2s are of particular interest. The measures of determination are between 34% and 41% and indicate that our variables have some information content. Overall, the unexplained fraction of the variability of credit spreads is sizeable. This result is particularly remarkable given the comprehensive set of explanatory variables which we have applied. In this context, we have also computed the correlation of the residuals from the three regressions. From Table 3 we have seen that the interdependence between the first differences of the spreads is sizeable. We would expect the residuals to show a weak correlation, because the common factors are accounted for by the explanatory factors. Therefore, the residuals are a proxy for the idiosyncratic component, which is not captured by our set of explanatory variables. Table 7 shows that the correlations between the residuals are only fractionally smaller than those between the dependent variables. This pronounced interdependence in the residuals indicates the presence of a large unobserved common component, which is not reproduced by our models. A similar result is documented by Collin-Dufresne et al (2001) for US corporate bonds. They show that the residuals from regressions on the spreads of individual bonds are heavily correlated. Their interpretation is that US credit markets are segmented from stock and Treasury markets. Another interpretation of the unobserved component is offered by Elton et al (2001). These authors argue that the US credit spreads are influenced by default risk, fiscal aspects and a risk premium. According to their estimations, the returns on corporate bonds contain a sizeable risk premium due to a systematic source of risk which cannot be diversified.

Table 7

Correlation of residuals of complete model for the euro area

Variable	ε_{eu}^{i}	ε_{eu}^{f}	ε_{eu}^{s}
ε_{eu}^{i}	1.000		
ε_{eu}^{f}	0.813	1.000	
ε_{eu}^{s}	0.676	0.763	1.000

In this context, the size of the correlation of US dollar and euro swap spreads is of interest. There may be expected to be some commonalties between the spread series. We find that the two series are correlated with a value of -0.02 for the time period from January 1997 to July 2001. This weak interdependence indicates the absence of a common component between US dollar and euro swap spreads.

3.2 Comparative analysis with US evidence

In order to represent the US credit markets, we use the Merrill Lynch Bond Indices for US Industrials with an investment grade rating. This index is representative of the developments in the market for debtors with a rating between AAA and BBB. Given the state of development in this market, we use a longer sample, starting on 8 January 1991 and ending also on 24 July 2001. Our series contains 551 observations. The median spread is 98 bp, the maximum of 223 bp was reached on 26 December 2000 and the minimum of 60 bp on 30 July 1996. These descriptive statistics show that the general level of the spread is higher in the US than in the euro area. One reason for this difference lies in the fact that the US series contains a complete business cycle whereas the euro area index is not available for a period of significant defaults.

The estimation results for the model comprising all variables and the specification chosen by our model selection procedures are presented in Table 6 after the results for the euro area. As in the euro series, the level and the slope of the term structure show very high significance. According to Graph 2 the influence of the interest rate related factors on the credit spread is roughly the same as in the European markets. Thus, in both markets, the proxy for the risk-free rate is of prime importance for determining the changes in credit spreads. The results of the model selection procedure show that the variability of stocks and Treasuries has no significant influence on US credit spreads. So, comparing the US and the euro area results, the main observation is that the volatility only has an impact in the euro markets. In contrast, US spreads are heavily influenced by stock returns.

Regarding the US credit spread for Industrials we can observe from Table 6 that both the current and the lagged return on the Wilshire 5000 are statistically significant, whilst for the euro Financials and Industrials this is only the case with respect to a single return, from the present or past period. Both respective coefficients are around -0.003. In terms of changes by one standard deviation, Graph 2 shows that this corresponds to a change of 0.5 basis points in the credit spread, which is about the same as for the European Industrials. However, Collin-Dufresne et al (2001) report that a change of 1% in the S&P is associated with a credit spread decrease of about 1.6, which is about five times more than what we have found.

With respect to the role of liquidity, some differences emerge. We find that different measures are significant: with regard to the complete model for the US market both measures are significant, though the liquidity spread of the entire government market is only significant at the 90% level and our selection procedure does not include this liquidity measure in the reduced model as was the case for the European model. For the US market however, the liquidity measure according to the spread between on-the-run and off-the-run 30-year benchmark bonds shows high significance with respect to the complete and the reduced model. One explanation for this difference is that, in the German government bond market, the spread between on-the-run and off-the-run issues has a lower information content regarding liquidity risk. The nominal coupons of successively issued 30-year bunds differ strongly and hence the spread between on-the-run and off-the-run benchmark bonds is partly due to this difference.

In general the estimation results for the two areas are quite similar. For example, the euro Industrials estimates show that the level of the term structure has an impact of -0.14. For the corresponding US series, the coefficient is -0.21. The slopes are even almost identical between the two regions. Finally, when we evaluate the R^2s, we find that the measure of determination is higher than in the three euro series. So, our set of variables has a higher explanatory value for the more developed US market. Overall, we can conclude that, despite some differences, there are considerable similarities between the two markets. This result shows that the state of development is not altogether strongly reflected in our estimates.

3.3 Additional variables

As regards other variables which we have not included in our initial set of explanatory factors, we found no factors adding information to our models. We proceeded in three steps. First, we tried various proxies for the short-term spot rate. For the US market we used the three-month Treasury bill rate and for the euro market the three-month Euribor. We also experimented with an estimated instantaneous spot rate, which we obtained from estimates of the entire term structure.[21] None of these proxies for the short-term rate showed a significant impact on the credit spreads. Second, we added price/earnings ratios to the set of variables. With respect to the credit spread of Industrials some evidence of statistical significance was found. However, according to our selection procedure, this factor adds the same information as equity returns because the procedure included price/earnings ratios alternatively to one of these variables. Finally, the influence of the reduced supply of US Treasuries observed since the beginning of 2000, was analysed through inclusion of a dummy variable. However, a significant influence was not found.

4. Conclusion

This paper has examined which factors influence the first differences of credit spreads in the euro area. We evaluate three series, namely the yield distance for Industrials, Financials and for plain vanilla interest rate swaps. By means of linear regressions, we examine the significance of various factors proxying for interest rate, credit and liquidity risk. Our principal result is that interest rates, in particular the level and slope of the risk-free term structure, are the most important determinants of credit spreads. In addition, stock returns, the volatility of stock returns and bond yields and proxies for liquidity risk are significant factors. We examine statistical as well economic significance to quantify the overall effects of the various factors. When we analyse the residual series from the three regressions, we find a sizeable common unobserved component. A comparison of the estimates for the euro area with the established US bond markets shows some differences. However, overall, the results are quite similar and therefore, support the robustness of our findings.

In order to extend the results in this paper we intend to analyse how the credit spreads behave according to our model in a crisis situation like a stock market crash. Another direction seems to be particularly interesting. Instead of relying on aggregate spreads taken from an index, it seems promising to study the euro corporate market on the level of individual issues. On such a disaggregate level, the variation of yields across debtors could increase the information set. In addition, a sample of individual bonds makes it possible to include more elaborate measures of credit risk. One frequently used measure is the expected default frequency (EDF). King (2001) shows that this variable, which combines stock prices and equity volatility in a Merton-type model, has a high explanatory value for the dynamics of yield differences.

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[21] The instantaneous spot rate was obtained from the same Svensson (1994) model from which the liquidity spread of the government bond market was derived. One of the model's parameters can be interpreted as the risk-free instantaneous spot rate - the spot rate with maturity converging to zero - and hence one gets a time series of estimates of the instantaneous spot rate by periodically fitting the discount function according to Svensson to observed market data and collecting the respective parameter estimates.

Appendix

Table 4: Descriptive statistics of variables used in regressions for euro area

	Δs^{i}_{eu}	Δs^{f}_{eu}	Δs^{s}_{eu}	Δy^{10}_{eu}	$\Delta\sigma^{y}_{eu}$	Δsl_{eu}	$\Delta\ell^{30}_{eu}$	$\Delta\ell_{eu}$	$r_{eu,i}$	$r_{eu,b}$	$\Delta\sigma^{r}_{eu}$
Mean	0.004	0.002	0.001	0.002	0.000	0.000	0.000	0.000	0.010	-0.056	-0.001
Median	0.002	0.007	0.002	-0.002	-0.065	-0.004	0.000	0.000	-0.167	-0.036	-0.017
Maximum	0.140	0.121	0.200	0.340	2.713	0.280	0.025	0.019	9.567	11.528	1.202
Minimum	-0.122	-0.116	-0.163	-0.301	-0.943	-0.252	-0.029	-0.012	-11.812	-14.770	-1.383
Std dev	0.045	0.043	0.057	0.098	0.359	0.077	0.008	0.004	3.455	3.199	0.393
Skewness	0.168	0.075	0.345	0.221	2.914	0.129	-0.367	0.654	-0.160	-0.584	0.205
Kurtosis	3.555	3.107	3.874	3.921	22.405	4.377	5.469	6.187	3.494	6.310	4.278
Jarque-Bera	2.8	0.2	8.2	6.9	2719.6	13.0	43.9	78.6	2.297	81.611	11.9
Probability	0.248	0.893	0.016	0.032	0.000	0.002	0.000	0.000	0.317	0.000	0.003
Δs^{i}_{eu}	1.000										Correlation matrix
Δs^{f}_{eu}	0.895	1.000									
Δs^{s}_{eu}	0.697	0.774	1.000								
Δy^{10}_{eu}	-0.441	-0.452	-0.417	1.000							
$\Delta\sigma^{y}_{eu}$	-0.015	0.015	0.095	0.191	1.000						
Δsl_{eu}	-0.481	-0.431	-0.111	0.290	0.303	1.000					
$\Delta\ell^{30}_{eu}$	0.015	-0.025	-0.007	0.123	0.040	-0.040	1.000				
$\Delta\ell_{eu}$	0.026	0.056	0.207	-0.001	0.138	0.089	-0.010	1.000			
$r_{eu,i}$	-0.096	-0.037	-0.023	-0.007	0.014	0.010	-0.045	-0.065	1.000		
$r_{eu,b}$	-0.197	-0.101	-0.100	-0.015	-0.065	-0.014	0.011	0.010	0.640	1.000	
$\Delta\sigma^{r}_{eu}$	0.148	0.088	0.107	-0.085	0.089	0.038	-0.158	0.093	-0.619	-0.672	1.000

Table 5: Descriptive statistics of variables used in regressions for US area

	Δs^{i}_{us}	Δy^{10}_{eu}	$\Delta\sigma^{y}_{us}$	Δsl_{us}	$\Delta\ell^{30}_{us}$	$\Delta\ell_{us}$	$r_{us,i}$	$\Delta\sigma^{r}_{us}$
Mean	0.000	-0.005	0.001	0.000	0.000	0.000	0.227	0.001
Median	-0.002	-0.013	-0.037	0.002	-0.001	0.000	0.399	-0.006
Maximum	0.385	0.505	1.223	0.275	0.094	0.035	7.556	1.518
Minimum	-0.152	-0.440	-0.476	-0.246	-0.051	-0.028	-10.183	-1.514
Std dev	0.045	0.132	0.193	0.063	0.011	0.007	2.088	0.327
Skewness	1.097	0.082	2.373	-0.123	1.986	0.403	-0.513	0.123
Kurtosis	12.971	3.469	13.546	4.743	16.295	5.352	4.790	6.106
Jarque-Bera	2393.2	5.7	3070.1	71.1	4420.4	141.9	97.7	222.8
Probability	0.000	0.058	0.000	0.000	0.000	0.000	0.000	0.000
Δs^{i}_{us}	1.000							Correlation matrix
Δy^{10}_{us}	-0.624	1.000						
$\Delta\sigma^{y}_{us}$	-0.025	0.115	1.000					
Δsl_{us}	-0.392	0.105	0.027	1.000				
$\Delta\ell^{30}_{us}$	0.108	-0.037	0.093	0.006	1.000			
$\Delta\ell_{us}$	0.020	0.119	0.048	-0.048	0.143	1.000		
$r_{us,i}$	0.035	-0.180	-0.073	-0.189	-0.074	-0.044	1.000	
$\Delta\sigma^{r}_{us}$	-0.007	0.072	0.069	0.140	0.071	0.059	-0.722	1.000

Table 6

Results of estimations for credit spread changes

	Euro-industrials: Δs_{eu}^{i}						Euro-financials: Δs_{eu}^{f}					
Var	**Complete model**			**Parsimonious model**			**Complete model**			**Parsimonious model**		
	Coeff	t-Stat	p-Val	Coeff	t-Stat	p-Val	Coeff	t-Stat	p-Val	Coeff	t-Stat	p-Val
Δy_c^{10}	-0.136	-4.453	0.000	-0.140	-4.610	0.000	-0.128	-4.615	0.000	-0.128	-4.756	0.000
$\Delta\sigma_c^y$	0.019	2.186	0.030	0.021	2.424	0.017	0.021	2.514	0.013	0.022	2.789	0.006
Δsl_c	-0.283	-7.102	0.000	-0.280	-7.029	0.000	-0.254	-7.048	0.000	-0.255	-7.175	0.000
$\Delta\ell_c^{30}$	0.279	0.781	0.436				0.087	0.258	0.797			
$\Delta\ell_c$	0.639	0.887	0.377				1.226	1.749	0.082	1.220	1.772	0.078
$r_{c,s}$	0.000	0.138	0.890				-0.001	-1.275	0.204	-0.002	-1.902	0.059
$r_{c,s}^{t-1}$	-0.002	-2.182	0.031	-0.002	-2.044	0.043	0.000	-0.222	0.825			
$\Delta\sigma_c^r$	0.020	1.976	0.050	0.017	2.296	0.023	-0.001	-0.058	0.953			
MA(1)	-0.170	-2.061	0.041	-0.148	-1.838	0.068	-0.345	-4.304	0.000	-0.344	-4.397	0.000
R^2		0.397			0.387			0.408			0.408	
$\bar{R}^2$		0.365			0.367			0.377			0.388	
DW		1.980			1.961			1.986			1.986	

	Euro-swap: Δs_{eu}^{s}						US-industrials: Δs_{us}^{i}					
Var	**Complete model**			**Parsimonious model**			**Complete model**			**Parsimonious model**		
	Coeff	t-Stat	p-Val	Coeff	t-Stat	p-Val	Coeff	t-Stat	p-Val	Coeff	t-Stat	p-Val
Δy_c^{10}	-0.201	-5.203	0.000	-0.201	-5.427	0.000	-0.211	-12.72	0.000	-0.207	-13.01	0.000
$\Delta\sigma_c^y$	0.022	1.815	0.072	0.022	1.974	0.050	0.006	0.591	0.555			
Δsl_c	-0.083	-1.687	0.094	-0.087	-1.805	0.073	-0.255	-9.208	0.000	-0.257	-9.460	0.000
$\Delta\ell_c^{30}$	0.273	0.590	0.556				0.273	2.725	0.007	0.316	2.956	0.003
$\Delta\ell_c$	3.248	3.328	0.001	3.313	3.438	0.001	0.372	1.720	0.086			
$r_{c,s}$	-0.002	-0.997	0.320				-0.003	-2.313	0.021	-0.003	-2.008	0.045
$r_{c,s}^{t-1}$	0.001	0.788	0.432				-0.003	-4.207	0.000	-0.003	-4.436	0.000
$\Delta\sigma_c^r$	0.001	0.060	0.952				0.001	0.128	0.898			
MA(1)	-0.382	-4.832	0.000	-0.387	-5.058	0.000						
R^2		0.342			0.332			0.547			0.544	
$\bar{R}^2$		0.307			0.315			0.542			0.540	
DW		2.004			2.002			1.950			1.944	

Note: The R^2 with bar denotes the R^2 adjusted for the number of parameters. DW is the Durbin-Watson test statistic for the presence of first order autocorrelation in the residuals. Under the null hypothesis that there is no autocorrelation in the first lag the Durbin-Watson statistic equals two. In addition the Breusch-Godfrey LM Test for serial correlation was performed. The results are the same, ie there is no evidence for autocorrelation. The residuals were also tested for the presence of heteroskedasticity using White's test and an ARCH-LM test. Both tests indicate that there is no heteroskedasticity in the residuals of the European models, but for the US models strong evidence for the presence of heteroskedasticity was found. Hence White's heteroskedasticity-consistent estimator was used to calculate the respective standard errors and covariance.

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Measuring capital market integration

Marina Emiris,[1] National Bank of Belgium

Abstract

The convergence of European economies in the wake of European monetary union, together with increasingly common dynamics in currency and equity returns, suggests that capital markets are at least partially integrated. We impose a dynamic factor analytical model for the returns on currency and stock portfolios on eight European markets, taking into account predictability by forward premia and dividend yields. The resulting asset pricing model is characterised by time-varying risk premia, and constant betas and return variances. We propose a measure of the degree of integration and examine its evolution from 1979 until 1997. We find that the degree of integration for equity markets increased in the 1990s but that this was mainly due to an increase in the premium for extra-European currency risk. We also find that the sources of co-movement lie only in part in the US equity markets.

1. Introduction

This paper studies the extent to which capital markets in Europe are integrated. If markets are completely integrated, assets possessing the same risk characteristics will have the same price even if they are traded on different markets. In completely integrated capital markets, investors face common and country-specific or idiosyncratic risk, but price (identically in all markets) only common risk factors, because country-specific risk is fully diversifiable. When markets are partially integrated, investors face both common and idiosyncratic risks and price them both. If markets are completely segmented, investors face and price only country-specific sources of risk. In this case, the same projects in two countries can have different expected returns, since the sources of risk and their prices may differ across markets.

One way to measure the degree of financial integration is to study the effect of legal barriers and taxes on capital flows[2] or prices,[3] such as restrictions on foreign stock ownership and regulations on mutual funds' investments. This approach suffers from the disadvantage that, on the one hand, not all countries impose the same formal restrictions on capital flows, and on the other hand, investors find ways to circumvent legal barriers to arbitrage, so that cross-country comparisons and the effective intensity of segmentation become difficult to measure.

Another approach is to test whether markets are integrated by assuming an asset pricing model. Under the assumption of fully integrated capital markets, the price of an asset will depend on its covariance or beta with the return on a mean variance efficient benchmark portfolio. This approach has been used extensively to study world capital market integration: for example by Harvey (1989, 1991) and De Santis and Gerard (1997) through a world CAPM; by Ferson and Harvey (1993, 1994) through a multiple risk observable factor model; and by Adler and Dumas (1983), Stulz (1981, 1998), Dumas and Solnik (1995), Dumas (1994) and De Santis et al (1998) through a world CAPM with currency risk and a consumption-based model. Testing integration in this framework entails testing the

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[1] NBB Research Department, e-mail: marina.emiris@nbb.be. I am grateful to Lucrezia Reichlin, Jorge Rodrigues and Bas Werker for helpful suggestions and comments. All errors are mine. The views expressed are those of the author.

[2] See, for example, Portes and Rey (1999) and Lemmen and Eijffinger (1995). More recently, Bekaert and Harvey (1995) have used capital flows together with other macroeconomic variables to date integration in world markets.

[3] For example, Hietala (1989) and Bailey and Jagtiani (1994) study the price differential between restricted and unrestricted shares that have identical payoffs, and Bonser-Neal et al (1990) study the differences between official and black market exchange rates, between official and offshore interest rates, or between the market price and the net asset value of closed end mutual funds.

pricing restriction imposed on all the assets by the model. Therefore, if the benchmark portfolio is misspecified, in the sense that it does not capture all systematic sources of risk, the test will reject the integration hypothesis incorrectly. In order to curtail this problem, it is possible to consider that, even though the benchmark portfolio is unobservable, the covariance matrix of the asset returns follows a latent factor structure. Arbitrage pricing theory (APT) tells us that, as long as the latent risk factors are correctly identified, assets can be priced accurately through their covariance with the factors. In this case, identification of the systematic sources of risk is, from a statistical point of view, more complicated, in the sense that one needs to make assumptions on the statistical properties of the data generating process for returns. Such assumptions are made on the conditional mean of returns (Campbell and Hamao (1992), Bekaert and Hodrick (1992)), the conditional variance of returns or the conditional variance of the factors, such as the factor-ARCH model used by Engle et al (1990) and many others more recently, such as Ferson and Harvey (1999). The APT provides us with a pricing restriction that can be tested or used to ascertain the validity of the factor model. In the framework of an international APT, this is the approach followed by King et al (1994) and Sentana et al (1999) to study the sources of time variation in the correlations between market returns and the effects of EMU on the cost of capital.

In this paper, we use a K-latent dynamic factor model with constant betas and constant conditional second moments for currency and stock returns on eight European markets. A dynamic factor approach is needed in order to capture the predictability of monthly returns.[4] In particular, the asset pricing model is dynamic in the sense that conditional expected returns vary through time because common factor risk premia are time-varying.[5] Furthermore, because an investor would price only systematic sources of risk, the model for returns should be able to distinguish between this type of risk and idiosyncratic or diversifiable risk. Therefore, I adopt the dynamic factor model proposed by Forni and Reichlin (1998). This model imposes returns to be predictable, the source of predictability and co-movement being “European” common shocks that propagate across markets and countries and generate the observed co-movement of returns. In fully integrated markets, these common shocks also constitute systematic or undiversifiable “business cycle risks”, as opposed to idiosyncratic or country-specific sources of risk which a European investor can completely diversify away by investing in the different markets.

This paper evaluates the extent to which the source of common risk valued by investors in European markets is “macroeconomic” fluctuations, in contrast to “financial” ones, and investigates whether their source lies in Europe or spills over from the US economy and financial markets. Having imposed the dynamic factor model on the set of asset returns in different European countries, we are able to extract their common component. This is, by construction, the part of each market’s expected asset return that is spanned by the same systematic risk premia and it is used to investigate the following questions concerning the sources of the common shocks: What are the sources of common fluctuations in stock returns? Have the aggregate currency and market risk premia increased? Does the source of EU-wide market risk lie in US or home output? Furthermore, are European financial common components mainly due to spillovers from the US stock markets?

The organisation of this paper is as follows. Section 1 presents the dynamic factor model, which we impose on returns on currency and stock portfolios across European markets. Section 2 describes the asset pricing model and uses a “no arbitrage opportunities” argument to show that asset returns will follow a one-factor model under the hypothesis that capital markets are perfectly integrated. Section 3 presents the estimation methodology and the measure of the degree of integration. Section 4 presents the empirical application and the results. Section 5 summarises and concludes.

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4 For the United States, see Fama and French (1992), Fama (1990) and Bekaert and Hodrick (1992); see also Campbell and Hamao (1992) for international currency and stock returns and Canova and DeNicolo (1997) for currency and bond returns in Europe.

5 In a general equilibrium model, common factor risk premia would reflect the price of risk associated with the business cycle.

2. The conditional factor model for returns

The starting point for the analysis is a dynamic factor model for returns, based on the dynamic factor analytical model proposed by Forni and Reichlin (1998). Assume a world with a large number of countries, i = 1...N. For each country, consider the returns on two types of portfolios: a currency portfolio with excess return χ_{it}^{c}, and a stock portfolio with return χ_{it}^{r}. Stock returns are expressed in home currency, in excess of the eurocurrency rate for a one-month investment on the London market. Currency returns are considered for a covered investment in USD and, under interest rate parity, we have that currency returns are currency prices in excess of the previous month forward rate. Consider also dividend yields, χ_{it}^{dy}, and forward premia, χ_{it}^{fp}. Let us assume that the vector return process χ_{it}, of size equal to J = 4, containing the stacked $\left\{\chi_{it}^{(j)}\right\}$ $j = \{c, r, dy, fp\}$, has the following dynamic factor structure:

$$\chi_{it} = \mu_i + \sum_{k=1}^{K} C_k^i(L) u_{kt} + \varepsilon_{it}\,, \quad i = 1...N \tag{1}$$

$K < NJ$ is the dimension of the factor model. Of course, we can write equation (1) for each variable separately, but for what we will need further on, we will just present the two equations concerning returns:

$$\chi_{it}^{c} = \mu_i^{c} + \sum_{k=1}^{K} C_{ck}^{i}(L) u_{kt} + \varepsilon_{it}^{(c)} = \chi_{it}^{(c)} + \varepsilon_{it}^{(c)} \tag{2}$$

$$\chi_{it}^{r} = \mu_i^{r} + \sum_{k=1}^{K} C_{rk}^{i}(L) u_{kt} + \varepsilon_{it}^{(r)} = \chi_{it}^{(r)} + \varepsilon_{it}^{(r)} \tag{3}$$

where $\left\{\mu_i^j\right\}$ are the unconditional means of the variables, u_{kt}, $k = 1...K$ are K shocks or systematic risk factors, common to all European capital markets and economies, $\left\{\varepsilon_{it}^{(j)}\right\}$ are country- and variable-specific or idiosyncratic components associated with currency, stock returns, dividend yields and forward premia in each country respectively, $\left\{C_{jk}^{i}(L)\right\}$ are infinite order lag polynomials in the lag operator L and $\left\{\chi_{it}^{(j)}\right\}$ will be called the common components. The common shocks are uncorrelated with each other contemporaneously and at all leads and lags, and uncorrelated with all idiosyncratic variables. In particular, for E_{t-1}, noting the conditional expectation with respect to the information set, the following assumptions are made:

1. The common shocks u_{kt}, $k = 1...K$ and the idiosyncratic components, $\left\{\varepsilon_{it}^{(j)}\right\}$, are zero mean variables, mutually uncorrelated and orthogonal at all leads and lags, ie $E_{t-1}u_{kt} = 0$ for $k = 1...K$ and $E_{t-1}\varepsilon_{it} = 0$,
   $E_{t-1}u_{kt}u_{lt} = 0$ for $k, l = 1...K$, $E_{t-1}u_{kt}\varepsilon_{it} = 0$ for $k = 1...K$

   which, in turn, implies:

   $E_{t-1}u_{lt}u_{kt-s} = 0$ for $s = 1, 2...$, and $E_{t-1}u_{kt}\varepsilon_{it-s} = 0$ for $k = 1...K, s = 1, 2...$

2. $E_{t-1}(u_{kt-1})^2 = E(u_{kt-1})^2 = \sigma^2$ for $k = 1...K$: the common shocks have constant conditional variances.

3. $E_{t-1}\left(\varepsilon_{it}^{(j)}\right)^2 \prec \infty, \forall j$: the idiosyncratic term also has constant and finite conditional variance.

Furthermore, as in Forni and Reichlin (1998), it is assumed that the idiosyncratic components are mutually orthogonal, although they could be autocorrelated.

The model allows for cross section and time series heterogeneity, since the degree of the lag polynomials may differ across countries. Using a law of large numbers argument, Forni and Reichlin

(1998) show that as the cross section becomes asymptotically large, because of the orthogonality property of the idiosyncratic components, the idiosyncratic component "vanishes" when we form *K* aggregates of the variables.[6] This means that the *K* aggregates, formed by taking linear combinations of the variables, will span the space of the common shocks and that we can use them to identify the number of common shocks, recover the common component and also estimate the factor risk premia.

This factor model for the asset returns is observationally equivalent to the general *K*-factor model with time-varying conditional mean for returns and constant second moments used in the financial literature by, for example, Fama (1990), Campbell and Hamao (1992) and Bekaert and Hodrick (1992). To see this, note that equation (1) can be rewritten in the following way:

$$\begin{aligned} \chi_{it} &= E_{t-1}\chi_{it} + \sum_{k=1}^{K} C_k^i(0)u_{kt} + \varepsilon_{it} = E_{t-1}\chi_{it} + \eta_{it} \\ \text{with } E_{t-1}\chi_{it} &= \mu_i + \sum_{k=1}^{K} C_k^i(L)u_{kt-1} \end{aligned} \tag{4}$$

where $E_{t-1}\chi_{it}$ is the vector of the conditional mean returns on the currency and stock portfolios or, in other terms, the risk premia for the portfolios in country *i* and η_{it} is the corresponding unanticipated (at *t*-1) component for returns. Notice that the information set I_{t-1} also contains the past of dividend yields and forward premia. The usual factor representation for the covariance structure of returns is the following:

$$\chi_{it} = E_{t-1}\chi_{it} + \sum_{k=1}^{K} \beta_{ik} f_{kt} + \varepsilon_{it} \tag{5}$$

The factors, f_{kt}, are mutually orthogonal and uncorrelated with the idiosyncratic term ε_{it}, and the time-invariant beta coefficients β_{ik} measure the sensitivity of each asset to the common sources of risk. In the general case, the statistical model for returns does not explicitly restrict the conditional mean to depend on the factors. An asset pricing restriction obtained through an economic model such as a partial equilibrium consumption model, or through a model-free assumption, such as a no arbitrage opportunities argument, will link the conditional mean of returns to time-varying factor risk premia. Furthermore, all time variation in the risk prices is assumed to be captured by a few state variables in the information set. The dynamic factor model imposes that the state variables in the economy and the asset returns span the same space, which in turn is spanned by the common shocks. The conditional mean of the returns depends for this reason on the factors themselves and the betas measure not only the sensitivity of individual asset returns to the different sources of risk, but also the delay in propagation of the shocks in each market and country.

Equations (2) and (3) decompose returns into two components. The first, χ_{it}, is spanned by the present and past of the common shocks or risk factors and the second, ε_{it}, is country- and variable-specific. Equations (4) and (5) decompose the unanticipated component of returns into two parts: the first depends on the current realisation of the common shocks but differs across countries depending on the sensitivity of each variable in each market with respect to the risk under consideration; the second is the idiosyncratic component and, under the assumptions, it is diversifiable. Note that the two representations are observationally equivalent and further assumptions need to be made to estimate the two models. One possibility is to model the variance of the asset returns as a GARCH process. In this case, the time variation of conditional asset returns stems from the time variation of factor variances, as for example in King et al (1994) and Engle et al (1990). Another possibility is to consider that time variation in conditional mean returns stems from time-varying prices/risk premia of common factor risk, as for example in Bekaert and Hodrick (1992). The dynamic factor model also uses this second approach.

The motivation for this is twofold. First, we would like to focus on whether a few European-wide shocks can generate common cycles in currency and stock returns across countries. There is evidence in

[6] The same result is obtained through milder conditions on the idiosyncratic components in Forni and Lippi (2000) and Forni et al (1999).

Europe that a few variables have the ability to forecast returns on different markets and for different types of assets. Canova and De Nicolo (1995), based on a theoretical model developed in Canova (1993), present some empirical evidence on the relation between stock returns and real activity in Europe in the form of Fama regressions. Calibration of their theoretical model to European data supports the view that international linkages in stock returns emerge because foreign variables contain information about the future path of domestic variables. In another paper, Canova and De Nicolo (1997) examine the relation between stock returns, the term structure of interest rates, inflation and real activity for the United States, Japan, the United Kingdom and Germany from an open economy perspective. They find that nominal stock returns are linked with US inflation and United States, rather than European real variables, and that real and financial variables do not respond to innovations in inflation and exchange rates. Patelis (1997) confirms for the United States that variables that predict the US business cycle, such as the term spread, have the ability to predict US stock returns.

The second motivation for using a dynamic factor model is that, when using weekly or daily data, asset pricing models that impose time variation in second moments perform well empirically, and the GARCH modelling approach seems more suitable; with monthly data however, conditional return variances appear to be constant whereas time variation in the conditional mean is more important, and therefore, the second approach should be more appropriate. Predictability of stock returns, which is associated with time-varying expected returns, is mainly observed over long horizons, as shown for the US by Fama (1990), and Schwert (1990). However, changes in the conditional variance of stock returns are observed mainly in daily and weekly data and not over longer periods. In particular, volatility does not seem to move with business cycles, whereas there is some evidence (in the United States) that expected returns do (Schwert (1990), Harvey (1991)). Forecasts of excess stock returns do not appear to move proportionally with estimates of the conditional variance (Harvey (1989, 1991)). Finally, from a theoretical point of view, one would like ultimately to derive time-varying volatility of returns endogenously from a general equilibrium model. For example, the asset pricing restriction that we will derive in the next section can be obtained through the consumption capital asset pricing model if d_t the stochastic discount factor, is interpreted as the common intertemporal marginal rate of substitution in consumption, with power utility function. Unfortunately, as Campbell (1998) points out, there is no evidence of cyclical variation in consumption or dividend volatility that could be the source of stock market volatility or the source of time-varying mean returns.

3. Asset pricing

In the previous section, we imposed a factor structure for the asset returns. Now we will derive a pricing restriction that must hold for all assets in every market under the assumption of full integration. Then we will show how to estimate the model if we relax this assumption and how to construct a measure of integration for each market in each country.

In the general case, any factor model implies the following restriction for the conditional mean of returns using our previous notation, where λ_{kt} is the price of risk for the k^{th} risk factor[7]

$$E_{t-1}\chi_{it}^{j} = \sum_{k=1}^{K} \beta_{ik}^{j} \lambda_{kt} \quad \text{for } j = c,r \tag{6}$$

This restriction can be obtained in different ways and in each case there will be a different interpretation for the K priced sources of risk. For example, in Campbell (1996) the restriction obtains in an intertemporal asset pricing model, for a closed economy consumption CAPM, while in Adler and Dumas (1983) and Dumas (1994), it obtains for an open economy consumption CAPM with idiosyncratic exchange rate risk. Equivalently, the pricing restriction can be obtained by using arbitrage pricing theory. If no arbitrage opportunities exist, it is possible to show that, under some conditions on the size of the idiosyncratic component, a pricing kernel or stochastic discount factor will always exist and that it will allow assets to be priced correctly through its covariance with the return on each asset.

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[7] The risk premia λ_{kt} belong to the information set I_{t-1}.

This approach is particularly useful in our context since, under the model assumptions, if we allowed the cross section to increase asymptotically and then formed K portfolios using the assets at hand, these aggregate portfolios would contain no idiosyncratic risk. Since the predictable component of the return of each aggregate portfolio is a linear combination of the K-factor risk premia, we can use conditional expected aggregate returns as estimates of the factor risk premia.

King et al (1994) show for a static factor model with time-varying conditional factor variances that, under a mild no arbitrage condition and under the assumption that the idiosyncratic component "vanishes" as the cross-sectional dimension increases asymptotically, there exists a stochastic discount factor d_t which prices the available assets by discounting their random payoffs to their present value. Since the condition on the idiosyncratic component is also satisfied by this dynamic factor model, we will follow their line of argument to obtain a pricing relation under the null hypothesis of completely integrated European markets.

Under the hypothesis that financial markets are fully integrated, there exists a stochastic discount factor which prices all types of assets in all markets. The discount factor can be thought of as the return on a portfolio that captures only aggregate sources of risk. For example, in a closed economy APT model, the pricing kernel is reduced to the return on the risk-free asset. In a consumption CAPM model, the pricing kernel is the intertemporal elasticity of substitution in consumption. In other words, the pricing kernel provides us with a measure with which to evaluate the riskiness of the assets. As with observable benchmark asset pricing models, the premium of the asset depends on its covariance with the benchmark portfolio, in this case d_t. Since we are considering currency returns that are in excess of the risk-free rate and stock returns that are hedged for currency risk, the absence of arbitrage opportunities in perfectly integrated markets implies the following pricing restriction on returns χ_{it}:

$$E_{t-1} d_t \chi_{it}^j = 0 \quad \text{for } j = c, r \tag{7}$$

Furthermore, since d_t is a return on an asset, it has a factor representation as in (1):

$$\begin{aligned} & d_t = d_t^* + \sum_{k=1}^{K} C_k^*(0) u_{kt} + \varepsilon_t^{(*)} \\ & \text{where } d_t^* = E_{t-1} d_t \end{aligned} \tag{8}$$

Now, replacing the definition for d_t from (8) and for returns from (2-3) in (7) and under the model assumptions (1) to (3), obtain:

$$E_{t-1} d_t \chi_{it}^j = 0 \Leftrightarrow d_t^* E_{t-1} \chi_{it}^j + \sum_{k=1}^{K} C_k^*(0) C_{jk}^i(0) \sigma_k^2 + E_{t-1} \varepsilon_t^* \varepsilon_{it}^{(j)} = 0 \quad \text{for } j = c, r$$

Under the null of perfectly integrated markets, d_t is, by definition, the return on a well diversified portfolio, therefore the idiosyncratic term is zero in conditional mean squares (assumption (3) in the model). So asset excess returns χ_{it} and d_t are correlated only through the common risk factors $u_{1t}, \ldots, u_{Kt}$ and as a consequence, the last term of the above sum converges to zero. It follows that the pricing restriction (7) becomes:

$$\begin{aligned} & E_{t-1} \chi_{it}^j = -\sum_{k=1}^{K} \frac{C_k^*(0)}{d_t^*} C_{jk}^i(0) \sigma_k^2 \Leftrightarrow E_{t-1} \chi_{it}^j = \sum_{k=1}^{K} C_{jk}^i(0) \pi_{kt} \\ & \text{with } \pi_{kt} \equiv \frac{C_k^*(0)}{d_t^*} \sigma_k^2 \quad \text{for } j = c, r \text{ and } k = 1 \ldots K \end{aligned} \tag{9}$$

where π_{kt} are the K-factor risk premia.[8] Equation (9) is the linear factor pricing model for risk and provides a connection between the conditional mean of returns and the factor risk premia. Factor risk premia measure the amount of expected return that the agent is willing to give up to reduce variability

8 Notice that $\pi_{kt} \in I_{t-1}$ since $d_t^* \in I_{t-1}$.

by σ_k^2 units. Notice that the risk premia depend on the common factors (shocks), not the assets, and that under the null of completely integrated markets, idiosyncratic risk is not priced. Factor risk premia are time-varying because the conditional mean of the pricing kernel, d_t^*, is time-varying. Full integration implies that all risk premia will be proportional to $\left(\frac{1}{d_t^*}\right)$. The next section explains how to proceed with estimation and testing.

4. Estimation and testing

The pricing equations in (9) state that the *2N* conditional expected returns on the currency and stock portfolios are proportional to the expected returns on *K* well diversified portfolios or, equivalently, to *J* linear combinations of the *K*-factor risk premia, $C(0)\pi_t$. In the next section, we follow the methodology proposed in Forni and Reichlin (1998) to construct *J* aggregates and estimate the common component of returns.

4.1 Aggregation and estimation of the common components

Under the assumptions (1)-(3) of the factor model, Forni and Reichlin (1998) show that when the cross section is asymptotically large, the idiosyncratic component vanishes through aggregation. This implies that, if *K* is known, *K* aggregates and the common shocks span the same space and, therefore, we can use the aggregates to determine the number of common (priced) risks under the null of completely integrated markets. Aggregation can be achieved using different types of averaging sequences as long as they satisfy the properties presented in Forni et al (1999). One possibility is to use simple averages, but we must check that the aggregates obtained in this way are not collinear. Collinearity would have as a potential consequence the underestimation of the dimension of the factor space *K*. One advantage of taking simple averages compared to other aggregation methods, such as static or dynamic principal components, is that they produce aggregates which are straightforward to interpret. We construct the aggregates by averaging each variable over *N* countries.

$$\chi_t^c = \frac{1}{N}\sum_{k=1}^{N}\chi_{it}^c,\ \chi_t^r = \frac{1}{N}\sum_{k=1}^{N}\chi_{it}^r,\ \chi_t^{dy} = \frac{1}{N}\sum_{k=1}^{N}\chi_{it}^{dy},\ \chi_t^{fp} = \frac{1}{N}\sum_{k=1}^{N}\chi_{it}^{fp}$$

To estimate *K*, we use a procedure based on the dynamic eigenvalues of χ_{it} described in Forni et al (1999). Then, to obtain a consistent estimate of the common component, we regress each variable (demeaned) on the past, present and future of the aggregates as in equation (10):

$$\chi_{it}^j = \sum_{j=c,r,dy,fp}\left(\sum_{l=-p}^{p}\gamma_{j,l}\chi_{t-l}^j\right) + \hat{\varepsilon}_{it}^j \Rightarrow R_{ij}^2 \tag{10}$$

Finally, we perform diagnostic tests on the estimated idiosyncratic components, $\hat{\varepsilon}_{it}^j$ to confirm that they are only mildly correlated, as is required by the model assumptions.

4.2 Measuring the degree of integration

In this section, we define the degree of integration between two markets in different countries, disentangle two sources of European-wide risk and study their evolution. Sentana et al (1999) and De Santis et al (2000) find that the prospect of European monetary union has mainly had two effects: first, to reduce the premium associated with interest rate fluctuations, as a result of a single monetary policy. In their study, Sentana et al (1999) find that lower idiosyncratic exchange rate risk leads to lower interest rate risk premia, one of the reasons being that, with a single currency, national central banks are not forced to defend their currency against other European currencies. Second, they find evidence that although the single currency eliminates intra-European currency risk, this effect is small relative to the increase in the premium for non-EMU risk.

We define the degree of integration of market *j* in country *i* to be the adjusted R^2 of regression (10). Then, to disentangle the evolution of the premia for two sources of common risk, aggregate currency risk and aggregate market risk, we use the following definitions: first, we assume that aggregate exchange rate risk is captured by the return on the aggregate currency portfolio. Aggregate currency portfolios do not contain other types of aggregate or idiosyncratic risk. Second, we define what remains once exchange rate risk is accounted for as the risk associated with a country's stock market.

$$\begin{aligned} \chi_t^c &= a_{c0} + a_{c1}\chi_t^r + e_t^c \\ \chi_t^r &= a_{r0} + a_{r1}\chi_t^c + e_t^r \end{aligned} \tag{11}$$

The components e_t^c and e_t^r represent the aggregate return in excess of the risk-free rate that rewards currency risk and market risk, respectively.

Did the elimination of intra-European currency risk also reduce risk with respect to the dollar? To what extent are co-movements in stock returns due to European-wide common market shocks? To answer these questions, we use the following decomposition: with *J* aggregates, the model is associated with a measure of fit defined previously as R_{ij}^2. We run a regression of the common component of currency returns χ_{it}^c (after we have controlled for the influence of χ_t^r) on e_t^c, and the associated $R_{c,ic}^2$ is the percentage of total variance explained by the reward to aggregate currency risk. This reflects the part of the common fluctuations of currency portfolio returns in $R_{r,ic}^2$ that can be explained by the aggregate currency risk premium. In the same way, $R_{r,ic}^2$ reflects the importance of the component of common fluctuations of stock returns that rewards EU-wide currency risk. Finally, $R_{r,ir}^2$ measures the importance of EU-wide market risk in explaining the common component of stock returns in country *i*. To summarise, $R_{c,ic}^2$, $R_{r,ir}^2$ and $R_{r,ic}^2$ give an indication of the part of total variance of the common component of returns explained by risk premia and are, in fact, the partial correlation coefficients of χ_{it}^c and χ_{it}^r with respect to χ_t^c and χ_t^r computed using the following regressions:

$$\chi_{it}^c = \gamma_{0i}^c + \gamma_{1i}^c\chi_t^c + \gamma_{2i}^c\chi_t^r + w_{it}^c \Rightarrow R_{c,ic}^2 \tag{12}$$

$$\chi_{it}^r = \gamma_{0i}^r + \gamma_{1i}^r\chi_t^c + \gamma_{2i}^r\chi_t^r + w_{it}^r \Rightarrow R_{r,ir}^2, R_{r,ic}^2 \tag{13}$$

In the absence of perfect capital market integration, we are interested in finding out whether financial integration has increased nonetheless, and how the relative importance of the different components evolves over time. The sample (1979:1-1997:12) was split into four subsamples, with break dates 1984:4, 1989:4 and 1993:6. Furthermore, we use rolling estimation of the R_{ij}^2 (equation (10)) to identify dates associated with a steady increase (or decrease) of financial integration. We use a 36-month regression window, starting from the period 1979:2-1982:2 and move this window forward by one month at a time.

Finally, we would like to investigate whether the sources of the common fluctuations in stock returns are associated with the economies of some European countries in particular, the US economy or the US stock market. To answer these questions, we regress the common component of stock returns on aggregate industrial production growth $(\Delta\log(\mathrm{IP_t}))$, aggregate industrial production growth in the United States $(\Delta\log(\mathrm{IPUS_t}))$ and stock returns in the United States $(\Delta\log(\mathrm{RUS_t}))$.

$$\hat{\chi}_{it}^r = a_i\Delta\log(IP_t) + b_i\Delta\log(IPUS_t) + c_i\Delta\log(RUS_t) \tag{14}$$

The estimated coefficients and the partial correlation coefficients in this regression will tell us if the source of European-wide stock market risk lies in the European business cycle, the US business cycle or spillover effects from the US financial markets.

5. Empirical application

5.1 Data

We estimate the models described in the previous sections using monthly data for currency and stock returns on eight European markets between January 1979 and December 1997. Currency returns were constructed using exchange rates in excess of the forward rate for the previous month, which under interest rate parity is equivalent to exchange rate changes in excess of the difference between the eurocurrency rate on the London market and the one-month US Treasury bill rate. Excess equity returns were constructed from price and dividend yield data and were expressed in home currency in excess of the eurocurrency rate on the London market. Notice that the sum of equity returns and currency returns yields the dollar return in excess of the US risk-free rate for an equity investment in country *j* market. The eight countries considered were: Belgium, France, Germany, Italy, the Netherlands, Spain, Finland and the United Kingdom. Of these, the United Kingdom does not participate in EMU. Stock portfolios for each country are capitalisation-weighted market portfolios and at country level they represent well diversified portfolios, in the sense that all sector-specific risk has been eliminated and only country-specific risk is present. We also consider dividend yields ($log(div_{it}/P_{it})$), and forward premia ($log(f_{it}/e_{it})$). The factor model allows us to capture the dynamics of the asset returns. In particular, these variables have been shown by Bekaert and Hodrick (1992) and Campbell and Hamao (1992) to have forecasting power for the currency and stock returns.

Table 1, panel A provides summary statistics on the excess returns in the sample over the entire period. Currency returns are characterised by lower means than stock returns. France, Germany, the Netherlands and the United Kingdom present negative excess currency returns, implying that these portfolios constitute a hedge for the period under study. The cross-sectional variation of standard deviations is relatively low, in agreement with other studies, ranging from 11.48% (Finland) to 13.22% (Spain). Average equity excess returns range from 7% (United Kingdom) to 14% (Spain) in annualised terms. The respective standard deviations are 13.01% and 21.17%. In terms of capitalisation, the largest markets in Europe are the United Kingdom, which represents one third of total capitalisation, and the French and German markets, which together account for another third of total EU-11 capitalisation. The French market presents a mean of 7.48% and standard deviation of 21.04%, which makes it the third most volatile European market in our sample after Italy and Spain. The German market presents a mean excess return of 7.94%, and volatility of 16.91%.

Table 1, panel B presents summary statistics on dividend yields and forward premia. Notice that all variables are stationary except for dividend yields, and that there are clearly some important dynamics in returns and in forward premia.

Table 2 presents the contemporaneous correlation coefficient between currency and stock excess returns. For currency returns, a comparison of correlation averages computed by excluding correlation with the country itself leads us to form three groups of countries: the first includes Italy, Finland and Spain with average correlation 72%, the second contains the Netherlands, Belgium, France and Germany with average correlation 83% and finally, as expected, the United Kingdom stands alone with 67%. Average stock return correlations are very much lower, the maximum presented by the Netherlands and Belgium (43% and 45% respectively) and the minimum by Finland (27%). The average correlation for the other markets does not vary (32% to 37%). Correlations for both types of portfolio returns appear to be quite strong, suggesting that markets are integrated at least to some degree, and, in particular, because of the ERM, currency markets co-move more strongly than equity markets.

Table 2, panel B presents the cross-country correlation coefficients between currency and stock portfolios, and means over all countries. First notice that correlations are negative. Furthermore, it appears that foreign exchange and stock markets co-move relatively strongly in the United Kingdom (–19.4%), Belgium (–20.4%) and the Netherlands (–28.9%). Spillovers for all the other markets are between 16% and 12%, except for France, where the two markets appear to move independently from each other. Looking at the average cross-correlations, we see that stock returns are more affected by currency fluctuations than the contrary. The French currency market is the least sensitive to foreign stock market fluctuations.

Table 1

Panel A: mean (μ_i), standard deviation (σ_i) and autocorrelation coefficient ($\rho_i(1)$) for currency returns in USD ($\chi_{it}^{(c)}$) and stock returns in national currency ($\chi_{it}^{(r)}$), in percentages, annualised

Period: 1979:02-1997:12

		$\chi_{it}^{(c)}$			$\chi_{it}^{(r)}$	
	μ_i	σ_i	$\rho_i(1)$	μ_i	σ_i	$\rho_i(1)$
Belgium	0.111	3.490	0.142	0.651	4.196	0.338
France	– 0.110	3.332	0.904	0.623	6.080	0.19
Germany	– 0.422	3.504	0.144	0.662	4.886	0.032
Italy	1.053	3.394	0.181	0.615	6.262	0.296
Netherlands	– 0.390	3.544	0.135	0.922	3.791	0.351
Spain	0.879	3.820	0.471	1.268	6.172	0.151
Finland	0.088	3.317	0.144	1.009	5.634	0.363
United Kingdom	– 0.093	3.434	0.132	0.638	3.757	0.195

Panel B: mean (μ_i), standard deviation (σ_i) and autocorrelation coefficient ($\rho_i(1)$) for currency returns in USD ($\chi_{it}^{(dy)}$) and stock returns in national currency ($\chi_{it}^{(fp)}$), in percentages, annualised

Period: 1979:02-1997:12

		$\chi_{it}^{(dy)}$			$\chi_{it}^{(fp)}$	
	μ_i	σ_i	ρ_i (1)	μ_i	σ_i	$\rho_i(1)$
Belgium	0.431	0.212	0.991	– 0.213	0.653	0.874
France	0.350	0.154	0.943	– 0.168	0.733	0.256
Germany	0.320	0.080	0.982	0.417	0.859	0.901
Italy	0.200	0.056	0.949	– 1.379	1.182	0.340
Netherlands	0.393	0.127	0.989	0.258	0.970	0.197
Spain	0.874	0.577	0.995	– 1.209	1.959	0.172
Finland	0.302	0.179	0.987	– 1.032	1.385	0.872
United Kingdom	0.378	0.075	0.975	– 0.117	0.839	0.213

Table 2

Panel A: correlation coefficients between currency and stock portfolios. Above the diagonal are $corr\left(\chi^r_{it}, \chi^r_{i't}\right)$ and below the diagonal are $corr\left(\chi^c_{it}, \chi^c_{i't}\right)$ for $i, i' = 1...N$

	BE	**FR**	**DE**	**IT**	**NL**	**ES**	**FI**	**GB**	**mean χ^r_{it}**
Belgium	1	0.485	0.486	0.352	0.623	0.307	0.348	0.473	0.439
France	0.940	1	0.503	0.252	0.387	0.279	0.131	0.274	0.330
Germany	0.969	0.938	1	0.314	0.530	0.331	0.193	0.317	0.382
Italy	0.809	0.803	0.795	1	0.404	0.393	0.327	0.393	0.344
Netherlands	0.941	0.930	0.959	0.803	1	0.291	0.394	0.541	0.453
Spain	0.750	0.751	0.732	0.703	0.738	1	0.255	0.381	0.320
Finland	0.765	0.779	0.746	0.770	0.762	0.692	1	0.292	0.277
United Kingdom	0.675	0.679	0.662	0.629	0.694	0.634	0.717	1	0.377
mean x^c_{it}	0.836	0.831	0.829	0.759	0.833	0.714	0.747	0.670	

Panel B: cross-correlation coefficients between currency and stock portfolios $corr\left(\chi^c_{it}, \chi^r_{i't}\right)$. On the diagonal are $corr\left(\chi^c_{it}, \chi^r_{it}\right)$ for $i, i' = 1...N$

	BE	**FR**	**DE**	**IT**	**NL**	**ES**	**FI**	**GB**	**mean**
Belgium	– 0.204	– 0.103	– 0.168	– 0.224	– 0.273	– 0.203	– 0.251	– 0.222	– 0.206
France	– 0.201	– 0.090	– 0.163	– 0.232	– 0.270	– 0.190	– 0.249	– 0.215	– 0.217
Germany	– 0.196	– 0.106	– 0.162	– 0.218	– 0.268	– 0.235	– 0.228	– 0.243	– 0.213
Italy	– 0.087	– 0.047	– 0.104	– 0.123	– 0.205	– 0.085	– 0.149	– 0.175	– 0.122
Netherlands	– 0.195	– 0.093	– 0.160	– 0.203	– 0.289	– 0.201	– 0.258	– 0.222	– 0.190
Spain	– 0.169	– 0.053	– 0.192	– 0.188	– 0.324	– 0.120	– 0.289	– 0.166	– 0.197
Finland	– 0.116	– 0.095	– 0.098	– 0.145	– 0.214	– 0.086	– 0.129	– 0.184	– 0.134
United Kingdom	– 0.083	– 0.053	– 0.102	– 0.068	– 0.197	– 0.102	– 0.152	– 0.194	– 0.108
mean	– 0.150	– 0.079	– 0.141	– 0.183	– 0.250	– 0.158	– 0.225	– 0.204	

5.2 Integration

To estimate the degree of integration, the first step is to construct the aggregate variables, currency and stock portfolios, aggregate dividend yields and forward premia, using the methodology described in the previous section, and then estimate the common components. We also have to check that the aggregates constructed in this way are not perfectly collinear; if they were, we would be at risk of underestimating the number of factors. The results in Table 3 show that the aggregates are not perfectly correlated: maximum correlation is between aggregate currency returns and aggregate forward premia (–53.6%), minimum correlation is between aggregate dividend yields and stock returns.

We estimate K and find that it is equal to four ($K = 4$). Next, we estimate the common component for the currency and stock portfolios and compute the corresponding adjusted coefficients of determination, R^2_{ij}. Following Forni and Reichlin (1998), to estimate the disaggregated model we regress the individual currency and stock returns on the present, past and future of the aggregates. The R^2_{ij} of these OLS regressions can be used to assess the relative importance of the common and idiosyncratic component for each variable. These values are shown in Table 4, for all four variables and for four subperiods. The corresponding R_{ij}^2 is a measure of the fit of the dynamic factor model, and it is also a measure of the degree of integration, in the sense that it represents the contribution of the common component to the total variance for each variable in each country. We therefore concentrate on the R_{ij}^2 from the currency and stock returns. The first column presents the R_{ij}^2 over the whole period, whereas the subsequent columns present the results for the four separate subsamples.

Table 3

Correlation between aggregates $corr\left(\chi_{it}^{(j)}, \chi_{it}^{(j')}\right)$ for *j, j' = c,r,dy,fp*, for aggregate currency, stock portfolios, aggregate dividend yields and forward premia

Panel A: currency returns

	c	*r*	*dy*	*fp*
c	1	– 0.276	– 0.156	– 0.530
r	– 0.276	1	– 0.049	0.030
dy	– 0.156	– 0.049	1	0.337
fp	– 0.530	0.030	0.337	1

Table 4

Percentage of total variation of excess currency, stock returns, dividend yields and forward premia explained by their common component R_{adj}^2 from *JN* regressions for the estimation of the common components $\chi_{it}^{(j)}$

(I. 1979:02-1984:04, II. 1984:05-1989:04, III. 1989:05-1993:06, IV. 1993:07-1997:12)

Panel A: currency returns

	I-IV	I	II	III	IV
Belgium	0.884	0.725	0.772	0.707	0.532
France	0.864	0.727	0.746	0.683	0.440
Germany	0.885	0.742	0.771	0.705	0.489
Italy	0.757	0.711	0.670	0.670	0.452
Netherlands	0.868	0.716	0.770	0.687	0.586
Spain	0.770	0.625	0.708	0.666	0.436
Finland	0.743	0.627	0.713	0.614	0.396
United Kingdom	0.637	0.440	0.619	0.672	0.434

Panel B: stock returns

	I-IV	I	II	III	IV
Belgium	0.532	0.260	0.577	0.554	0.548
France	0.440	0.434	0.460	0.434	0.560
Germany	0.489	0.361	0.445	0.601	0.529
Italy	0.452	0.409	0.487	0.575	0.471
Netherlands	0.586	0.562	0.568	0.552	0.584
Spain	0.436	0.348	0.406	0.536	0.513
Finland	0.396	0.227	0.411	0.528	0.463
United Kingdom	0.434	0.429	0.366	0.566	0.485

Panel C: forward premia					
	I-IV	**I**	**II**	**III**	**IV**
Belgium	0.568	0.478	0.475	0.524	0.527
France	0.453	0.568	0.332	0.613	0.359
Germany	0.652	0.542	0.475	0.485	0.424
Italy	0.401	0.588	0.309	0.289	0.511
Netherlands	0.544	0.302	0.470	0.618	0.390
Spain	0.676	0.600	0.633	0.600	0.601
Finland	0.427	0.624	0.271	0.603	0.482
United Kingdom	0.358	0.409	0.273	0.575	0.424

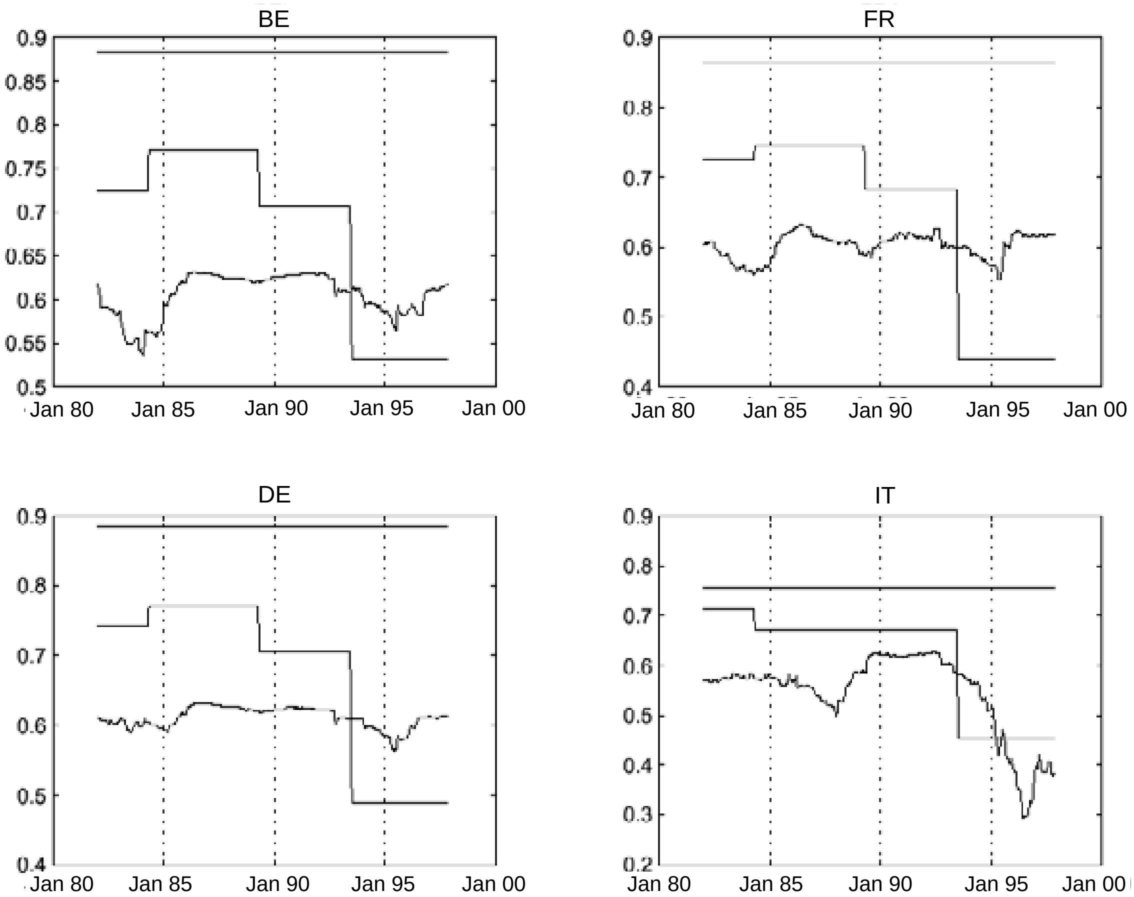
Panel D: forward premia					
	I-IV	**I**	**II**	**III**	**IV**
Belgium	0.886	0.585	0.718	0.358	0.683
France	0.822	0.601	0.636	0.626	0.672
Germany	0.704	0.673	0.559	0.574	0.495
Italy	0.178	0.494	0.589	0.583	0.205
Netherlands	0.806	0.655	0.314	0.649	0.654
Spain	0.872	0.464	0.709	0.466	0.572
Finland	0.782	0.608	0.664	0.626	0.479
United Kingdom	0.662	0.469	0.450	0.563	0.593

Foreign exchange markets appear to co-move more strongly than equity markets, the high degree presented by the foreign exchanges in Belgium, Germany, the Netherlands and France. The UK market appears to move more independently. Notice that it is the only market for which the R_{ij}^2 increases over the second period, probably because sterling joined the EMS in December 1989 even if it eventually dropped out. Italy, Spain and Finland lie somewhere in between. Stock markets are clearly less integrated than foreign exchange markets, the lowest degree of co-movement attained by Finland (39.6%). Under the null of perfectly integrated markets, the same aggregates should have been able to explain equally well the co-movements in both stock markets and equity markets, but this is not the case. Table 4 shows that the aggregates explain co-movements in the foreign exchange markets better. However, it is also clear from Table 4 that there has been a positive evolution in equity markets towards integration. Comparing the R_{ij}^2 over the four subsamples, we see that the increase has been more prominent in small markets such as Belgium, Spain and Finland, where the same common shocks double their explanatory power between the first and the last period. The increase is smaller for Germany and France. The UK's degree of market integration remains unchanged. We observe a different evolution in the foreign exchange markets, where the R_{ij}^2 remain relatively constant over the first three periods, and then decrease in the fourth, implying that the variation in exchange rates with respect to the US dollar becomes idiosyncratic.

Next, we examine the evidence provided by the rolling estimation using a window of three years and moving it forward by a month. Graphs 1-4 present graphs of the rolling R_{ij}^2 for the currency and stock portfolios. They confirm that the R^2 are indeed constant for Belgium, France, Germany and the Netherlands, which have been in the EMS longer. Countries whose currencies were at the centre of the currency crisis, ie Finland, Italy, Spain and the United Kingdom, show more variation over the sample: notice the large decrease in 1985 and 1992 for Finland and the steady decrease after mid-1993 for Italy and the United Kingdom. As far as the stock markets are concerned, it appears that, as in the previous analysis, small markets become more integrated. However, there are differences in timing. For Belgium and Finland, the process already starts in 1979 and stabilises after 1989. In Spain, the process starts later (1989) and has peaked by 1995. The rolling estimations reveal that Germany and the Netherlands also follow a similar process, starting in 1988 and peaking in 1990 for the Netherlands and 1993 for Germany. In conclusion, there appear to be differences between countries with regard to the starting dates of the integration process and the time it takes for the process to peak.

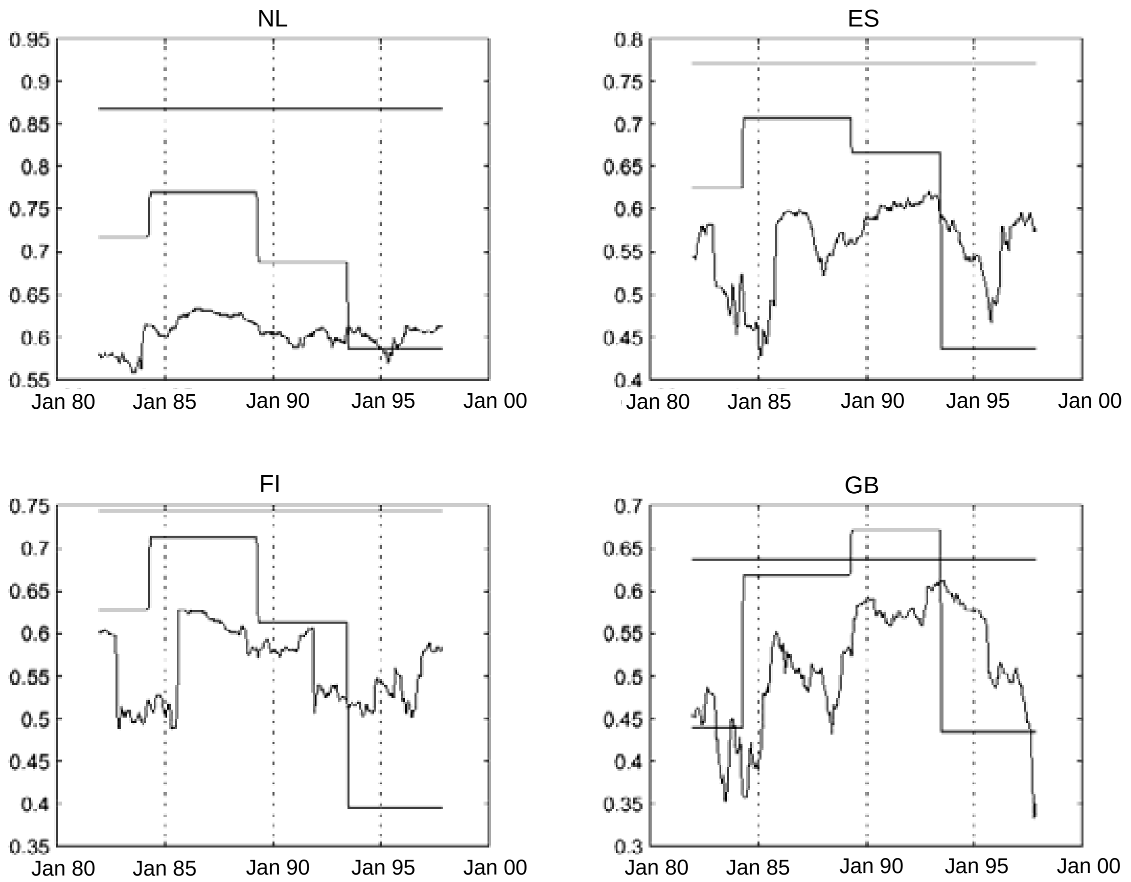
Graph 1

Currency returns: estimation of R_{ij}^2 over the entire period, four subsamples and rolling estimation for Belgium (BE), France (FR), Germany (DE) and Italy (IT)



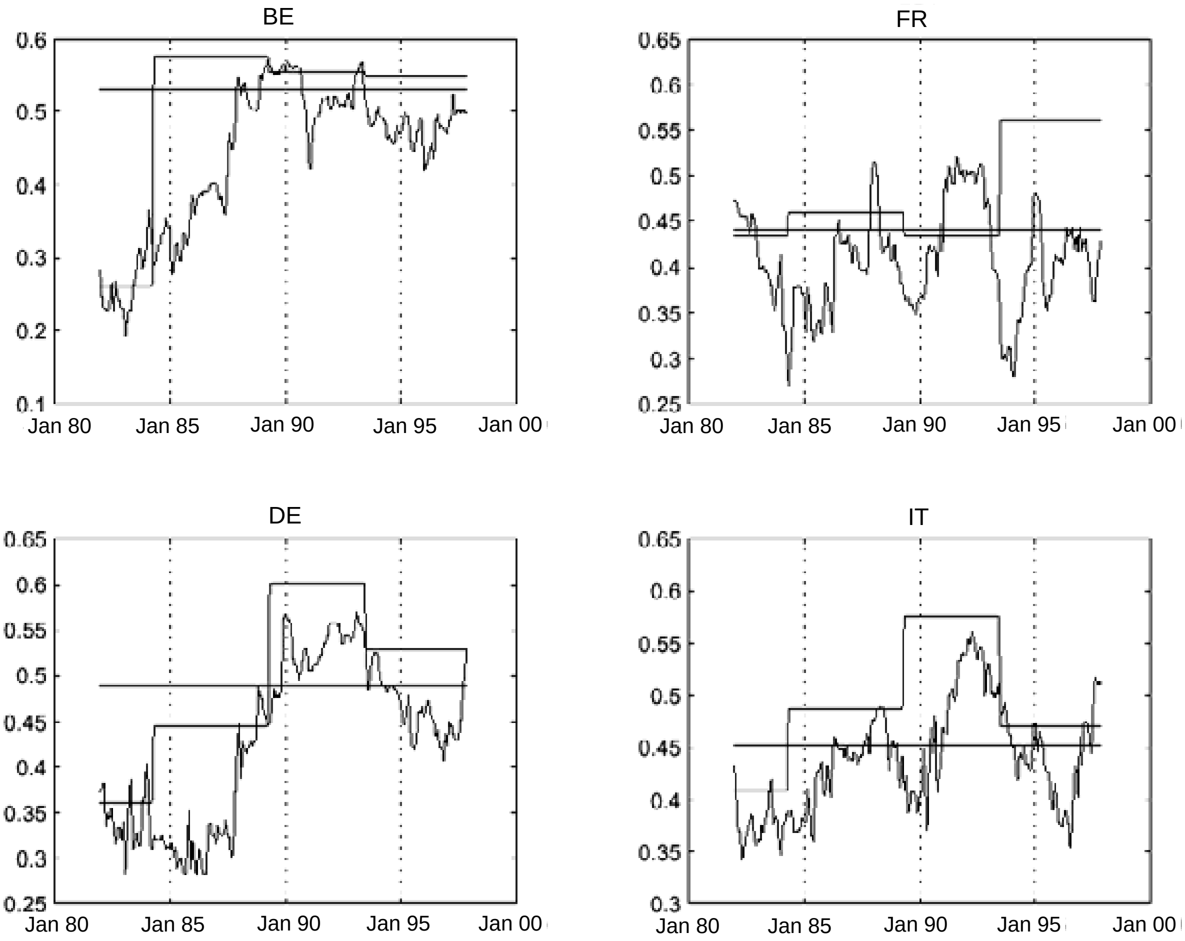
Graph 2

Currency returns: estimation of R_{ij}^2 over the entire period, four subsamples and rolling estimation for the Netherlands (NL), Spain (ES), Finland (FI) and the United Kingdom (GB)



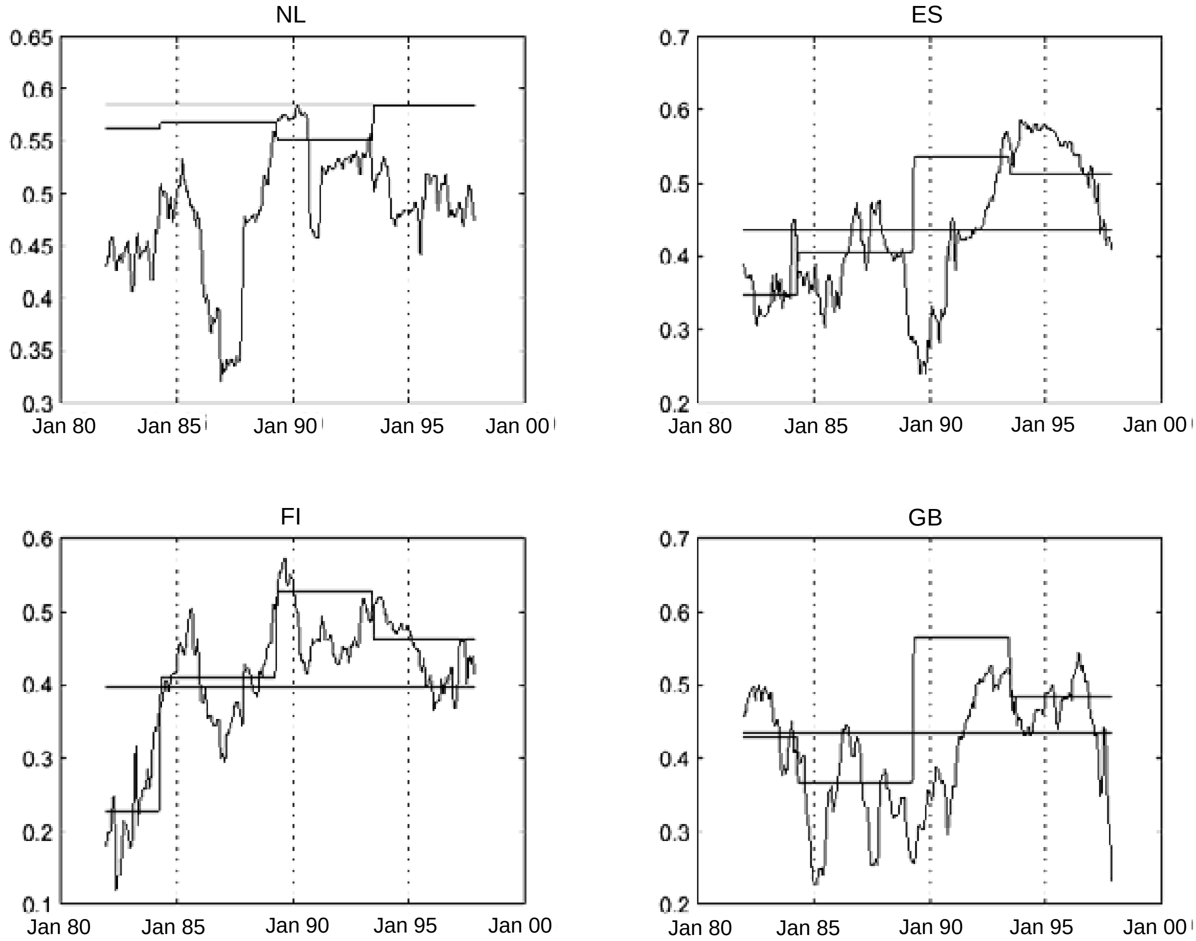
Graph 3

Stock returns: estimation of R_{ij}^2 over the entire period, four subsamples and rolling estimation for Belgium (BE), France (FR), Germany (DE) and Italy (IT)



Graph 4

Stock returns: estimation of R_{ij}^2 over the entire period, four subsamples and rolling estimation for the Netherlands (NL), Spain (ES), Finland (FI) and the United Kingdom (GB)



For our next point, we investigate whether the positive evolution in equity markets is due to an increase in the EU market risk premium. First, Panel A of Table 5 illustrates the evolution of foreign exchange markets. The aggregate exchange rate risk premium explains most of the variance of the common component of currency returns (>95%), with the exception of Spain (86%). This confirms our assumption that the aggregate currency portfolio reflects the currency risk premium, ie the premium required by investors for holding a portfolio of European currencies.

Panel B of Table 5 shows the decomposition of the degree of stock market integration into two components: one linked to a currency risk premium and the other linked to a market risk premium. Aggregate market risk explains more than 88% of the variance of the common component of stock returns, except in the case of Finland (74%). As before, this component stays invariant during the first three subperiods and then increases sharply in the fourth, in all countries except for the Netherlands (from 79% to 64%) and France (from 64% to 51%).

What is the importance of systematic currency risk in the pricing of European stocks? To answer this question, we examine the $R_{r,ic}^2$ in panel C of Table 5. Over the whole period, aggregate currency risk does not seem to play a role for stock valuation, except in the case of the French market. However, the evolution across subperiods is quite different across markets. The currency premium increases in the Netherlands, Belgium and the United Kingdom, and decreases in France and Spain. The growing degree of integration that we have observed in Table 4 appears to be due to an increasing EU-wide market premium and a decreasing currency premium, except for the Netherlands and the United

Kingdom (which also show an increasing currency premium). This result supports the idea of EU-wide market risk reflecting EU business cycle risk: As economies become more integrated, the synchronisation of business cycles increases systematic risk and its premium. On the other hand, elimination of intra-European currency risk reduces the currency premium, at least for the countries participating in the euro. Only in the Netherlands and the United Kingdom does the component of currency risk in the investment portfolio increase. This result agrees with De Santis et al (2000), who find that the European component of currency risk in an international investment portfolio increases in the 1990s (even if the relative increase in the extra-European component is more important).

Table 5

Relative importance of the market and currency risk premium in currency returns (Panel A) and stock returns (Panels B and C). We report the partial R^2 for regressions (12) and (13).

I. 1979:02-1984:04, II. 1984:05-1989:04, III. 1989:05-1993:06, IV. 1993:07-1997:12

Panel A: $R^2_{c,ic}$

	I-IV	I	II	III	IV
Belgium	0.969	0.952	0.970	0.926	0.925
France	0.984	0.951	0.967	0.951	0.907
Germany	0.954	0.942	0.972	0.902	0.951
Italy	0.967	0.895	0.954	0.926	0.867
Netherlands	0.982	0.930	0.971	0.945	0.943
Spain	0.853	0.687	0.800	0.838	0.667
Finland	0.951	0.900	0.966	0.510	0.915
United Kingdom	0.932	0.722	0.879	0.930	0.690

Panel B: $R^2_{r,ir}$

	I-IV	I	II	III	IV
Belgium	0.960	0.839	0.903	0.881	0.826
France	0.896	0.649	0.846	0.729	0.512
Germany	0.892	0.587	0.713	0.827	0.744
Italy	0.930	0.648	0.680	0.859	0.701
Netherlands	0.882	0.796	0.796	0.829	0.640
Spain	0.882	0.372	0.706	0.907	0.784
Finland	0.747	0.580	0.307	0.582	0.695
United Kingdom	0.890	0.648	0.709	0.904	0.717

Panel C: $R^2_{r,ic}$

	I-IV	I	II	III	IV
Belgium	0.072	0.173	0.100	0.057	0.383
France	0.169	0.386	0.004	0.131	0.037
Germany	0.025	0.141	0.093	0.393	0.115
Italy	0.000	0.033	0.018	0.091	0.026
Netherlands	0.090	0.003	0.210	0.045	0.134
Spain	0.002	0.243	0.081	0.220	0.021
Finland	0.092	0.195	0.012	0.215	0.190
United Kingdom	0.039	0.028	0.030	0.169	0.167

Having estimated the common component of currency and stock returns, we use them to examine the sources of stock return co-movement. Do market and currency premia reflect rewards to a common business cycle risk or do they reflect systematic responses of EU markets to US equity markets? Table 6 presents the results from regression (14). It appears that industrial production, European or US, does not help explain the common component of stock returns in European markets. On the other hand, there are some spillovers from the US stock markets: 17.8% of co-movements in Belgium, 16.2% in the United Kingdom and 14% in France and Germany can be explained by US market-related factors. We conclude that even if there are spillovers from US markets to European equity markets, the systematic effect is not very large.

Table 6

Sources of stock market co-movement from regression (14). R^2_{ip} **,** $R^2_{ip,us}$ **,** $R^2_{r,us}$ **are the partial correlation coefficients for aggregate IP growth in Europe, aggregate IP growth in the United States and stock returns in the United States.**

	R^2_{ip}	$R^2_{r,us}$	$R^2_{ip,us}$
Belgium	0.000	0.005	0.178
France	0.000	0.001	0.144
Germany	0.001	0.000	0.140
Italy	0.001	0.005	0.172
Netherlands	0.001	0.006	0.154
Spain	0.001	0.001	0.155
Finland	0.001	0.023	0.140
United Kingdom	0.001	0.004	0.162

6. Summary and conclusion

This paper examines whether the convergence of European economies towards economic and monetary union has lead to integration of European stock markets. There are several reasons why economic integration should imply financial integration. Apart from the convergence of inflation and short-term interest rates, convergence of monetary and fiscal policies leads to convergence of real expected cash flows and to increased synchronisation of business cycles across European economies, which in turn leads to higher correlations of stock returns. Furthermore, since 1993, intra-European exchange rates have been fixed through the EMS, so intra-European exchange rate risk associated with exchange rate fluctuations should have been gradually eliminated. Assessing whether capital markets are integrated is important in order to measure the effective restrictions on capital flows in Europe and the effectiveness of the policies aimed at the liberalisation of capital markets. It is also important for investors: if markets have indeed become fully integrated, optimal portfolio composition should shift from country diversification to sector diversification. And for firms: if integration reduces the cost of issuing new stock, it may encourage investment.

The paper examines whether the stock markets of eight European countries are fully integrated using a double approach. First, we define a generating process for returns that allows us to exploit the common dynamics of currency returns, stock returns, forward premia and dividend yields. The model assumes that each variable follows a dynamic factor analytical model, and decomposes the variables into a common and an idiosyncratic (variable- and country-specific) component. Financial integration is then defined as a process whereby stock markets become increasingly affected by the common, EU-wide risk factors, while the influence of country-specific risks is gradually reduced. In completely integrated markets, country-specific risks are fully diversifiable and thus investors require no reward to hold assets that contain such risk. In other words, in a completely integrated market investors face both common and idiosyncratic sources of risk, but they price only the first. Imposing a mild no arbitrage condition on the generating process for returns yields exactly this pricing restriction for returns. Exploiting the properties of the factor model to construct well diversified portfolios, the paper examines whether the data satisfy the pricing restriction. Then it measures the degree of integration and examines its evolution during two periods. Finally, the paper investigates whether the sources of common risk lie within Europe or have spilled over from real and financial variables in the United States, and seeks to determine the financial component of a country's inflation.

The empirical application has shown that European equity markets are not perfectly integrated and it has found that the markets examined in this study show similar degrees of integration for the end of the period under study. However, the strongest evolution occurred for the smallest markets, ie Belgium, Spain and Finland. The importance of the common component varies across countries and variables but is generally higher for foreign exchange markets. Furthermore, we have found that the degree of integration is constant for currency markets until 1994, whereas it increases strongly for equity markets during the 1980s and 1990s. There appear to be differences in timing between countries as far as the start of the process is concerned. This increase is primarily due to an increase in the premium associated with European-wide market risk and a decrease in the premium associated with fluctuations of European currencies with respect to the US dollar. Finally, we have found that the sources of the common shocks cannot be explained by changes in European or US industrial production and that they lie only in part in the US equity markets.

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Interactions between cash and derivatives bond markets: some evidence for the euro area

Wolfgang Schulte, Deutsche Bundesbank
and Roberto Violi, Bank of Italy[1]

Abstract

This paper provides a broad empirical examination of the interactions between cash and derivatives markets for government bonds in the core euro area countries (Germany, France and Italy) in the aftermath of the launch of the third stage of European monetary union (EMU). Since the launch of the euro, liquidity in derivatives markets has concentrated in a handful of capital market futures contracts, in particular those traded on Eurex. The tremendous level of activity in Eurex contracts has raised concerns about the risk of a shortage in the cheapest bond to deliver. The paper assesses cash market-, repo market- and futures market-based approaches to preventing such shortages, and finds that a combination of approaches is preferable.

The paper goes on to analyse how changes in liquidity and trading activity in government bond markets since the start of EMU have affected price formation. Based on the conceptual framework set out by the financial market microstructure and asset market equilibrium literature, econometric evidence on the determinants of yield spreads is presented. The results confirm that fluctuations in yield spreads across euro government bonds contain a significant transitory component, which could represent temporary deviations from fundamental values. This "mispricing" component increased at the time of the Russian and LTCM financial crises and peaked around the launch of the euro. Based on the size of the estimated mispricing component in bond yields, liquidity in euro government bond markets returned to pre-1998 levels during 2000. Moreover, liquidity conditions appeared to converge across the G5 countries, although UK and US bond markets maintained a positive liquidity differential with respect to euro area markets. Among euro area government securities markets, prices appear to be least distorted, and liquidity closest to that of the UK and US markets, in Italy's cash market, perhaps reflecting the advantages of an advanced trading infrastructure.

1. Introduction

This paper provides a broad empirical examination of the interactions between cash and derivatives markets for government bonds in the core euro area countries (Germany, France and Italy) in the aftermath of the launch of the third stage of European economic and monetary union (EMU). In our analysis we place special emphasis on the changes under way in the government bond market structure, integration and linkages and their implications for the relationship between prices, trading volume and liquidity in the main segments of the European fixed income securities markets.

Since the advent of the euro, market participants have been intensively discussing the effects and consequences of a more integrated money and bond market in Europe. While the precise role of EMU may be difficult to determine, the euro is widely recognised as perhaps the major factor that triggered the dramatic transformation of European capital markets.[2] By wiping out currency risk, the euro has eliminated an important source of segmentation in the supply of debt instruments. By speeding up the process of market integration, the single currency has increased the potential demand for national

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[1] Not for quotation without permission. The authors are grateful to Maria Pia Mingarini for research assistance. Keywords: EMU, bond markets, market integration, liquidity; JEL classification: G15, G14, E43, E44, F21.

[2] See Danthine et al (2000) for a broad assessment of the impact of the euro for the emergence of a pan-European capital market.

bonds and intensified competition among sovereign issuers, providing a strong incentive to reform markets and pursue efficiency and transparency standards. Unprecedented issues in public debt management for the 12 independent sovereign states have been raised concerning whether, and to what extent, coordination and cooperation among them would be required to foster market integration. More recently, decreasing public debt and the prospect in Europe of further budget consolidation and, possibly, surpluses, as a result of the implementation of the Stability Pact, may have profound implications for the smooth functioning of European capital markets. In addition, the impact of more recent government measures, as triggered by the announcement of buyback plans by the US Treasury and the sales of UMTS mobile phone licences in the core countries of the EMU, has spurred relative value adjustment across the maturity range and issuers in the European bond markets.

As the fixed income markets change shape in Europe a process of adjustment is under way in the dynamic of price discovery about macroeconomic fundamentals owing to shifts in supply and liquidity. As a result, yield spreads are responding to a new ebb and flow of liquidity across markets. We aim at providing some assessment of the main factors underlying the recent trend of widening bond and swap spreads in the euro area. Some econometric evidence is brought to bear on the determinants of such recent developments, in order to identify the sources of changes in the factors driving the adjustment process. We intend to ground our econometric analysis in the conceptual framework provided by the recent literature on financial market microstructure and asset market equilibrium.

The paper is organised as follows. Section 1 attempts to provide an overview of changes and innovations in the European cash and derivatives markets for government bonds resulting from stronger competition between futures exchanges and products. One of the most interesting and heavily traded markets is the segment for 10-year government bonds and the related interest rate futures and swap contracts. Section 2 examines both the consequences of the transition to monetary union and the strategic innovations introduced by Eurex and MATIF on the 10-year Euro Bund futures contract and the 10-year Euro Notional futures contract respectively as the most important 10-year interest rate futures contracts traded in Europe. The data used for this part of the paper cover the period from mid-1998 to mid-2000. In Section 3 we provide a methodological assessment of the relevant concept of liquidity and related liquidity measures based on the dynamic decomposition of price effects into transitory ("mispricing") and permanent ("fundamental value") parts. In Section 4 we deal with the econometric application on the measurement of information efficiency and price behaviour of bonds, swaps and interest rate derivatives in the euro area. Finally, Section 5 concludes by summarising our main results.

2. Upheaval in the European cash and derivatives markets - an overview of developments since the transition to monetary union

Derivatives markets, being an integral part of the international financial markets, are subject to constant change. One of the most extraordinary changes regarding exchange-traded interest rate derivatives has been the worldwide increase in electronic trading, leading to an ongoing displacement of floor trading in interest rate futures. Furthermore, the growing corporate and agency bond markets have affected international interest rate derivatives markets, resulting either in more intensive trading in derivatives products or leading probably to shifts in the respective weight of OTC and exchange-traded interest rate derivatives. Finally, the transition to EMU has caused lasting changes, adjustments and problems for the European derivatives markets, which are presented in detail in the following sections.

Looking first at exchange-traded interest rate derivatives in the three main trading areas Asia, North America and Europe, the respective development of turnover shares for interest rate futures demonstrate that no major shift has occurred in trading activities among these areas.[3] The ongoing tendency towards electronic trading of interest rate derivatives has apparently caused major shifts within each trading area, particularly in Europe, but there is no evidence of major changes worldwide, despite remote membership of electronic exchange trading systems for interest rate derivatives.

[3] See Annex 1.

However, a clearer trend between the two main interest rate derivatives, swaps and futures, has become apparent during the past few years. While the global outstanding amounts of interest rate futures, primarily used for hedging cash positions in government bonds, remained stable during 1998 2000, the outstanding amounts of interest rate swaps expanded strongly during the same period.[4] A similar evolution, with slightly decreasing amounts of interest rate futures outstanding, is evident in the euro area.[5] As interest rate swaps and non-government bonds as a rule show stronger correlations in terms of their yield movements compared with those of interest rate futures and non-government bonds, the global growth of swap markets seems to be attributable to the worldwide increase in cash market activities in non-government bonds, leading to rising hedging requirements.

Following this more general overview of the evolution of interest rate derivatives markets, the focus will now turn to the European exchange-traded derivatives markets.

At the beginning of 1998, the respective percentage shares of the major European futures exchanges in capital market products already revealed a slight lead of Eurex over LIFFE, which up to 1997 was the largest European futures exchange.[6] However, MATIF and the Spanish futures exchange MEFF also accounted for sizeable percentages of the total contract volume in European capital market futures.

The situation changed fundamentally in mid-1998 and moved further in favour of Eurex, which accounted for nearly 4 out of every 5 futures contracts on fixed income underlyings traded prior to the start of stage three of EMU. This constantly rising trend in the trading share of capital market futures won by Eurex was broken by MATIF in December 1999, when Eurex's market share of the total trading volume in European capital market futures peaked at 95%. In the course of 2000, MATIF gained market share in contracts relating to European capital market products, rising to as much as 25%.

What is the reason for the marked increase in MATIF's market share?

Annex 5 shows the market shares of 10-year interest rate futures contracts held by each European futures exchange. It confirms that the revival in trading in capital market products at MATIF has been based almost exclusively on an increase in traded contracts in the 10-year Euro Notional futures contract which, in fact, reached a market share of over 36% in April 2000. It is noteworthy that this remarkable revival in turnover in the 10-year Euro Notional futures contract has not been created by the market itself but rather as the result of an initiative of the French banking federation. The liquidity required for raising turnover in this contract has been provided by market-making, conducted by eight French market participants. However, winning new interest in trading this contract has apparently been difficult during recent months because open interest peaked at around 150,000 contracts on average in June 2000.[7] The leap in open interest in this contract from May 2000 is due to a change in the method of calculating open interest by MATIF.[8]

Apart from the revival of the 10-year Euro Notional futures contract, the following decisions made by MATIF immediately after the transition to EMU revealed the intention to intensify competition among European futures exchanges:

2.1 Adjustment of products

By launching the two-year E-Note futures contract at the end of January 1999, MATIF rounded off the spectrum of its range of capital market products, so that both MATIF and Eurex now offer interest rate futures contracts for two-year, five-year, 10-year and 30-year government bond maturities.

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[4] See Annex 2.

[5] See Annex 3.

[6] See Annex 4.

[7] See Annex 6.

[8] Open interest was previously calculated by MATIF as net open interest; since 23 May 2000 it has been calculated as gross open interest.

While turnover and liquidity in the 10-year Euro Notional futures contract have increased since December 1999, liquidity in the two-year and five-year MATIF futures contracts has as yet been insufficient, in contrast to the equivalent Eurex contracts.

2.2 Change in contract conditions

In response to two squeezes in deliverable issues of the Euro Bund futures contract (September 1998, June 1999 deliveries), MATIF extended the number of government bonds deliverable in the two-year, five-year and 10-year futures contracts from originally French issues only to include German issues, too, while for the 30-year E-Bond futures contract, designed as a multi-issuer basket, sovereign issues of France, Germany and the Netherlands are deliverable.[9]

As government bond yields during the first half of 1999 clearly moved below the level of the notional contract coupon used for futures contracts at Eurex (6%) and MATIF (5.5%), MATIF decided to lower the notional contract coupon of the 10-year Euro Notional futures contract from 5.5% to 3.5%, and of the five-year Euro futures contract from 4.5% to 3.5% as well.[10] Simultaneously, LIFFE took the same decision by lowering the notional contract coupon of its 10-year Euro Bund futures contract from 6% to 4%.[11]

Despite squeeze risk, Eurex, at the same time, felt compelled neither to open up the deliverable basket of the Euro Bund futures contract to other euro area sovereign issuers nor to lower the notional contract coupon of this contract. Only the contract conditions of the five-year Bobl futures contract were modified in June 2000 by making exclusively German government bonds with remaining terms between 4.5 and 5.5 years eligible for delivery.[12]

Turning from the derivatives markets to the European cash markets, efforts to raise the size of sovereign issues, particularly those of German government bonds, are desirable to avoid the risk of squeezes in deliverable bonds. While the largest size of German 10-year government bonds issued before mid-1999 amounted to EUR 15.3 billion, the size of the last three German equivalent bonds was raised by between EUR 5 and 8 billion to EUR 20-23 billion, thus approaching the size of the largest French 10-year OAT issues amounting to EUR 22 to 25 billion.

In the light of these strategic decisions by Eurex and MATIF, the following section seeks to describe and analyse their consequences for the relationship between European cash and derivatives markets since the transition to EMU.

3. Consequences of the transition to EMU for the relationship between European cash and derivatives markets

3.1 Squeeze concerns in the Euro Bund futures contract

Before looking at the range of problems faced, it is necessary to define what is meant by a squeeze. In this context, a squeeze is taken to mean a shortage in the cheapest-to-deliver (CTD) bond deliberately caused by market participants so as to make it difficult for other market participants to fulfil their obligations either in the futures market or in the cash and repo market as well. In fact, at no time - including during the September 1998 and June 1999 squeezes - has any failure or a delayed delivery of the Euro Bund futures contract at the contract's delivery date occurred. Nevertheless, squeeze

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9 Two-year E-Note futures contract: dual-issuer basket since March 1999 delivery; five-year Euro and 10-year Euro Notional futures contract: dual-issuer baskets since June 1999 delivery.

10 Adjustment of the notional contract coupon for both futures contracts since June 1999 delivery.

11 Adjustment of the notional contract coupon of this contract since June 1999 delivery. The notional contract coupon was changed again by LIFFE from 4% to 6% on 20 December 1999 for March 2000 delivery.

12 Previous remaining term to maturity for bonds deliverable in the Bobl futures contract: 3.5 to five years.

concerns circulated in the market owing to the confluence of various circumstances, which are examined in detail below. But, if no squeeze has happened yet in the futures market, in which market has a squeeze or a shortage in the CTD bond actually occurred? The following description of the range of problems might give an answer.

3.1.1 Range of problems

In mid-1998, half a year before the transition to EMU, the capital market environment across European cash and derivatives markets may be described as follows:

1. Apart from the Eurex Euro Bund futures contract, no other liquid alternatives traded on other European futures exchanges were available for hedging 10-year European government bonds. Moreover, this futures contract has usually been used in addition for hedging non-government 10-year issues (eg German Pfandbriefe) and 30-year bonds. These issues are not eligible for delivery in the Euro Bund futures contract. Comparing the real deliverable volume of the Euro Bund futures deliverable basket with the potential deliverable volume calculated via the open interest in this contract at peak times reveals that the potential volume exceeded the real deliverable volume of the basket several times over. Then as now, squeeze concerns have been stimulated by this fact.

2. During 1999, yields on 10-year government bonds dropped to a historically low level, far below the level of the notional contract coupon of the Euro Bund futures contract (6%). Only at the yield level of the notional contract coupon is the adjustment of the price differences of the deliverable bonds, caused by coupon and term inequalities, calculated correctly by the conversion factor of each deliverable bond. A deviation from the real yield level to the yield level of the notional contract coupon leads to a bias when calculating the CTD bond at the contract's delivery date. If real yields stay above the level of the notional contract coupon (6%), the conversion factor would determine the deliverable bond with the highest modified duration within the basket as being CTD, while real yields below 6% would determine the bond with the lowest modified duration as being the CTD bond, assuming that all deliverable bonds stay at the same yield.

3. An exceptionally low yield level such as prevailed during the Euro Bund futures squeezes in the September 1998 and June 1999 deliveries may become a problem if the deliverable basket of a futures contract consists of only a few government bonds with very different modified durations. If, however, the price sensitivity of several different deliverable bonds is largely identical, these bonds will probably be able to become CTD after small relative yield changes, so that the deliverable volume of the bonds likely to become CTD will potentially increase. In fact, the deliverable basket of the Euro Bund futures contract, during both squeezes, was composed of few bonds with very different modified durations, so that the probability of a rotation of the CTD bond was low.[13] Furthermore, predicting the CTD bond at the contract's delivery date was easy, due to the bias of the conversion factor when real yields differ from the yield level of the notional contract coupon.[14] Under these circumstances, it was possible for market participants to squeeze the CTD bond in the cash market, particularly when the size of this bond was insufficiently large.

4. The previous discussion on squeezes of the Euro Bund futures contract was mainly focused on the insufficient deliverable volume of the Euro Bund futures basket and the respective CTD bonds. However, another essential problem was given less consideration: the arbitrage mechanism between the cash and derivatives markets did not function smoothly, owing to an insufficiency in the repo market that is the liquidity provider for this arbitrage. Cash-and-carry arbitrage (if the implied repo rate is above repo rate) as well as reverse-cash-and-carry arbitrage (if the implied repo rate is below repo rate) will be possible if the CTD bond is either clearly predictable at the end of the contract or the net basis of the CTD bond is negative. But, obviously, market participants did not exploit the risk-free opportunities for profit. Looking at the single arbitrage steps suggests that one reason for the inadequately

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[13] See Annex 8: Euro Bund futures contract: September 1998 and June 1999 deliveries.

[14] When both squeezes occurred, CTD was the bond with the lowest modified duration within the basket.

functioning arbitrage mechanism was the repo market, where the CTD bond was not expected to be redelivered in time.

Cash-and-carry arbitrage (long CTD bond, short future)

1. After raising a loan in the repo market, the debtor buys the CTD bond, being cheaper than its fair price, on the cash market, which is then given as collateral to the creditor of the loan (long bond).
2. Simultaneously, the debtor initiates a short futures position (short future).
3. At the contract's delivery date, the debtor can deliver any bond eligible for delivery, but he will deliver the bond he has given as collateral to the creditor in the repo market. If the creditor failed to return this bond to the debtor or were not able to deliver it in time according to the futures settlement date, the debtor would personally fail to satisfy the obligation to deliver this bond into the futures contract. High penalties from the futures exchange would be the consequence.

Reverse cash-and-carry arbitrage (short CTD bond, long future)

This arbitrage consists of

1. borrowing the CTD bond in the repo market,
2. selling this bond in the cash market, while simultaneously
3. buying futures contracts.

This arbitrage will work successfully only if arbitrageurs are able to predict with a high degree of probability which bond within the deliverable basket is going to be CTD at the contract's delivery date, because they need to recover the CTD bond they previously sold in the cash market via the futures contract at the delivery date. The last step would be to return the CTD bond to the lender in the repo market after the futures contract's settlement. However, the existence of insufficient fulfilment of repo contracts will cause market participants not to borrow the CTD bond that is "special" in the repo market, so that reverse cash-and-carry arbitrage would not work.

Even though risk-free profitable arbitrage opportunities were offered by the market, most of the market participants were not willing to pick them up because of insufficient fulfilment in the repo market. If the arbitrage mechanism between the cash and derivatives markets had functioned well, price inefficiencies between the futures and cash market would have been unlikely, because the repo market would have provided sufficient liquidity when deviations between real and fair prices of the futures contract and the CTD bond, respectively, had been realised by arbitrageurs.

3.1.2 Solutions for the prevention of squeezes

Different approaches to preventing squeezes in futures contracts can be envisaged. Depending on the market they refer to, cash market, repo market and futures market-based solutions are possible. However, it is worth noting that the solution is not based on just one of the three markets mentioned above. In fact, composite approaches straddling the three markets seem to alleviate or prevent the shortages of the CTD bond.

3.1.2.1 Cash market-based solutions

Cash market-based solutions are designed to optimise the liquidity of each deliverable bond by increasing the size of a bond. Market participants who attempt to buy large amounts of the CTD bond are likely to be unsuccessful if they try to cause a squeeze in this bond. In this light, the size of the last three German government issues (nos 113513, 113515 and 113516) was increased by between EUR 5 and 8 billion to EUR 20-23 billion. However, it has to be pointed out that despite the high real delivered volume of the CTD bond on the futures contract delivery date, when squeezes occurred no real problems were noticeable in the delivery of the CTD bond.[15]

An alternative approach to avoiding the risk of a squeeze focuses on the price sensitivity of a deliverable bond and seeks to create deliverable baskets with bonds of similar price sensitivities. The measure for the calculation of bond price sensitivity in terms of yield changes is the modified duration,[16] which is determined by the coupon (exogenously fixed according to the prevailing market yield at the issue date) and the term to maturity of a bond. It is quite possible that two bonds, despite being issued on different issue dates, mature on the same date.[17] The difference in the modified durations of these two bonds is then exclusively based on the coupon difference. If, however, two or more deliverable bonds have similar price sensitivities in terms of yield changes, even small relative yield changes between these bonds will be sufficient to cause a rotation in the CTD bond even if there are clear deviations between the market yield level and the level of the notional contract coupon. In that case, the CTD bond would no longer be clearly predictable, so that it would be difficult for market participants to cause a shortage in a CTD bond.

3.1.2.2 Repo market-based solutions

Approaches to avoiding and alleviating squeeze risk via the repo market are aimed at fulfilling repo contracts in an orderly fashion. Therefore, high penalties for non-fulfilment or delayed fulfilment of repo contracts might be a possible solution to the problem. A more far-reaching approach, however, might be to set up a central counterparty within the repo market in order to avoid the counterparty default risk of repo market participants. Both approaches are suited to activating both the arbitrage mechanism between cash and derivatives markets and the liquidity-providing function of the repo market. Finally, one should bear in mind that longer-term requirements for delivery or delayed delivery of securities could be reduced significantly within Europe by setting up a central European clearing house via which all cross-border transactions would be settled.

3.1.2.3 Futures market-based solutions

In the aftermath of the squeezes in the Euro Bund futures contract, MATIF and LIFFE made two decisions regarding the futures markets:

1. MATIF extended the deliverable basket of the 10-year Euro Notional futures contract to German government bonds deliverable in the Euro Bund futures contract.
2. MATIF and LIFFE simultaneously changed the notional contract coupon from 5.5% (MATIF)/6% (LIFFE) to 3.5% (MATIF)/4% (LIFFE), respectively.

In the following, the consequences of both steps in terms of contract behaviour will be demonstrated.

Dual/multi-issuer basket

The reduction of squeeze risk in an environment of increasing trading volume and open interest by extending the outstanding volume of the 10-year Euro Notional futures basket to include German issues was the main reason MATIF gave for changing the contract specifications of its futures contracts.[18] However, as stated above, it is not the total volume of the deliverable basket but rather a small outstanding amount of the CTD bond - ie the bond mainly delivered at the contract's delivery date - that is one of the primary reasons for squeeze risk. Nevertheless, the extension of the deliverable basket of MATIF futures contracts might prove a quite successful approach for avoiding squeezes. A look at the price sensitivities in terms of yield changes of the deliverable issues in the 10-year Euro Notional futures contract reveals that the combination of German 10-year sovereign

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[15] See Annex 8: Euro Bund futures contract: September 1998 delivery: delivered volume of the CTD bond: 29% of the size; June 1999 delivery: delivered volume of the CTD bond: 35.5% of the size.

[16] Modified duration is defined as the relative change (in %) of the bond's price in terms of a yield change of 1 bp.

[17] See eg DBR 4.75% 04.07.2008, issued on 10.07.1998 and DBR 4.125% 04.07.2008, issued on 30.10.1998.

[18] See MATIF press release: Dual issuer base for Euro Notional and five-year Euro contracts, 27 January 1999. For the June 1999 delivery, the outstanding volume of the Euro Notional futures contract was EUR 127 billion compared with EUR 63 billion of the Euro Bund futures contract.

issues, to be redeemed in January and July, and French 10-year sovereign issues, to be redeemed in April and October, reduces the gap between the modified durations of the deliverable bonds. This, however, leads to a more homogeneous price behaviour of single bonds deliverable in this basket after relative yield changes. Under these circumstances, the CTD bond should change fairly smoothly.

Since the June 1999 delivery, when the 10-year Euro Notional futures basket was redesigned as a dual-issuer basket, a smooth rotation of the CTD bond in this contract has not occurred. Due to the yield spread between German and French government bonds, only French issues have been CTD so far.[19] As long as this yield spread exists, a CTD change as a response to small relative yield changes will, in fact, be impossible. Despite this obvious shortcoming in functioning, the features of this dual-issuer basket, as far as the price behaviour of the deliverable bonds after relative yield changes is concerned, are more positive than those of the 10-year Euro Bund futures contract.

In conclusion, a dual/multi-issuer basket is able to reduce squeeze risk if

1. there are no large yield spreads between different sovereign issues,
2. there is only a small gap between the modified durations of the deliverable bonds, so as to change the CTD bond after only small relative yield changes,
3. each deliverable bond is large in size.

Change in the notional contract coupon

As mentioned above, the conversion factor of each deliverable bond will be able to correctly adjust the price differences, due to coupon and term differences of these bonds, if the market yield level equals the yield level of the notional contract coupon. In this ideal scenario, all deliverable bonds will be CTD. As, therefore, several bonds in the deliverable basket might become CTD despite their unequal modified durations, the potential CTD volume at the contract's delivery date will increase, so that the squeeze risk will diminish. Yield deviations from the level of the notional contract coupon will cause a bias by increasing the likelihood that bonds with the highest modified duration within the basket will be CTD if the market yield level stays above the level of the notional contract coupon. On the other hand, if market yields stay below the level of the notional contract coupon, the bond with the lowest modified duration will be CTD.[20] However, the adjustment of the notional contract coupon, as carried out by MATIF and LIFFE in response to the two Euro Bund futures squeezes, will lead merely to a temporary solution of the squeeze problem. As soon as the market yield level moves away from the level of the adjusted notional contract coupon, the bias of the conversion factor will again clearly favour a bond within the basket if the deliverable basket consists of bonds with very different modified durations. The squeeze problem is then once again focused on only one single bond.[21]

Turning to the 10-year Euro Notional futures contract, the bond with the highest modified duration within this basket has been CTD since the lowering of the notional contract coupon from June 1999 deliveries onwards.[22] Since the bond with the highest modified duration is the last issued bond (benchmark bond), this bond, therefore, carries a double function, being CTD and benchmark bond simultaneously. In order to avoid squeezes in this bond - as long as the yield spread between German and French sovereign issues averages 10 to 15 bp, this bond, carrying a double function, will be a French OAT bond - the issuer is forced to place this bond with a high issue size as soon as possible. Given the small amounts of the CTD bond for this contract which have actually been delivered at the contract's delivery date, no shortages have occurred in the CTD bond during the contract periods investigated.[23] This suggests that, compared to the Euro Bund futures contract, the essentially smaller open interest in the Euro Notional futures contract and the large size of French OAT issues might be reasons for this.

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19 See Annex 8: Euro Notional futures contract; the yield spread averages about 10 to 15 bp in favour of German 10-year government bonds.

20 Assumption: all deliverable bonds have the same yield.

21 See Annex 7.

22 See Annex 8: Euro Notional futures contract June 1999 delivery onwards.

23 See Annex 8: Euro Notional futures contract, column: Delivered volume.

In conclusion, it should be pointed out that changes in the notional contract coupon will help to alleviate the squeeze risk as long as the adjustment is not too extreme. As for the rest, it should be remembered that, for currently traded contracts, a change in the contract parameters is not possible. Since three contract deliveries, for instance in the Euro Bund futures contract, are traded permanently, the earliest opportunity to adjust the notional contract coupon in this contract is nine months later. In the face of such a large time lag, an adjustment of the notional coupon makes sense and is likely to be successful only if the adjusted coupon covers the yield level of deliverable bonds with a high probability over a long period of time.

3.2 Hedge quality of futures contracts and OTC derivatives

Concerning the hedging of German, French and Italian 10-year sovereign issues with 10-year Eurex/MATIF futures contracts or 10-year swaps, the transition to EMU has led to different results for each of the three core euro area countries. The hedge quality of both 10-year futures contracts and 10-year swaps is measured by calculating the daily and weekly correlations of the effective price changes of the 10-year futures/swap contracts and the respective German, French or Italian 10-year benchmark or CTD bonds. The following results should be noted:

1. The transition to EMU, which, in fact, started in May 1998 with the fixing of the bilateral exchange rates between the 11 EMU member countries, has not affected the hedge quality of 10-year Eurex/MATIF futures contracts for German and French sovereign bonds to any great extent. Instead, both the Russian and the LTCM crisis in summer/autumn 1998 and the Euro Bund futures squeezes in September 1998 and June 1999 deliveries did seriously affect the hedge quality of both 10-year futures contracts, especially the Euro Bund futures contract, and 10-year swaps for the corresponding sovereign bonds.[24] On the other hand, prior to the start of stage three of EMU, hedging Italian 10-year government bonds with Italian 10-year swaps proved to be more successful than hedging via 10-year Eurex/MATIF futures contracts.[25] Ever since June 1999 deliveries, however, weekly correlations have shown that 10-year futures contracts of Eurex and MATIF, as opposed to 10-year Euro-swaps, are the better hedge instrument for Italian 10-year government bonds, due to a stabilisation of yield spreads of these bonds in terms of German and French sovereign issues.

2. As far as the hedge quality of 10-year futures contracts compared to 10-year swaps is concerned, the appropriate hedge instruments for German and French 10-year benchmark and CTD bonds during the time period investigated (September 1998 - September 2000) have been 10-year Eurex and MATIF futures contracts.

3. Another interesting question arising in terms of hedging sovereign issues of the core euro area countries is which of the two 10-year futures contracts of Eurex and MATIF has had the better hedge quality during the period under review. Looking at the effective daily price changes of both futures contracts and benchmark bonds, the 10-year Euro Notional futures contract has demonstrated better hedging properties in terms of daily price changes, with the exception of the December 1998 delivery. However, looking at the effective price changes on a weekly basis, the results have been different. Weekly correlations during December 1998, June 1999, December 1999 and June 2000 deliveries show that the 10-year Euro Bund futures contract has been the better hedge instrument at least for German benchmark and CTD issues, although not for French and Italian government bonds.[26]

What are the reasons for different results in hedge quality of the Euro Bund futures contract measured either daily or weekly?

One explanation might be that this contract is used both as a hedge instrument and as a speculative trading tool. Furthermore, due to its tremendous liquidity, the contract is used as a hedge instrument

[24] See Annex 8: Correlations for September 1998 and June 1999 deliveries.

[25] See Annex 8: Correlations for September 1998 to March 1999 deliveries for Italian benchmark bonds.

[26] See Annex 8: Daily/weekly correlations between German/French benchmark bonds and 10Y EUREX/MATIF futures contracts.

for a variety of domestic and foreign government and non-government issues (eg German Pfandbriefe) with maturities from 10 to 30 years. In both cases, the price of the Euro Bund futures contract changes, although the prices of the respective benchmark or CTD bonds do not necessarily change to the same extent. After the announcement of news causing price movements in the Euro Bund futures contract, these movements might be stronger within a daily trading period. During a weekly trading period, however, these exaggerations in prices recede or even out. Therefore, the hedge quality of the Euro Bund futures contract seems to be better from the weekly point of view.

Daily price movements in the Euro Bund futures contract seem to play an important role in this context. Looking at daily price movements of the respective CTD bonds of this contract, according to which the price of the futures contract itself should normally move, correlations show that prices of the futures contract and the CTD bond have not moved in tandem, leading to visible movements of the net basis of the CTD bond.[27]

In what way has the change in the notional contract coupon of the 10-year Euro Notional futures contract as of June 1999 (from 5.5% to 3.5%) affected hedging of the French benchmark bond?

As long as yields of 10-year government bonds stay above the level of the notional contract coupon (3.5%) of this contract, the deliverable bond with the highest modified duration, ie the last issued bond within the deliverable basket, will, as a rule, be CTD.[28] Therefore, either the French benchmark bond or, assuming that yield spreads between 10-year government bonds of Germany and France do not exist, the German benchmark bond would be CTD in this contract. Since the price of the futures contract should normally follow the price movements of the CTD bond, hedging the respective French benchmark with the Euro Notional futures contract is likely to be more successful than hedging the respective German benchmark bond, which should not be CTD simultaneously, with the Euro Bund futures contract.[29]

4. Liquidity, market efficiency and price discovery: a conceptual framework

A financial market is said to liquid when at all times there are a large number of buyers and sellers, such that incoming orders can easily be matched without causing prices to move by a large amount. Liquidity measures should account for both trading volume and concurrent price change. A liquid market absorbs large volume with little price change. Hence, price changes should be relatively invariant to the size of transactions and display limited. An illiquid market yields price concessions on low trading volume. No uniformly accepted single, unambiguous, theoretically correct measure of liquidity exists; all measures suffer one or more limitation. Hence, there are both different concepts of liquidity and different ways of measuring liquidity.[30]

Asset prices change both in response to transitory variations in supply and demand and a result of permanent shifts in the equilibrium value of the asset. In the absence of new information, buy and sell orders would come into the market in a random fashion, leading prices to swing back and forth without any trend. As new information arrives, however, prices are driven to a new level. In these instances, big price movements can occur even on small volume trading. This is where the distinction between liquidity and efficiency becomes most significant.[31]

The critical factor in the analysis is the recognition that price changes are not all alike in origin and significance. Random variations in price are noise and liquid markets keep those random variations tight and minimal, regardless of the size or number of transactions.

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[27] See Annex 8: Correlations of the CTD bonds of the Euro Bund futures contract.

[28] Assumption: the yields of all deliverable bonds are the same.

[29] This result is supported by comparison of the daily/weekly correlations between the Euro Notional futures contract/Euro Bund futures contract and the respective benchmark bonds within each futures contract from June 1999 deliveries onwards.

[30] Cf Bernstein (1992), who concludes that “no single measure tells the whole story about liquidity” (p 61).

[31] Dimson and Mussavian (1999) provide a clear presentation of the distinction between market efficiency and liquidity.

4.1 Price change, volatility and measurement of market efficiency

Price efficiency is synonymous with accurate reflections of equilibrium values. Prompt price changes in response to new information are essential as they are the key signal to fundamental values and expectations. An efficient market should let prices move fast when market participants' perception changes, hence price changes tend to be discontinuous. As a result, efficient markets may not attract large number of active investors, especially knowledgeable investors who are able to profit from pricing errors. Yet, liquid and efficient markets both need a large number of active interested and investors. This is where tension arises between liquidity and efficiency or, in terms of market participants, between noise traders and information traders. In an efficient market information-motivated shifts in supply and demand should have a free rein impact on prices; conversely, in a liquid market random swings in supply and demand should have a minimal impact on price. Noise traders, acting on imperfect information, will frequently push prices away from equilibrium values. The resulting undervaluation or overvaluation attracts information traders (arbitrageurs), who push prices back to equilibrium values. Therefore the dynamic properties of price changes and the price effects of trading need to examined. Ideally a theoretical model of prices and price revisions due to trading would provide a framework to decompose price changes into transitory and permanent parts.

To measure informational efficiency in two different markets, financial economists look at the so-called lead-lag relationship. The basic intuition is that in an efficient frictionless market, the prices of two identical assets should be identical (law-of-one-price) - therefore perfectly correlated - and instantaneously reflect all available information.[32] A lead-lag relationship, with one price adjusting earlier than the other one, will develop if market imperfections are present. To detect the presence of a lead-lag relationship, the first task would be to model the intertemporal and cross-market characteristics of returns in both market. Additional insight into the informational efficiency of the two markets can be obtained by comparing the time series properties of volatilities. If returns are driven by information arrival and the rate of information arrival is non-constant, possibly stochastic, then volatility will evolve over time.[33] For example, periods with few news releases might be followed by periods with fast information arrival inducing changes in return volatility. Two efficient and frictionless markets trading the same asset and receiving the same information shocks should exhibit a similar volatility pattern. If, however, volatility patterns differ across the two markets, then we may conclude that either (i) information flows to one market prior to the other, or (ii) the two markets receive the same information, but differ in their speed of adjustment to information shocks. As the former proposition is very difficult to test, one would normally assume that the two markets receive the same information and examine the differences in volatility adjustment mechanisms by employing a model of time-varying volatility.

4.2 Dynamic analysis of price discovery

The endogenous character of the pattern of price changes and activity and the asymmetric information revelation across markets induce lagged effects on the adjustment process driving market price discovery. To take into account the statistical properties of financial series (including their non-stationarity), the vector error-correcting model (VECM) seems a suitable multivariate framework for modelling interest rate dynamics. Vector autoregression (VAR) models have already been widely introduced into the market microstructure literature.[34]

Let Z_t be a vector of (nx1) of financial (eg interest rates) series, integrated of order 1 (eg I(1)) and with mean 0, for simplicity, and assume that the rank of cointegration is m, namely there exists a matrix A (nxm) of rank m - the number of cointegrating vectors - such that the linear combinations $W_t \equiv A'Z_t$ are stationary (eg I(0)) vector of variables. It follows that changes in Z_t admit the VAR representation

[32] See, for example, Dimson and Mussavian (1998).

[33] See Tauchen and Pitts (1983), Andersen (1993).

[34] See Hasbrouck (1993).

$$\Delta Z_t = \Gamma A' Z_{t-1} + \sum_{i=1}^{q} \Gamma_i \Delta Z_{t-i} + \varepsilon_t^{\Delta Z},$$
$$\text{cov}(\varepsilon_t^{\Delta Z}) = \left\langle \sigma_{\Delta Z}^2 \right\rangle \quad (1)$$

where Γ is a an (mxn) matrix, $\{\Gamma_i\}$ are (nxn) matrices and < · > indicates a (nxn) diagonal matrix. In our analysis Z_t may also include stationary (eg I(0)) variables; matrix Γ would be adjusted accordingly to take this case into account.

The element of Z_t can be explained in terms of a smaller number (n-m) of I(1) variables, F_t , called common factors, plus a vector of I(0) (stationary) components, T_t:

$$Z_t = A_1 F_t + T_t \quad (2)$$

One can estimate such a common factor decomposition from the VECM (1); to identify the long-run common factors, one has to impose that F_t be the linear combination of the observed time series vector of variables Z_t.[35]

$$F_t = \Gamma^{*\prime} Z_t \quad (3)$$

We identify $P_t = A_1 F_t$ as the permanent (long-run) component of Z_t, with factor loadings represented by matrix A_1. Analogously, the transitory part, T_t, can be expressed in terms of a common set of factors, W_t, again constructed as a linear combination of the observed time series vector of variables Z_t, $W_t = A' Z_t$, where $T_t = A_2 W_t$, with factor loadings represented by matrix A_2. As a result, we can summarise the permanent transitory decomposition as

$$P_t = A_1 F_t = A^*(A^{*\prime}\Gamma^*)^{-1} F_t$$
$$T_t = A_2 W_t = \Gamma(A'\Gamma)^{-1} W_t \quad (4)$$

where A' is the matrix of cointegrating vectors; Γ is the matrix of the contribution of the "correction" term in the VAR, given by the (transitory) deviation, $W_{t-1}=A'Z_{t-1}$, from the stationary (long-run) equilibrium level, on the changes of Z_t; A* and Γ* orthogonal matrices to A and Γ, respectively (eg A'A*=0 and $\Gamma'\Gamma^*=0$).

It is convenient to provide an AR representation for the factor decomposition written down in equations (2)-(4):

$$\begin{pmatrix} a(L) & b(L) \\ c(L) & \text{d(L)} \end{pmatrix} \begin{pmatrix} \Delta P_t \\ T_t \end{pmatrix} = \begin{pmatrix} \varepsilon_t^{\Delta P} \\ \varepsilon_t^{T} \end{pmatrix},$$
$$\text{cov} \begin{pmatrix} \varepsilon_t^{\Delta P} \\ \varepsilon_t^{T} \end{pmatrix} = \begin{pmatrix} \Omega_{\Delta P} & 0 \\ 0 & \Omega_{\text{T}} \end{pmatrix} \quad (5)$$

where ΔP_t denotes the time changes of the permanent (long-run) component of decomposition (2) and a(L) to d(L) are polynomials in the lag operator; the error terms, $\left(\varepsilon_t^{p}, \varepsilon_t^{x}\right)$, are supposed to be uncorrelated (eg the covariance matrix of disturbances is diagonal).

4.3 Dynamic decomposition through the VAR impulse response function

The AR representation (5) allows a very general dependence of the decomposition Z_t into permanent and transitory components as a function on contemporaneous and past shocks. However, a restriction

[35] See Gonzalo and Granger (1995) for a formal proof.

on the polynomial lags structure (multipliers) follows from equation (3); it requires that T_t, the transitory component, does not Granger-cause P_t, the permanent component, in the long run (eg at frequency 0)

$$b(1) = 0 \tag{6}$$

The effects of shocks on the decomposition can be computed from the impulse response of an AR model by transforming (4) into the following vector moving average (VMA) representation:[36]

$$\begin{pmatrix} \Delta P_t \\ T_t \end{pmatrix} = \begin{pmatrix} \alpha(L) & \beta(L) \\ \gamma(L) & \delta(\mathrm{L}) \end{pmatrix} \begin{pmatrix} \varepsilon_t^{\Delta P} \\ \varepsilon_t^{T} \end{pmatrix} \tag{7}$$

To illustrate the usefulness of the VMA form, consider the equation for the long-run changes in more detail

$$\Delta P_t = \sum_{j=0}^{\infty} \alpha_j \varepsilon_{t-j}^{\Delta P} + \sum_{j=0}^{\infty} \beta_j \varepsilon_{t-j}^{T} \tag{8}$$

In words, long-run changes are infinite sums of past innovations $\left(\varepsilon_t^{\Delta P}\right)$ and $\left(\varepsilon_t^{T}\right)$. The effect of unit innovations on the *change* in the long-run component k periods ahead is measured by α_k and β_k , respectively; the effect of unit innovations on the short-run component k period ahead is measured by γ_k and δ_k, respectively

$$T_t = \sum_{j=0}^{\infty} \gamma_j \varepsilon_{t-j}^{\Delta P} + \sum_{j=0}^{\infty} \delta_j \varepsilon_{t-j}^{T} \tag{9}$$

Thus the coefficients of the VMA are exactly the desired impulse responses. The effect of a unit shock on the *level* of the permanent component k periods ahead is measured by partial sums of the impulse response:

$$p\varepsilon_{\Delta p}(k) = \sum_{j=0}^{k} \alpha_j , p\varepsilon_x(k) = \sum_{j=0}^{k} \beta_j \tag{10}$$

the total long-run effects of shocks are easily determined as limits of the partial sums as $k \to \infty$:

$$p\varepsilon_{\Delta p}(\infty) = \sum_{j=0}^{\infty} \alpha_j , p\varepsilon_x(\infty) = \sum_{j=0}^{\infty} \beta_j \tag{11}$$

Cochrane (1988) notes that this definition of the long-run effects of innovations is unique and independent of any particular decomposition of the price process into permanent and transitory parts (see De Jong et al (1996)).

4.4 “Noise” and “fundamental” value as decomposition of price change into transitory and permanent component

The impulse responses (8)-(9) provide all necessary information for decomposing Z_t into permanent and transitory components. Such a decomposition can be interpreted as an identification technique that separates “fundamental” factors, eg variables with a long-lasting effect on prices, from “noise” effects; the former measuring the efficient component of price changes, the latter the deviation of the

[36] Sims (1980) popularised the use of such a representation for VAR models.

observed price from the efficient price.[37] This approach is a natural extension of the Hasbrouck (1993) methodology, which decomposes an asset price into a random walk (permanent) component and a stationary component around the random walk, with the former representing the underlying equilibrium (efficient) price of the security in which all public information is reflected and the second, transitory, component generally regarded as the pricing error,

Hasbrouck (1993) proposes using the standard deviation of "efficient" and "noise" price components

$$\begin{aligned} \mathrm{var}(\Delta P_t) &= \left(\sum_{j=0}^{\infty}\alpha_j\right)\Omega_{\Delta P}\left(\sum_{j=0}^{\infty}\alpha_j\right)' + \left(\sum_{j=0}^{\infty}\beta_j\right)\Omega_T\left(\sum_{j=0}^{\infty}\beta_j\right)' \\ \mathrm{var}(T_t) &= \left(\sum_{j=0}^{\infty}\gamma_j\right)\Omega_{\Delta P}\left(\sum_{j=0}^{\infty}\gamma_j\right)' + \left(\sum_{j=0}^{\infty}\delta_j\right)\Omega_T\left(\sum_{j=0}^{\infty}\delta_j\right)' \end{aligned} \tag{12}$$

as a summary measure of the "quality" of a securities market. Intuitively they reflect how closely observed market prices track the "efficient" price on average. He suggests a market quality measure (mqm) of a noise-to-signal ratio type of indicator, namely the pricing error variance of the security divided by the "efficient" price change:

$$mqm = \sqrt{\frac{VARIANCE(T_t)}{VARIANCE(\Delta P_t)}} \tag{13}$$

The mqm indicator can be thought of as a measure of market efficiency for the price-discovery process. In practice, several factors can impinge upon the speed with which the process takes place, such as, among other things, transaction costs (large bid-ask spreads that prevent crossing the trade at the mid-price) as well as the lag with which securities prices adjust to the arrival of new information. In this sense it is understood as a "dynamic" measure of transaction costs that generalises the traditional Roll's estimator (Roll (1984)). Under Roll's special assumption VARIANCE(T_t) would be equal to half the realised bid-ask spread. A larger variance in the noise component would signal a rising uncertainty in the price discovery and declining informational efficiency.

5. Data description and statistical properties of interest rates in the euro area

The measurement technique presented in the previous section is used to assess bond cash market efficiency in the euro area. We concentrate our study on the long-term segment of the market (10-year maturity), focusing on the swap and government bond market benchmark yield. We confine our estimates to the largest government bond markets of the euro area (France, Germany and Italy) using the US and UK markets as a benchmark reference.

To achieve this goal we have assembled a data set of market interest rates covering the main segments of the euro area, including the interbank market (three-, six- and 12-month interest rate), the short futures rate (Eurex three-month futures rates up to one year maturity), the long futures price (on the 10-year bund), swap rates (with a maturity of two, three, five, seven and 10 years), Treasury benchmark (Bund, OAT and BTP yields with a maturity of three, five and 10 years) and corporate benchmark (10-year);[38] the data are daily quotes and cover the period from 3 January 1990 to 31 August 2000. Table 1 provides summary statistics over the period used in the estimation. Chart 1

[37] Other decompositions into permanent and transitory components are also possible. Hasbrouck (1993), who adopts the Beveridge and Nelson (1981) approach, shows that the Beveridge-Nelson decomposition gives a lower bound for the variance of the stationary price part among all possible decompositions.

[38] Data come from Datastream and Bloomberg; BTP benchmark yields are calculated by the Bank of Italy.

reports some of the spread for the larger countries in the euro area vis-à-vis the 10-year German bund yield.

Before going through the econometric estimation, we check some statistical properties of the series used in this paper. We first consider long-run properties for the level of interest rates, that is non-stationarity and cointegration; this is required since many papers have given evidence of non-stationary behaviour of interest rates.[39] In that case dealing with rates in level calls for a proper econometric handling. At this stage, we have to restrict our attention to a five series system $Z_t=(\Sigma_t,S_t,Y_t,L_t,R_t)$ of interest rate levels; these rates are as defined as follows:

Σ_t = implied forward rates in the three-month futures yield on the Euribor

(average of four consecutive three-month delivery dates).

S_t = 10-year interest swap rate on the euro.

Y_t = 10-year yield to maturity on German bund.

L_t = 12-month interbank rate (Libor) on the euro.

R_t = three-month interbank rate (Libor) on the euro.

Standard unit-root tests (as reported in Table 2, Panel A) allow us to conclude that interest rates in our sample can be considered non-stationary. Hence the framework laid out in the previous section provides a meaningful tool for assessing the extent to which changes in fundamental values vs the "noise" (idiosyncratic) component have impinged upon interest rates in the euro area. The following yield spreads are used for dynamic analysis:

(St - Yt , Σt - Rt , Rt - Lt , Lt - Yt)

These include a 10-year swap spread, S_t - Y_t , a forward term spread, Σ_t - R_t, a short-term rate spread, R_t - L_t, and a long-term yield spread, L_t - Y_t. In Chart 2 we plot the 10-year swap spread vis-à-vis the German bund; it displays a fair amount of volatility and an upward trend seems to have appeared since the start of EMU; a corporate bond spread displays a similar pattern. Although we expect to find yield spreads mostly stationary, unit-root tests for spreads (not reported) lead to a somewhat less clear-cut conclusion than on levels; all in all, the stationary component in the spreads does appear to be predominant at the significance level of 1%.

This is confirmed by the Johansen Maximum Likelihood (JML) procedure for the testing of cointegration relationships. For a VAR of order 7 (order suggested by the Akaike information criterion) at the significance level of 1% only one cointegrating vector appears to be selected by the trace test for cointegration rank (Table 2, Panels B-C). However, at the 5-10% significance level we could not reject the hypothesis of two cointegrating vectors. With two cointegrating vectors out of five variables there are 3 I(1) common factors driving the long-term dynamics of the interest rates. In addition, the (unrestricted) cointegrating vector coefficients nearly add up to zero, which would be consistent with the hypothesis that the long-run relationship among interest rates can be restricted to involve the information content of spreads only; a formal χ^2-square test of the unit restriction would not be rejected at the 1% significance level for both cointegrating vectors.

The JML procedure for the testing of cointegration relationships is applied to a sample of 10 bond yields in the G5 countries (Germany, France, Italy, the United Kingdom and the United States), as reported in Table 5; the data consist of 2,090 daily observations from 1993:1 to 2000:365. For a VAR of order 7 (order suggested by the Akaike information criterion) at the 5% significance level we cannot reject the hypothesis of only one cointegrating vector; as a result there are four common I(1) factors driving the whole system of interest rates in the long run and one common I(0) factor, the transitory component, capturing the common source of deviations from the permanent component ("mispricing" effect).

[39] See, for example, Hall et al (1992), Engsted and Taggart (1994), Drudi and Violi (1996) and Avouyi-Dovi and Jondeau (1999).

5.1 Econometric estimates of the determinants of bond market liquidity and price efficiency in the euro area

Cointegration and stationary spreads allow us to turn to a simple univariate equation estimate defining the long-run relationship between swap spread and forward spread, short-term spread and long-term spread:

$$S_t - Y_t = \lambda_0 + \lambda_1(\Sigma_t - R_t) + \lambda_2(R_t - L_t) + \lambda_3(L_t - Y_t) + \varepsilon_t^{SY} \tag{14}$$

The information content of the forward spread for the 10-year swap spread and the slope of the yield curve (short and long) are quite significant determinants of the swap spread; the adjusted R^2 of the regression is relatively high (0.34; Table 3) and the estimated slope parameters are significantly positive, although very far from 1 (actually close to zero or negative for the short-term slope of the yield curve). Deviation from 1 for the slope parameters (and zero for the constant term) in the regression does not imply immediate rejection of the no-arbitrage-restriction characterising the estimated model; it may simply be a consequence of the shorter horizon of the forward spread (one-year as against 10-year horizon) entering the estimated regression. However, while the estimated relationship seems fairly robust in recent years,[40] there are still clear signs of heteroskedasticity and autocorrelation in the regression residuals. A Garch (1,1) estimation of the conditional volatility process[41] for the swap spread equation (14)

$$(\sigma_t^{SY})^2 = \mu_0 + \mu_1(\sigma_{t-1}^{SY})^2 + \mu_2(\varepsilon_{t-1}^{SY})^2 \tag{15}$$

suggests that estimated time-varying volatility has been definitively higher since the beginning of EMU compared to the rest of the sample (see Chart 3). Most of the "excess volatility" does not seem to originate from increased forward and term spread volatility, rather it appears to reflect additional "noise" specific to the swap spread. We provide evidence for this hypothesis by extending equation (12) to a "state-space" (Kalman filter) specification in which the forward rate spread is only imperfectly observed - the 10-year consecutive forward rates are not traded in the market for the outer horizon - and the "true" forward spread $\Sigma_t^* - R_t$ follows an AR(1) process

$$\begin{aligned} S_t - Y_t &= \lambda_0 + \lambda_1(\Sigma_t^* - R_t) + \lambda_2(R_t - L_t) + \lambda_3(L_t - Y_t) + \varepsilon_t^{SY} \\ \Sigma_t - R_t &= \phi_0 + \phi_1(\Sigma_t^* - R_t) + \varepsilon_t^{\Sigma R} \\ \Sigma_t^* - R_t &= \varphi_0 + \varphi_1(\Sigma_{t-1}^* - R_{t-1}) + \varepsilon_t^{\Sigma^* R} \end{aligned} \tag{16}$$

The fit of the swap spread "measurement" equation improves substantially (R-squared increases to 0.99) and estimated coefficients for the spreads are much larger than those estimated for equation (14).

Swap spread equation errors increase significantly in the first six months of this year, especially at times when the swap spread widened during the second quarter of the year, in the wake of the UMTS mobile phone licence auction in Germany.

All in all, the econometric evidence suggests that, at least in part, fluctuations in the euro swap spread vis-à-vis the bund, over and above the movements related to the changes in the term structure of interest rates, may be due to idiosyncratic movements in the German government 10-year bond yield; only the French OAT has partially kept pace with the growing German swap spread, while the Italian swap spread has remained fairly stable.

A measure of the extent to which such fluctuations have affected efficient price discovery for euro interest rates can be gauged by estimating the parameters of the VECM (1); such estimates allow us to compute the impulse response associated with the system of equations (7); finally the market quality indicator, mqm, can be obtained from equation (13).

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[40] Eliminating the observations for 1999-2000 (ie the EMU sub-sample) from the data set little changed the results of the estimation, leaving the explanatory power of the forward spread almost identical.

[41] See for example Bollerslev, Chou and Kroner (1992) for details of Garch application in econometric finance.

Table 4 reports the calculated efficiency measures for each interest rate evaluated for several sub-samples. There is a clear worsening of "market quality" as witnessed by the increase in the mqm indicator from 1998 to 1999; it almost doubles for all interest rates but the average three-month futures rate. For the 10-year bund the mqm indicator continues to rise (from 0.019 to 0.026) signalling a further slight worsening in mispricing. Conversely, the 10-year swap rate mqm remains unchanged.

5.2 Comparing bond market liquidity and price efficiency in G5 countries: euro area vis-à-vis the United Kingdom and the United States

Table 6 reports results of the permanent-transitory decomposition of 10-year bond yields for the G5 countries (France, Germany, Italy, the United Kingdom and the United States; see Table 5 for some descriptive statistics). The standard deviation of the stationary part (transitory component) provides a measure of the extent of the "mispricing" (liquidity effect) as a result of deviations from the "fundamental" value (permanent component) of current bond yields. The proportion to the latter standard deviation (mqm indicator) shows a worsening of liquidity across countries in 1999 compared to 1998, especially in Germany and Italy (from 9 to 13.6 and 5.9 to 8.2 respectively); to a lesser extent the decline in market liquidity also affects the United Kingdom and, to a very limited scale, even the United States. Such a global phenomenon may be partly related to the consequences of the Russian/LTCM liquidity crisis; this is confirmed by inspecting the standard deviation of the common liquidity risk factor,[42] which exhibits a sharp increase in August 1998 (Chart 4).

It is worth noting that in 1999 the deterioration of market liquidity is caused by the increase in the standard deviation of the transitory part, whereas the standard deviation of the fundamental value (permanent component) is virtually unchanged across countries. The worsening of liquidity conditions, according to the mqm indicator, seems to have receded during 2000, when liquidity measures reverted to levels below the pre-crisis level. For Germany, the United Kingdom and the United States, the differences in the level of mqm is attributable to the standard deviation of the transitory part, a sort of absolute measure of "mispricing"; in Germany this measure is 5-16 times higher than in the United Kingdom and the United States, as evaluated in 2000. Italy displays an absolute level of its bond market liquidity measure much closer to that of the United Kingdom and the United States, eg a significantly lower "mispricing" than Germany and France. This is a persistent feature over the time span of our sample and it might be related to the advanced trading infrastructure and market participation developed by the Italian MTS in the early 1990s.

All in all relative liquidity measures confirm the high degree of bond yields convergence across the G5 countries, especially across the largest economies of the euro area. The United Kingdom and the United States bond markets still maintain a positive liquidity differential, as measured in relative terms, with respect to those of continental Europe.

Global convergence in bond yield fundamental values, especially vis-à-vis the United States (see Chart 5), broadly explains recent trends of liquidity convergence. According to the estimated VECM for the G5 countries, implied equilibrium 10-year bond yields - ie estimated permanent (price-efficient) components - only differed by less than 50 basis points at the end of 2000 between the euro area (taken as a simple average of French, German and Italian government bond market rates) and the United States. Long-run equilibrium rates in the United States have been persistently above those of the euro area since 1997; similarly, euro area equilibrium 10-year rates are estimated to be just over 50 basis points above those of the United Kingdom. Consequently, euro area 10-year bond rates are estimated at the end of last year to have been just over 25 basis points above their equilibrium level; UK rates were almost 75 basis points above their long-run equilibrium value; conversely, US rates were some 20 basis points below their long-run equilibrium level (Chart 6).

[42] The standard deviation refers to the simulated volatility of a GARCH(1,1) model for the common stationary factor, W_t, implied by the VAR-based decomposition in equation 4.

6. Concluding remarks

Notwithstanding increasing money and bond market integration in continental Europe since the launch of the euro, a reliable government yield curve is still struggling to establish itself. Market participants have responded to the introduction of the new currency by concentrating liquidity on Eurex's Euro Bund futures contract. The rapid expansion of the Eurex capital market futures contracts in the last few years and an active repo market have reaffirmed the benchmark prominence of German government bonds. However, the budgetary developments in Germany - implementation of the Stability Pact, tax reform resolution and the sale of UMTS mobile phone licences - may further reduce the already narrow base of deliverable bonds in the existing futures markets. The disproportion of futures and cash markets, if not properly counteracted from the supply side, could leave the euro area government bond market less liquid than it might otherwise be.

In the run-up to monetary union, there were far-reaching changes on OTC and exchange-traded derivatives markets in the core euro area countries (France, Germany and Italy). OTC derivatives trading, especially interest rate swaps, has expanded significantly both worldwide and at the European level when compared with exchange-based derivatives trading. This trend seems to be driven mainly by a rising demand for hedging instruments on spread products like agency and corporate bonds. Liquidity on European exchange-traded derivatives markets has become concentrated on a handful of futures exchanges, but this trend has not been evident on European cash and repo markets. With the transition to EMU, the European exchanges have intensified their efforts to create a joint market for exchange-traded European assets through mergers and cooperative ventures. For the cash markets, this intention has not yet been successfully carried out. In the case of exchange-traded derivatives, however, market participants made their decision at an early stage by bundling liquidity: LIFFE and Eurex have established themselves as the most liquid trading place for money market derivatives and capital market derivatives, respectively.

Electronic trading of derivatives has increased substantially on futures exchanges in Europe. By concentrating liquidity on a handful of exchanges, another decision has been made by the market: the electronic trading of derivatives, with the additional aim of organising cash and repo trading on a joint electronic trading platform. Although a liquid, electronically driven market for European government bonds with a connected repo trading facility has been created by EuroMTS, London, the Europe-wide landscape of trading opportunities for fixed income products remains fairly fragmented. A considerable share of the secondary market activity in European government bonds is still concentrated on the domestic market. The development in the last two years of electronic inter-dealer bond markets in several European countries (Belgium, France, the Netherlands, Portugal and, more recently, Germany), based on the Italian MTS trading system, has so far only partly changed the overall picture of country-based concentration of market liquidity. Clearly, the expansion of the MTS platform across Europe and the rapid development of EuroMTS bode well for the prospect of strengthening market integration in the euro area, but new challenges are still ahead for the successful establishment of a single cash bond market in Europe.

Concentration of trade in capital market futures on Eurex has produced positive effects in terms of liquidity. However, concerns about squeezes in capital market futures have not been dispelled, especially under certain stressed market conditions (flight to quality, reduced supply of on-the-run benchmark securities, scarcity of deliverable securities, etc). Even though no squeezes in capital market futures have actually occurred so far, there are recognisable deficiencies in the fulfilment of cash and repo market transactions, which may reinforce squeeze concerns. The success of an electronic trading platform in Europe (like EuroMTS) will, therefore, mainly depend on how fixed income products and their derivatives as well as the repo market are integrated on this platform and whether it will be able to eliminate counterparty risk. So far the integration has taken place on a very limited scale; the repo trading facility available on the Italian platform of MTS is the only case in point.

Since the start of monetary union, yield spreads have widened in the euro area. Liquidity considerations are becoming more important in the context of EMU, where investors are no longer confined to their domestic markets by either exchange rate concerns or restrictive regulations and investment rules. Several determinants of liquidity seem to be at play: segmentations related to legal and regulatory differences; increased basis risk related to the quality of hedging bond positions in the futures markets; variable access to an active repo market and obstacles in the cross-border management of collateral; differences in bid-ask spreads across markets. While such factors are likely to be relevant in explaining euro area yield spreads, their relative importance is difficult to assess.

Changing segmentation is bringing about adjustments in the pricing differentials across markets and variations in bonds' liquidity, thus affecting the process of price discovery. Price formation in the bond markets has been hit by shifting liquidity and trading activity; market participants are reassessing relative bond values in the euro area as a result of changes in the market structure and supply.

Preliminary econometric evidence confirms that fluctuations in yield spreads across the European Union contain a significant transitory part, which can be identified as a source of "mispricing" (ie a temporary deviation from fundamental values). According to the liquidity indicator estimated in this paper the level of "mispricing" temporarily increased around the euro launch date. This increase appears by and large to have been reversed in 2000, as the impact of the launch of the euro on market participants' learning process kept on unfolding and the global implication of the Russian/LTCM crisis receded. The reversal of liquidity conditions during 2000 brought liquidity measures back to levels below that of the pre-1998 crisis.

Liquidity measures display a high degree of convergence across the G5 countries. However, according to our indicator of relative market liquidity, UK and US bond markets still maintain a positive liquidity differential with respect to those of continental Europe. Within the euro area, relative measures of bond market liquidity are now fairly similar. Italy, however, displays an absolute level of its bond market liquidity indicator (standard deviation of the transitory component) much closer to the estimates for the UK and US markets, ie significantly higher than the level estimated for Germany and France. This might be related to the advanced trading infrastructure and market participation developed by the Italian MTS since the early 1990s.

All in all, relative liquidity measures confirm the high degree of bond yield convergence across the G5 countries, especially across the largest economies of the euro area. UK and US bond markets still maintain a positive liquidity differential, measured in relative terms, with respect to those of continental Europe. Global convergence in bond yield fundamental values broadly explains recent trends of liquidity convergence. At the end of 2000, implied equilibrium 10-year bond yields only differed by less than 50 basis points between the euro area and the United States, whose long-run equilibrium rates have been persistently above those of the euro area since 1997. Similarly, euro area equilibrium 10-year rates are estimated to have been just over 50 basis points above those of the United Kingdom. Consequently, euro area 10-year bond rates are estimated at the end of last year to have been just over 25 basis points above their equilibrium level at the end of last year. UK rates were almost 75 basis points above their equilibrium values. Conversely, US rates were some 20 basis points below their long-run equilibrium level.

Table 1
Euro short and long interest rate[1]
daily data

1993:1 2000:365	Descriptive statistics				
	S_t	***Y_t***	***L_t***	***R_t***	***$Sigma_t$***
mean	6.16	5.83	4.43	4.39	4.4
median	6.15	5.86	4.00	3.69	4.06
standard deviation	0.94	0.99	1.09	1.48	1.08
min	4.03	3.63	2.69	2.59	2.66
max	8.03	7.77	5.99	9.12	7.37
Correlations					
S_t	1	0.99	0.68	0.55	0.69
Y_t		1	0.67	0.57	0.68
L_t			1	0.89	0.95
R_t				1	0.91
$Sigma_t$					1

[1] German rates before 1999.

$Sigma_t$ = implied forward rates in the three-month futures yield on the Euribor (average of four consecutive three-month delivery dates). S_t = 10-year interest swap rate on the euro. Y_t = 10-year yield to maturity on German bund. L_t = 12-month interbank (Libor) rate on the euro). R_t = three-month interbank (Libor) rate on the euro.

Table 2

Panel A	**Unit root tests**				
1993:1 2000:365	***S_t***	***Y_t***	***L_t***	***R_t***	***$Sigma_t$***
ADF	–1.16	–1.31	–0.05	–1.04	–0.94
(P-values)	*0.92*	*0.89*	*0.99*	*0.93*	*0.95*
PHILLIPS	–5.51	–4.61	1.56	–3.02	–2.76
(P-values)	*0.78*	*0.85*	*1.00*	*0.93*	*0.95*
WTD-SYM	–1.48	–1.62	–0.54	1.85	–0.11
(P-values)	*0.89*	*0.85*	*0.99*	*1.00*	*1.00*
(Number of lags)	12	12	28	20	6
Panel B	**Cointegration vectors: Johansen ML proc.**				
1° cointegration vector	1.00	–1.06	–0.17	–0.07	0.20
2° cointegration vector	1.00	5.31	46.78	–7.93	–45.66
Eigenvalues	0.0363	0.0082	0.0078	0.0032	0.0003

Panel C	**Cointegration rank test**	
No of cointegration vectors: r	*Trace test*	*P-values*
HO: r=0	157.07	0.000
HO: r<=1	54.26	0.054
HO: r<=2	31.27	0.103
HO: r<=3	9.62	0.505

Table 3

Econometric estimates

Sample: 1993:1 2000:365	Constant	$Sigma_t$-R_t	R_t-L_t	L_t-Y_t	ADJ.R^2	SER	DW	LOG-LIK
OLS								
S_t-Y_t	0.43	0.0893	-0.0196	0.06937	0.34	0.106	0.13	2334
T-Statistic	*103.6*	*12.3*	*-3.08*	*26.9*				
Standard Error	*4.1.E-03*	*7.3.E-03*	*6.3.E-03*	*2.6.E-03*				
GARCH								
S_t-Y_t	0.30	-0.03329	-0.107	0.0153	0.70	0.042	0.54	3670
T-Statistic	*167.4*	*-12.7*	*-68.9*	*13.9*				
Standard Error	*1.8.E-03*	*2.6.E-03*	*1.6.E-03*	*1.1.E-03*				
Volatility param.	mu_0=0.234.E-03	mu_1=0.697	mu_2=0.336					
T-Statistic	*9.3*	*17.1*	*15.6*					
Standard Error	*2.5.E-05*	*4.1.E-02*	*2.1.E-02*					
KALMAN FILTER								
S_t-Y_t	0.00177	0.5507	0.697	0.452	0.99	0.015	0.56	12560
T-Statistic	*13.3*	*3328.8*	*4199.9*	*3545.9*				
Standard Error	*1.3.E-04*	*1.7.E-04*	*1.7.E-03*	*1.3.E-04*				
Volatility param.	mu_0=0.265.E-02	mu_1=0.716	mu_2=0.283					
T-Statistic	*17.1*	*15.6*	*14.0*					
Standard Error	*1.6.E-08*	*4.6.E-02*	*2.0.E-02*					

$Sigma_t$ = implied forward rates in the three-month futures yield on the Euribor (average of four consecutive three-month delivery dates). S_t = 10-year interest swap rate on the euro. Y_t = 10-year yield to maturity on German bund. L_t = 12-month interbank (Libor) rate on the euro). R_t = three-month interbank (Libor) rate on the euro.

Table 4

Government bond interest rates and market liquidity in G5 countries

		Market quality measure[1]				
		S_t	***Y_t***	***L_t***	***R_t***	***$Sigma_t$***
MQM: 1993:1	2000:365	0.053	0.061	0.013	0.006	0.007
MQM: 1993:1	1997:365	0.051	0.064	0.014	0.005	0.007
MQM: 1998:1	1998:365	0.010 (0.016)	0.008 (0.012)	0.002	0.003	0.001
MQM: 1999:1	1999:365	0.021 (0.032)	0.019 (0.028)	0.004	0.005	0.001
MQM: 2000:1	2000:365	0.021 (0.036)	0.026 (0.046)	0.003	0.007	0.003
Factor loadings		**A2:**		**A1:**		
		W1	**W2**	**F1**	**F2**	**F3**
S_t		0.00011	-0.000069	0.0056	0.0225	0.0054
Y_t		0.00005	-0.000010	0.0060	-0.0336	0.0019
L_t		-0.00019	0.000025	0.0146	0.0260	-0.0101
R_t		0.00014	-0.000026	-0.0221	-0.0640	0.0407
$Sigma_t$		-0.00011	3.13300D-07	-0.0130	0.0075	-0.0358

[1] In brackets: calculation with only one cointegration vector.

Table 5

Descriptive statistics

1993:1 2000:365	**Germany**	**France**	**Italy**	**UK**	**US**
mean	5.79	6.01	8.19	6.77	6.15
median	5.81	5.74	7.65	7.03	6.07
standard deviation	0.98	1.16	2.98	1.32	0.72
min	3.63	3.72	3.89	4.14	4.15
max	7.81	8.41	13.81	9.05	8.03
Correlations					
Germany	1.00	0.98	0.93	0.94	0.80
France		1.00	0.95	0.91	0.75
Italy			1.00	0.91	0.60
UK				1.00	0.74
US					1.00

Table 6

Ten-year government bond yield: liquidity measures in the G5 countries

Panel A	**Liquidity measures**				
	Germany	**France**	**Italy**	**UK**	**US**
Sample: 1993:1 - 2000:365					
MQM indicator	37.59	31.02	50.95	12.37	3.66
St. dev. (transitory)	5.25	8.05	1.75	0.84	0.22
St. dev. (permanent)	0.14	0.26	0.03	0.07	0.06
Sample: 1993:1 - 2000:365					
MQM indicator	23.69	20.21	35.18	8.80	2.76
St. dev. (transitory)	4.09	6.27	1.37	0.65	0.17
St. dev. (permanent)	0.17	0.31	0.04	0.07	0.06
Sample: 1993:1 - 2000:365					
MQM indicator	8.96	5.71	5.87	1.31	0.32
St. dev. (transitory)	0.45	0.69	0.15	0.07	0.02
St. dev. (permanent)	0.05	0.12	0.03	0.05	0.06
Sample: 1993:1 - 2000:365					
MQM indicator	13.57	6.43	8.24	1.81	0.50
St. dev. (transitory)	0.69	1.06	0.23	0.11	0.03
St. dev. (permanent)	0.05	0.16	0.03	0.06	0.06
Sample: 1993:1 - 2000:365					
MQM indicator	3.79	1.99	2.42	0.51	0.12
St. dev. (transitory)	0.16	0.24	0.05	0.03	0.01
St. dev. (permanent)	0.04	0.12	0.02	0.05	0.05

Panel B	**A2:**	**A1:**			
Factor loadings	**W1**	**F1**	**F2**	**F3**	**F4**
Germany	–0.02	0.0212	0.0196	0.0205	0.0011
France	0.04	0.0486	–0.0118	0.0077	0.0096
Italy	–0.58	–0.0033	–0.0110	0.0135	0.0093
UK	0.10	0.0345	0.0244	–0.0169	0.0443
US	0.18	0.0079	–0.0054	0.0248	0.0495

Panel C	**Cointegration rank test**		
No of cointegration vectors: r	*Trace test*	*P-values*	*Eigenvalues*
HO: r=0	79.96	0.057	0.0177
HO: r<=1	40.5	0.449	0.0086
HO: r<=2	22.96	0.481	0.0072
HO: r<=3	8.24	0.625	0.0027
HO: r<=4	2.78	0.89	0.0014

Chart 1

Euro area 10-year spread vs German bund yield: France, Italy and Spain

(daily data; in percentage points)

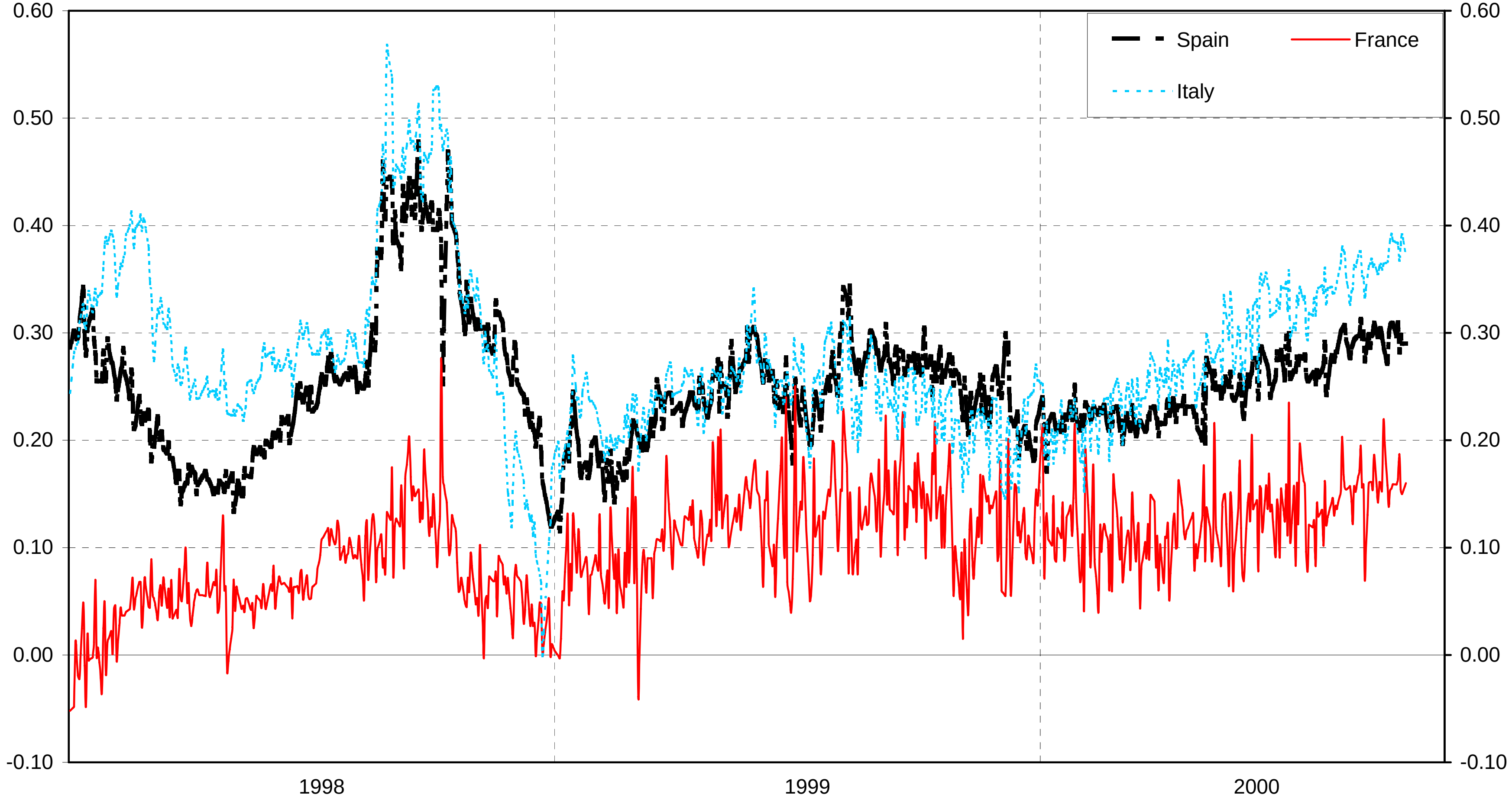


Chart 2

Euro 10-year spread vs German bund yield and corporate
(daily data; in percentage points)

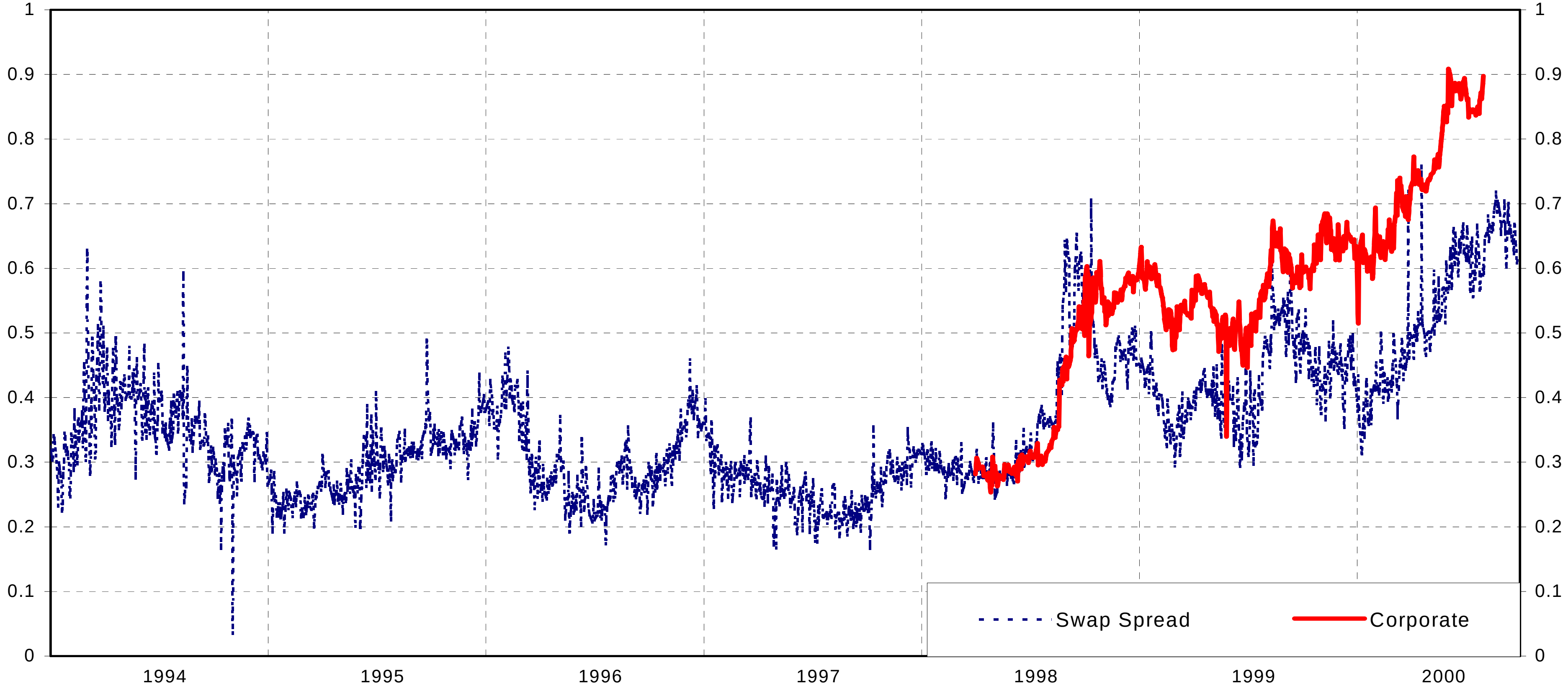


Chart 3

Estimated GARCH volatility of 10-year swap spread vs German bund

(daily data; in percentage points)

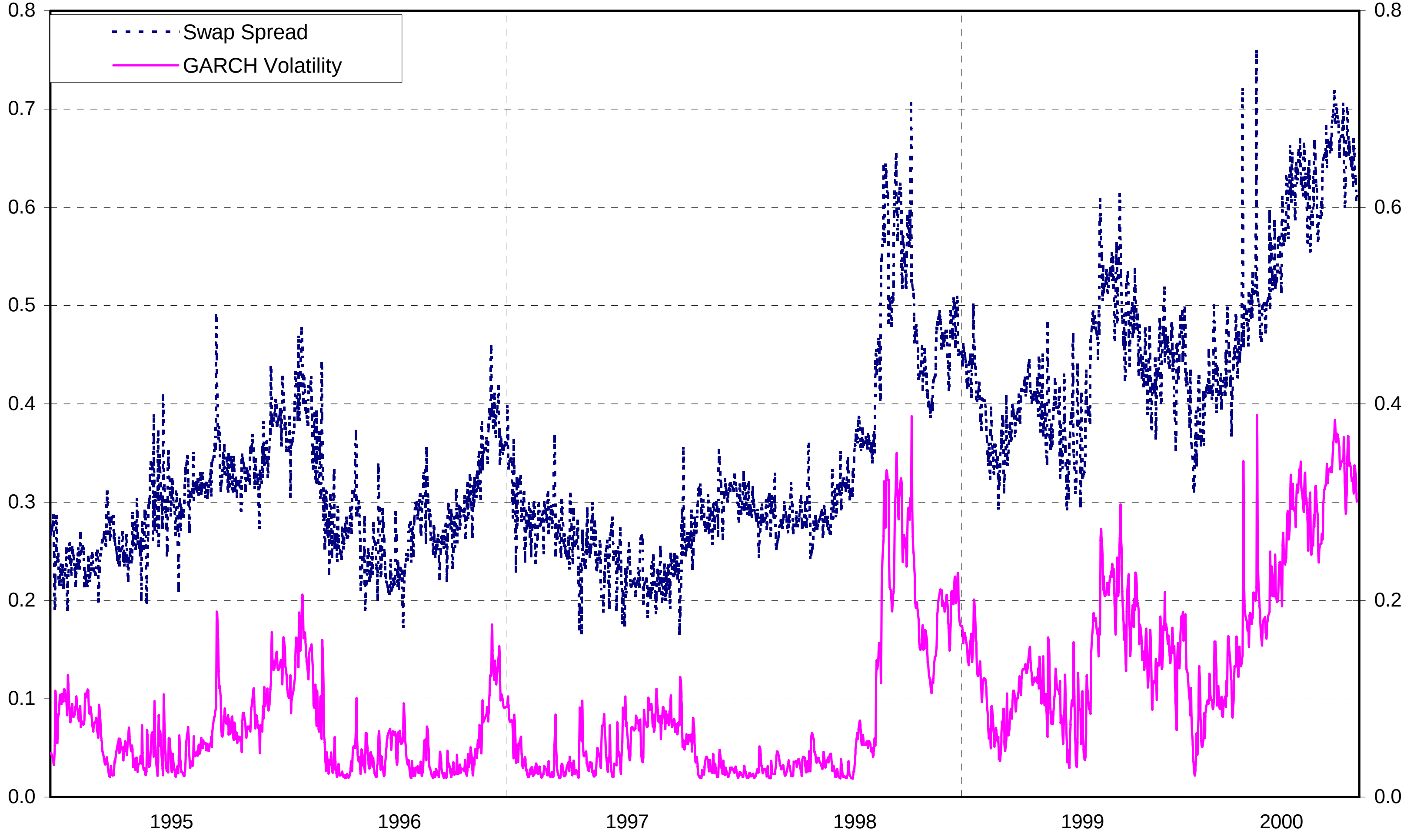


Chart 4

Common liquidity risk measure for the G5 countries

(daily data; in percentage points)

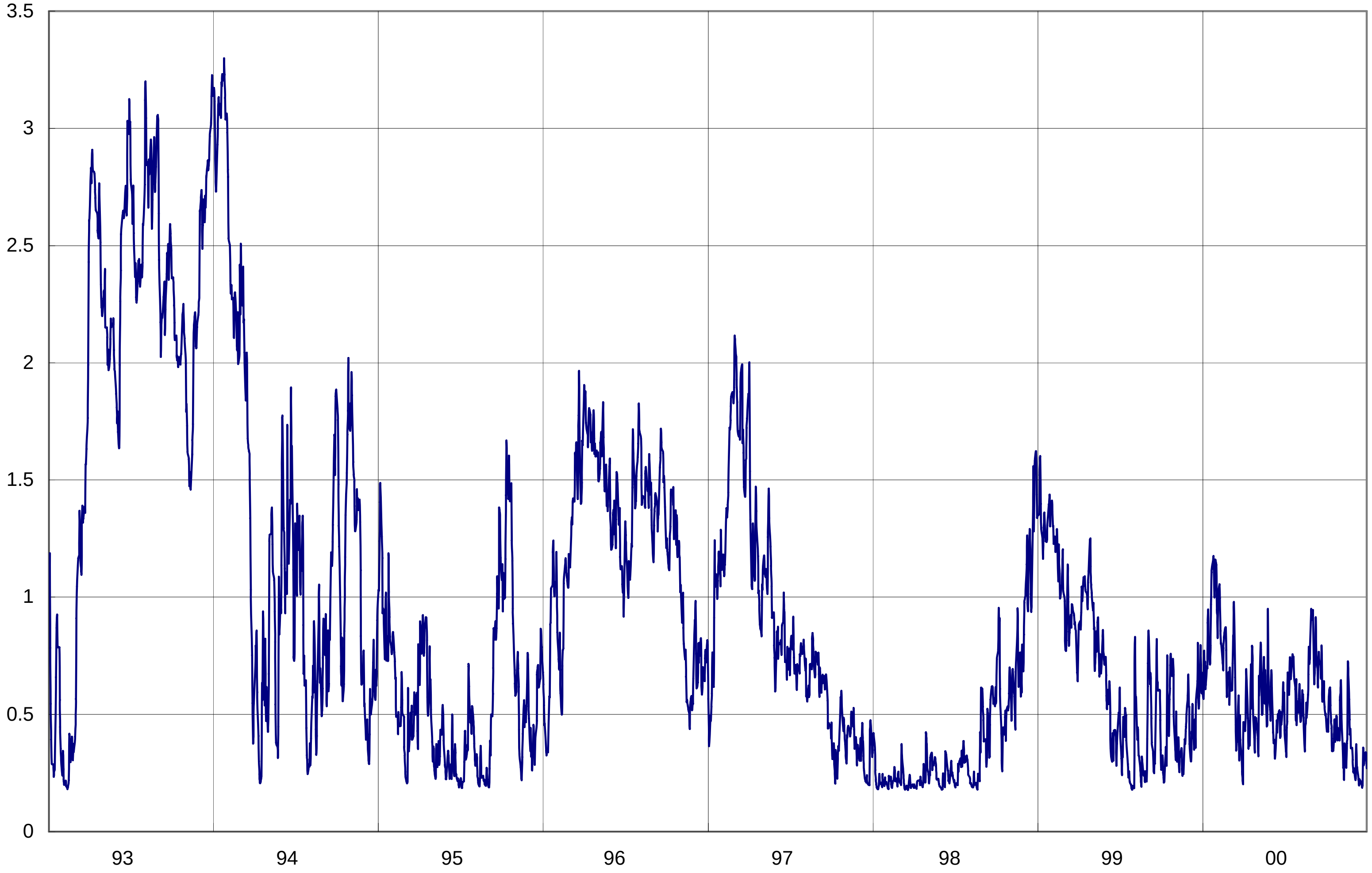


Chart 5

US, UK and euro area (France, Germany and Italy) government bond yields: deviation from fundamental values

(daily data; in percentage points)

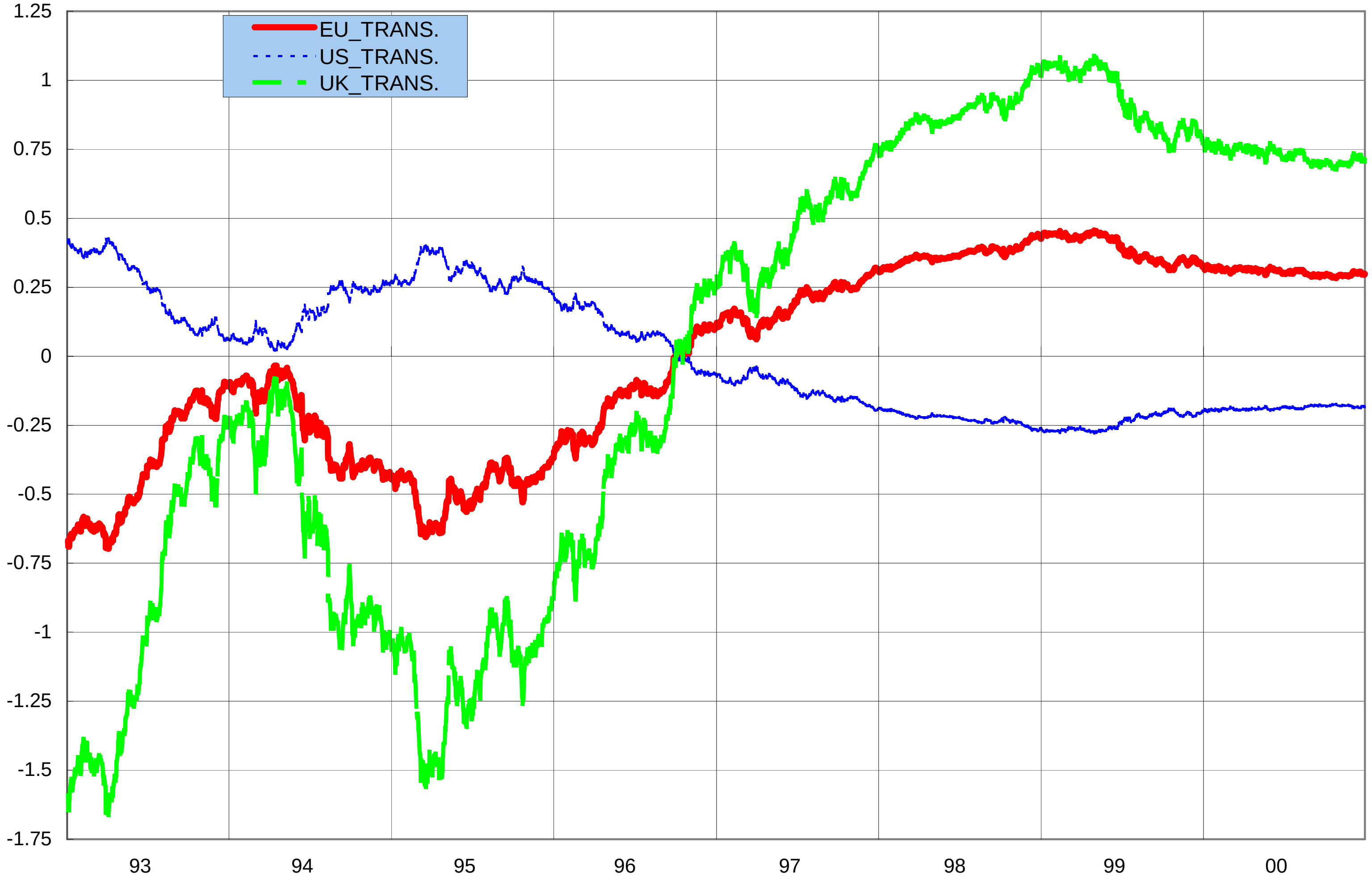
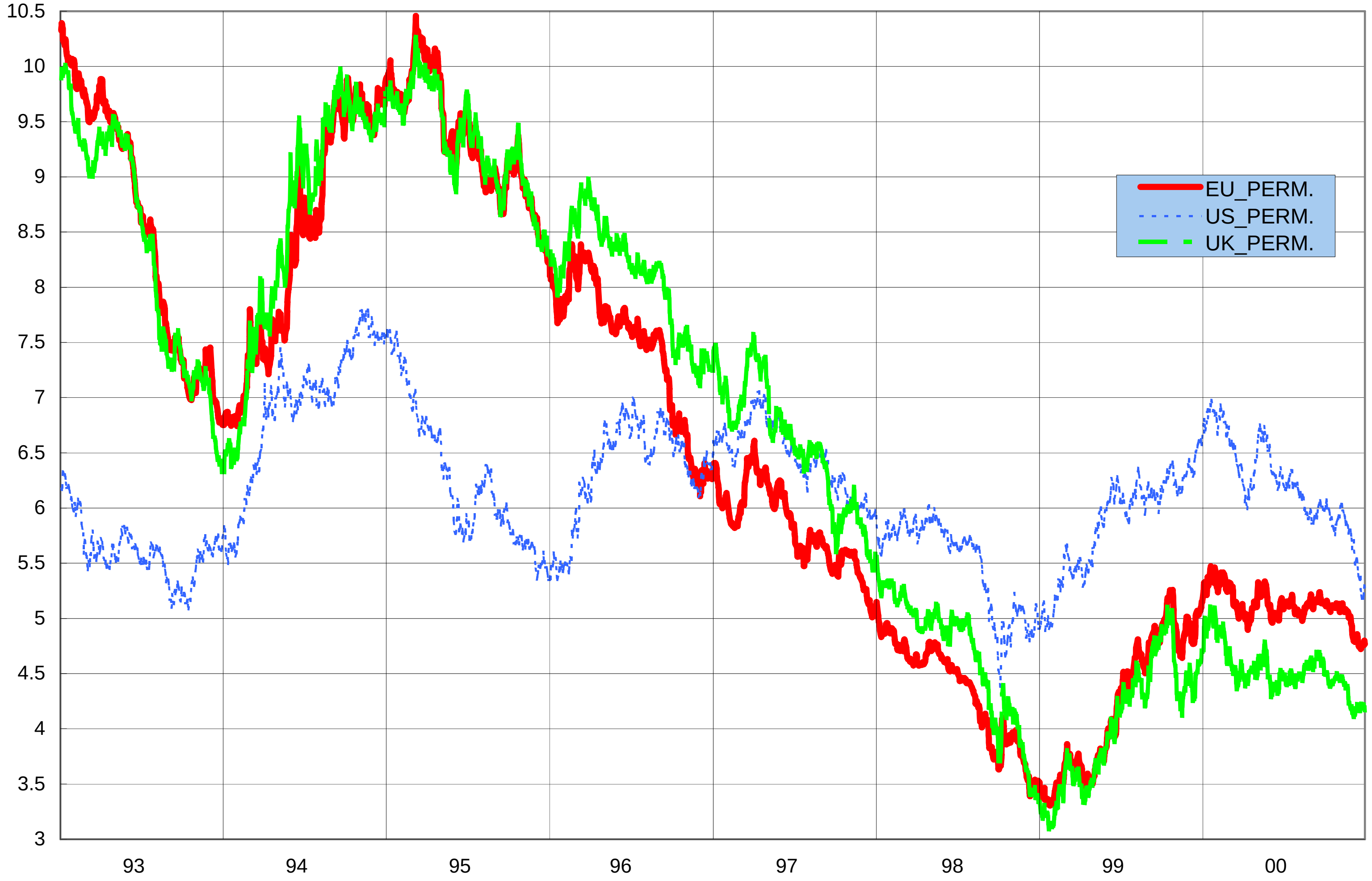


Chart 6

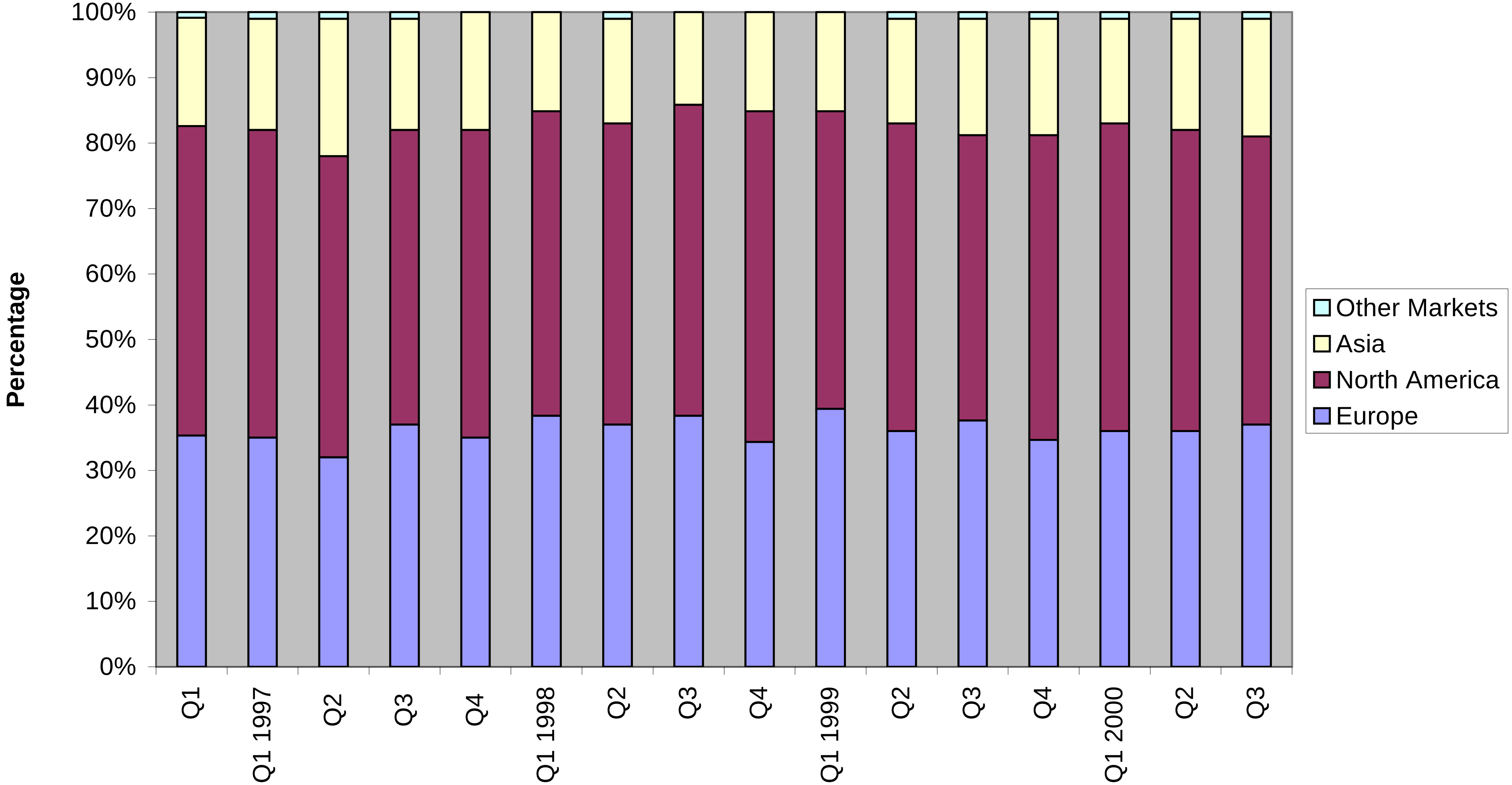
US, UK and euro area (France, Germany and Italy) 10-year government bond yield: fundamental (long-run) values

(daily data; in percentage points)



Annex 1

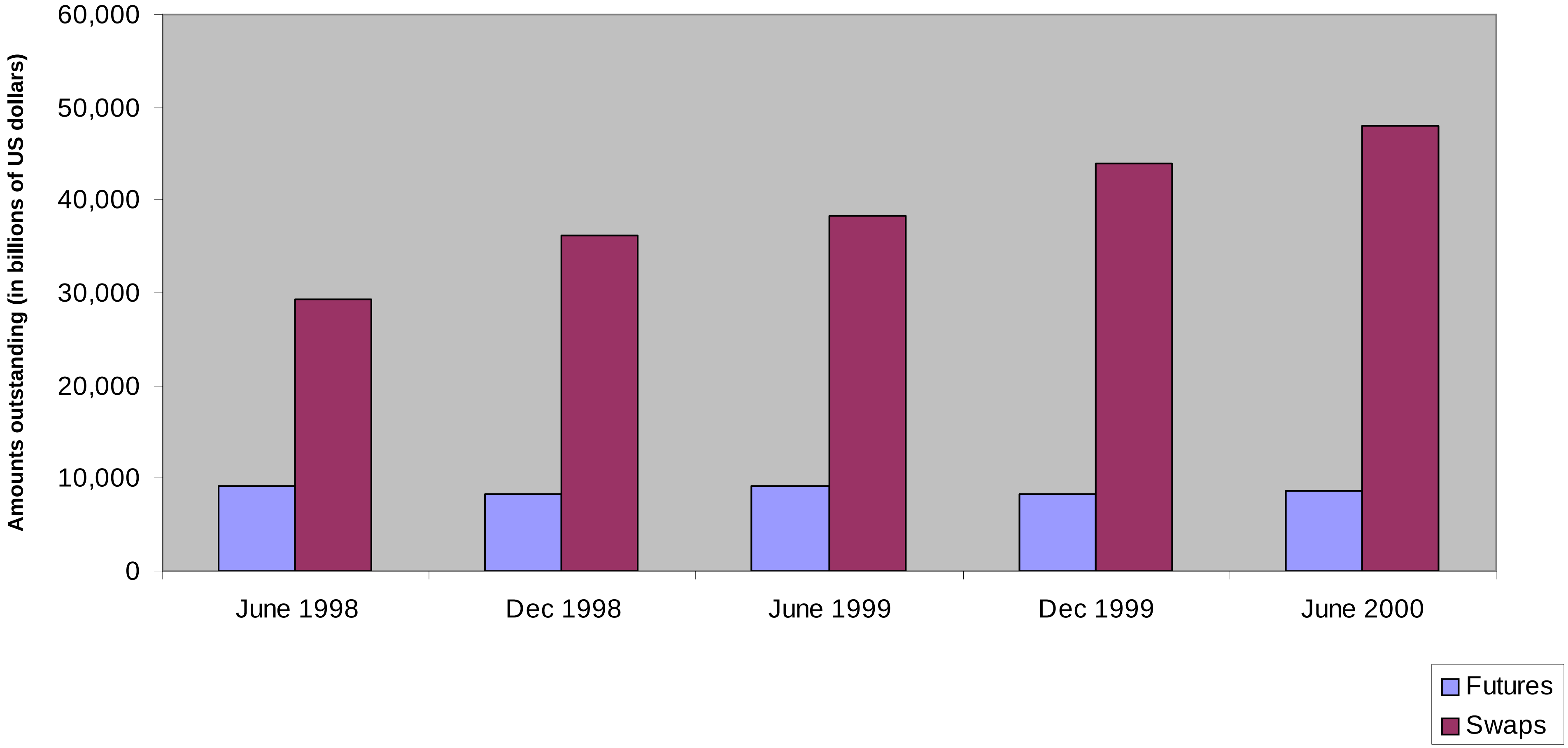
Turnover in exchange traded interest rate derivatives by location



Source: *BIS Quarterly Review.*

Annex 2

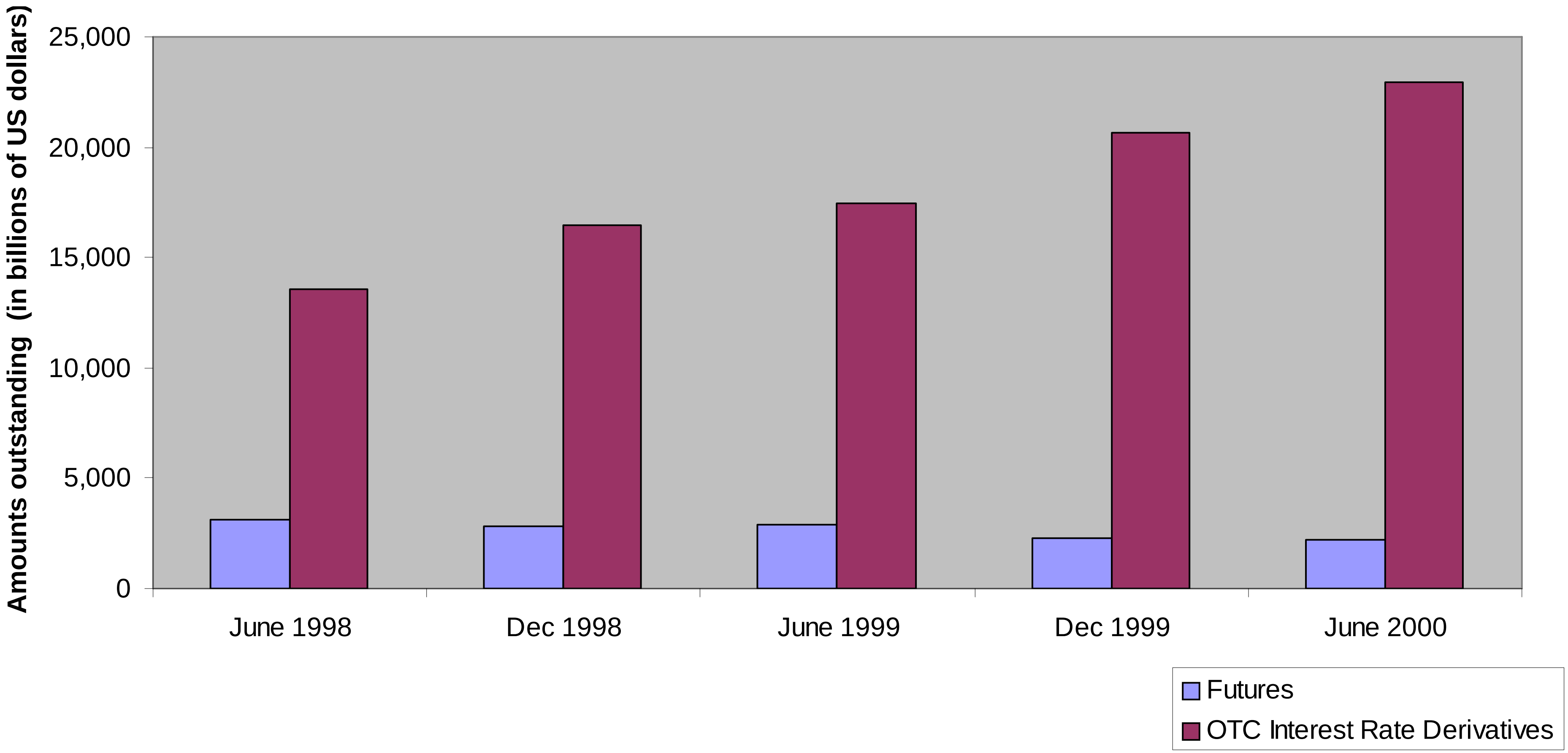
Amounts outstanding of OTC single currency interest rate swaps and exchange traded interest rate futures in all markets
(notional amounts in billions of US dollars)



Source: *BIS Quarterly Review.*

Annex 3

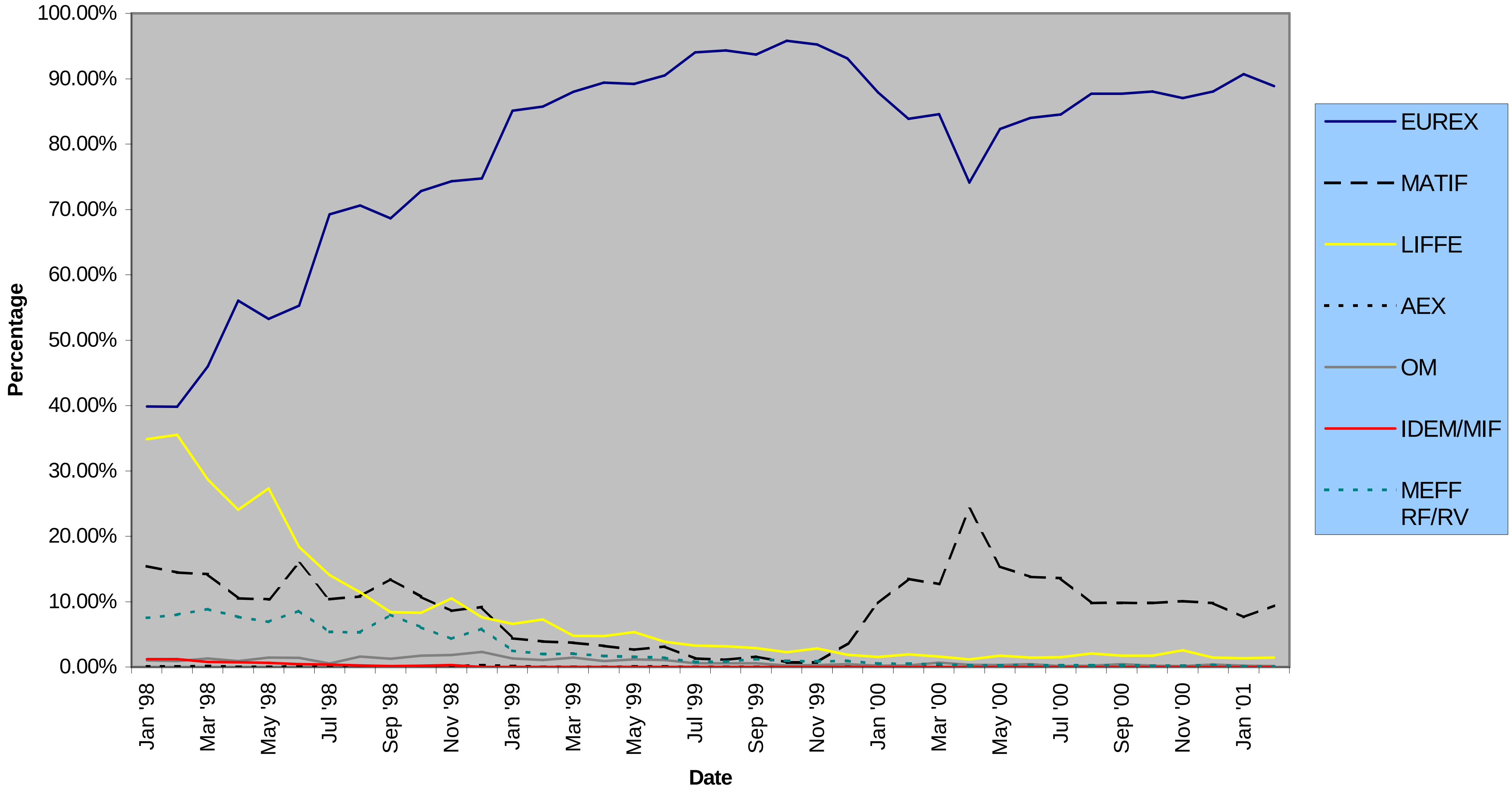
Amounts outstanding of OTC single currency interest rate derivatives and exchange traded interest rate futures in the euro area (notional amounts in billions of US dollars)



Source: *BIS Quarterly Review.*

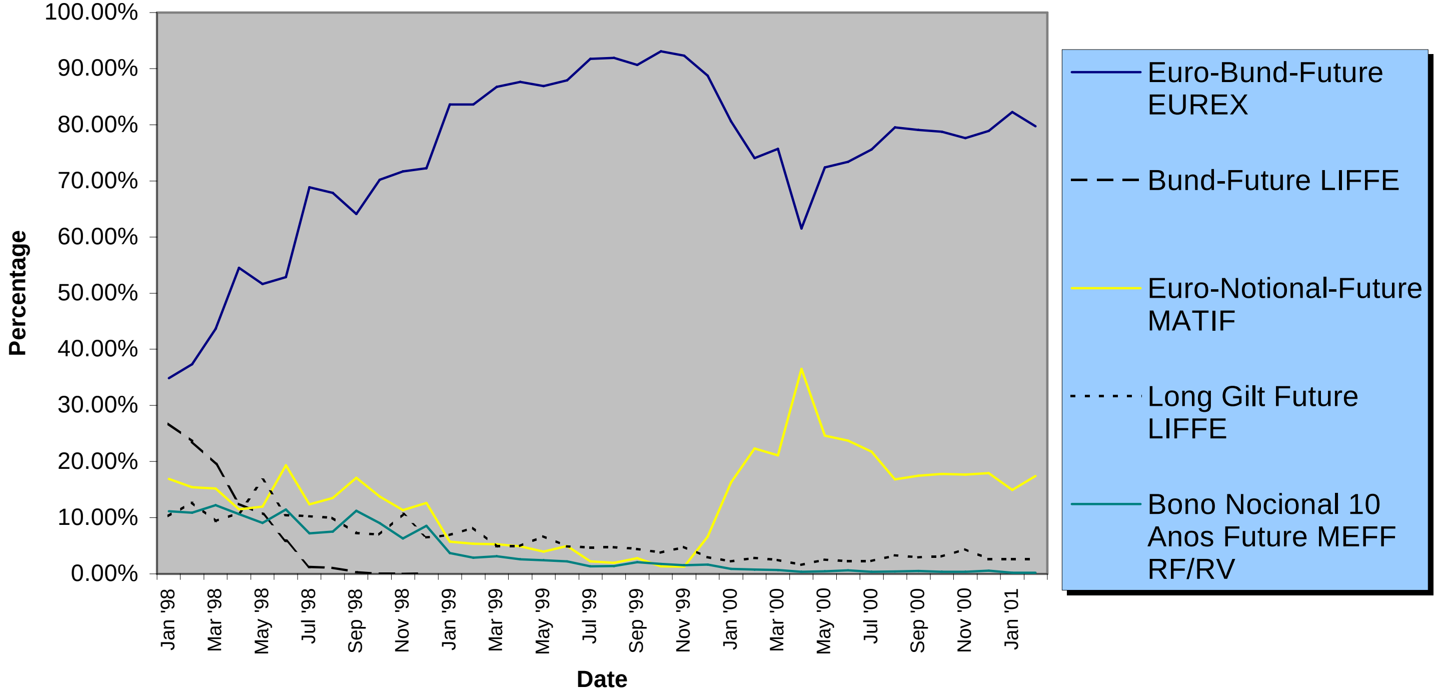
Annex 4

European futures exchanges - percentage of traded capital market products



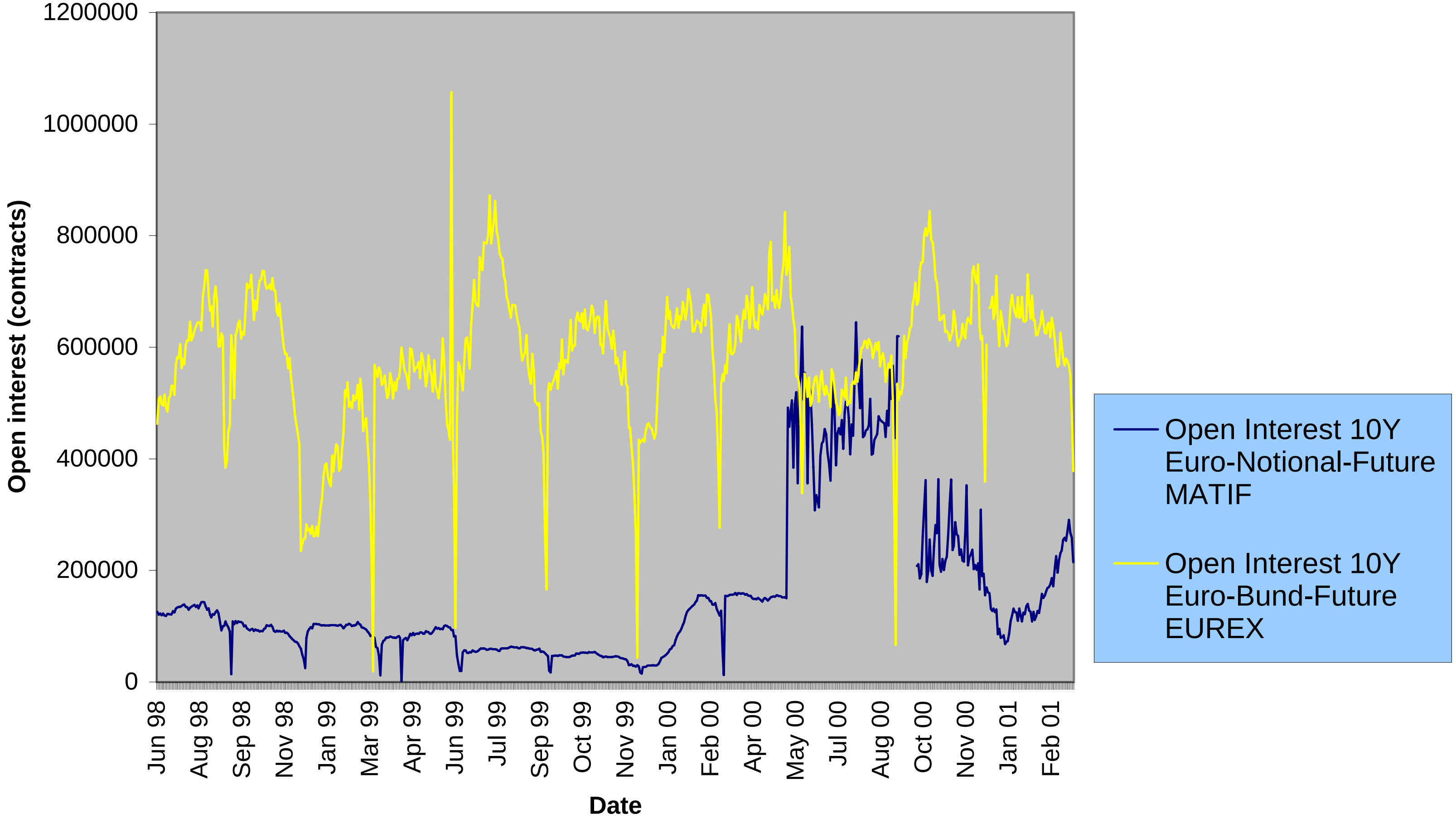
Annex 5

European 10Y capital market futures - traded contracts



Annex 6

Open interest 10Y futures EUREX/MATIF



Annex 7

Effect of a change in the notional contract coupon after the Euro Bund futures squeeze on the June 1999 delivery

Euro Bund futures contract: June 1999 delivery						
Contracts delivery date:	**10.06.1999**					
Bond No	113505	113507	113509	113510	113511	
Size (EUR millions)	15,339	8,692	13,805	14,000	11,000	
Coupon	5.25	4.75	4.125	3.75	4.00	
Maturity	04.01.2008	04.07.2008	04.07.2008	04.01.2009	04.07.2009	
Yield (ISMA in %)	6	6	6	6	6	
Duration	6.92	7.15	7.31	7.92	7.98	
Modified duration	6.52	6.75	6.90	7.47	7.53	Range: 1,01
Price	95.05	91.44	87.17	83.95	85.15	
Conversion factor (6%)	0.95049	0.914424	0.871737	0.839458	0.851507	
Converted price	***100.00***	***100.00***	***100.00***	***100.00***	***100.00***	Range: 0,00
Scenario1: Market yield level stays below the level of the notional contract coupon						
Yield (ISMA in %)	4	4	4	4	4	
Duration	7.05	7.32	7.47	8.07	8.18	
Modified duration	6.79	7.03	7.18	7.76	7.86	Range: 1,09
Price	108.90	105.61	100.93	98.03	99.96	
Converted price	***114.57***	115.49	115.78	116.77	117.39	Range: 2,82
Scenario 2: Relative yield change required to change the CTD bond						
Yield (ISMA in %)	***3.88***	4	4	4	4	
Duration	7.05	7.32	7.47	8.07	8.18	Range: 1,09
Modified duration	6.79	7.03	7.18	7.76	7.86	
Price	109.80	105.61	100.93	98.03	99.96	
Converted price	115.52	***115.49***	115.78	116.77	117.39	Range: 1,90
Scenario 3: The notional contract coupon is lowered to 4%, which was the market yield level on June 1999 delivery						
Conversion factor (4%)	1.088954	1.056048	1.009335	0.98027	0.999605	
Yield (ISMA in %)	4	4	4	4	4	
Duration	7.04	7.32	7.47	8.07	8.18	
Modified duration	6.77	7.03	7.18	7.76	7.86	Range: 1,09
Price	108.90	105.61	100.93	98.03	99.96	
Converted price	***100.00***	***100.00***	***100.00***	***100.00***	***100.00***	Range: 0,00
Scenario 4: Market yield level stays above the level of the adjusted notional contract coupon (4%)						
Yield (ISMA in %)	5	5	5	5	5	
Duration	6.98	7.23	7.39	8.00	8.08	
Modified duration	6.65	6.89	7.04	7.62	7.69	Range: 0,91
Price	101.68	98.21	93.74	90.65	92.19	
Converted price	93.37	92.99	92.88	92.48	***92.23***	Range: 1,14

The respective CTD bond is highlighted in each case.
The conversion factor for each deliverable bond is calculated according to the EUREX conversion factor formula; see EUREX circular 106/99 of 20 October 1999.

Annex 8.1

10Y Euro Bund futures contract (EUREX) vs 10Y Euro Notional futures contract (MATIF): September 1998 delivery

10Y Euro Bund futures contract September 1998 (09.06.98-08.09.98; delivery: 10.09.98)

Deliverable bonds	Start of accrued interest	Outstanding amount (Million Euro)	Coupon	Maturity	Conv. factor	Deliverable volume (Million Euro)	Open interest (high)	Days being CTD	Mod. duration	Yield
113503	25.04.1997	15.339	6	04.07.2007	0.999674	4,412.4 (29% of outst. amount)	738,281 (12.08.98)	63	6.85	4.275
113505	09.01.1998	15.339	5.25	04.01.2008	0.947629	25.4 (0.16% of outst. amount)		0	7.12	4.266
113507	10.07.1998	8.692	4.75	04.07.2008	0.909448			0	7.71	4.252
Total deliv. volume		39.370								

Nominal contract value: DEM 250,000

10Y Euro Notional futures contract September 1998 (16.06.98-14.09.98; delivery: 18.09.98)

Deliverable bonds	Start of accrued interest	Outstanding amount (Million Euro)	Coupon	Maturity	Conv. factor	Deliverable volume (Million Euro)	Open interest (high)	Days being CTD	Mod. duration	Yield
FR0000570665	25.10.1997	16,245	8.5	25.10.2008	1.227773	na	143,642 (10.08.98)	63	6.91	4.212
FR0000570574	25.04.1997	16,938	5.5	25.04.2007	0.99965			0	6.75	4.111
FR0000570590	25.10.1997	15,327	5.5	25.10.2007	0.999855			0	6.89	4.166
FR0000570632	25.04.1998	16,408	5.25	25.04.2008	0.981386			0	7.41	4.201
Total deliv. volume		64,918								

Nominal contract value: FRF 500,000

Sources: Bloomberg; Ministere de l'Economie des Finances et de l'Industrie: Monthly Report; Eurex: Monthly Report (Internet page: www.exchange.de); Clearnet: Bulletin for the delivery months.

Correlations (daily/weekly)

	Germany		France		Italy
	Benchmark bond	CTD bond	Benchmark bond	CTD bond	Benchmark bond
	113507	113503	570632	570665	
Bund future	0.847/0.805	0.880/0.948	0.898/0.886	0.889/0.884	0.593/0.379
Euro Notional future	0.879/0.920	0.895/0.972	0.919/0.960	0.920/0.955	0.690/0.621
DEM swaps	0.405/0.444	0.403/0.242	-	-	-
FRF swaps	-	-	0.665/0.608	0.676/0.606	-
ITL swaps	-	-	-	-	0.613/0.956

Daily period: 08.07.98-14.09.98. Weekly period: 17.07.98-11.09.98. Correlation is measured for futures by the effective daily/weekly price changes between futures and bonds, and for swaps by the effective daily/weekly yield changes between swaps and bonds.

Source: Bloomberg.

Annex 8.2

10Y Euro Bund futures contract (EUREX) vs 10Y Euro Notional futures contract (MATIF): December 1998 delivery

10Y Euro Bund futures contract December 1998 (09.09.98-08.12.98; delivery: 10.12.98)

Deliverable bonds	Start of accrued interest	Outstanding amount (Million Euro)	Coupon	Maturity	Conv. factor	Deliverable volume (Million Euro)	Open interest (high)	Days being CTD	Mod. duration	Yield
113503	25.04.1997	15.339	6	04.07.2007	0.999563	3,025.8 (19.7% of outst. amount)	767,452 (09.10.98)	63	6.66	3.895
113505	09.01.1998	15.339	5.25	04.01.2008	0.948987			0	6.94	3.854
113507	10.07.1998	8.692	4.75	04.07.2008	0.911092	3.19 (0.036% of outst. amount)		0	7.53	3.87
113509	30.10.1998	13,805	4.125	04.07.2008	0.866857			0	7.68	3.888
Total deliv. volume		53,175								

Nominal contract value: DEM 250,000

10Y Euro Notional futures contract December 1998 (15.09.98-14.12.98; delivery: 18.12.98)

Deliverable bonds	Start of accrued interest	Outstanding amount (Million Euro)	Coupon	Maturity	Conv. factor	Deliverable volume (Million Euro)	Open interest (high)	Days being CTD	Mod. duration	Yield
FR0000570665	25.10.1997	16,245	8.5	25.10.2008	1.223459	1,123.5 (6.92% of outst. amount)	109,367 (18.09.98)	64	7.16	3.862
FR0000570590	25.10.1997	15,327	5.5	25.10.2007	0.999824			0	7.03	3.824
FR0000570632	25.04.1998	24,703	5.25	25.04.2008	0.981761	50.5 (0.2% of outst. amount)		0	7.22	3.863
Total deliv. volume		56,275								

Nominal contract value: FRF 500,000

Sources: Bloomberg; Ministere de l'Economie des Finances et de l'Industrie: Monthly Report; Eurex: Monthly Report (Internet page: www.exchange.de); Clearnet: Bulletin for the delivery months.

Correlations (daily/weekly)

	Germany		France		Italy
	Benchmark bond	CTD bond	Benchmark bond	CTD bond	Benchmark bond
	113509	113503	571432	570665	
Bund future	0.821/0.917	0.854/0.952	0.849/0.961	0.849/0.966	0.600/0.871
Euro Notional future	0.674/0.921	0.722/0.922	0.799/0.923	0.772/0.920	0.534/0.709
DEM swaps	0.766/0.868	0.756/0.796	-	-	-
FRF swaps	-	-	0.792/0.951	0.820/0.963	-
ITL swaps	-	-	-	-	0.638/0.819

Daily period: 28.10.98-14.12.98. Weekly period: 06.11.98-11.12.98. Correlation is measured for futures by the effective daily/weekly price changes between futures and bonds, and for swaps by the effective daily/weekly yield changes between swaps and bonds.

Source: Bloomberg.

Annex 8.3

10Y Euro Bund futures contract (EUREX) vs 10Y Euro Notional futures contract (MATIF): March 1999 delivery

10Y Euro Bund futures contract March 1999 (09.12.98-08.03.99; delivery: 10.03.99)

Deliverable bonds	Start of accrued interest	Outstanding amount (Million Euro)	Coupon	Maturity	Conv. factor	Deliverable volume (Million Euro)	Open interest (high)	Days being CTD	Mod. duration	Yield
113505	09.01.1998	15.339	5.25	04.01.2008	0.949788	3,052.1 (19.9% of outst. amount)	591,424 (23.02.99)	58	7.01	4.089
113507	10.07.1998	8.692	4.75	04.07.2008	0.912935			0	7.26	4.077
113509	30.10.1998	13,805	4.125	04.07.2008	0.869567			0	7.41	4.094
113510	08.01.1999	14,000	3.750	04.01.2009	0.837267	11 (0.078% of outst. amount)		0	7.99	4.054
Total deliv. volume		37,836								

Delivered vol.: Bund future: 19,385 Contracts: 2,477.8 Mio Euro Nominal contract value: DEM 250,000
Euro ^Bund future: 5,743 Contracts: 574.3 Mio Euro Nominal contract value: Euro 100,000

10Y Euro Notional futures contract March 1999 (15.12.98-15.03.99; delivery: 19.03.99)

Deliverable bonds	Start of accrued interest	Outstanding amount (Million Euro)	Coupon	Maturity	Conv. factor	Deliverable volume (Million Euro)	Open interest (high)	Days being CTD	Mod. duration	Yield
FR0000570665	25.10.1997	16,245	8.5	25.10.2008	1.218868	1,125.7 (6.93% of outst. amount)	107,576 (19.02.99)	24	6.89	4.051
FR0000570590	25.10.1997	15,327	5.5	25.10.2007	0.999651			38	6.77	4.000
FR0000570632	25.04.1998	24,703	5.25	25.04.2008	0.982317			0	6.95	4.054
FR0000571432	25.04.1998	19,291	4	25.04.2009	0.885896				8.09	4.116
Total deliv. volume		75,566								

Nominal contract value: Euro 100,000

Sources: Bloomberg; Ministere de l'Economie des Finances et de l'Industrie: Monthly Report; Eurex: Monthly Report (Internet page: www.exchange.de); Clearnet: Bulletin for the delivery months.

Correlations (daily/weekly)

	Germany		France		Italy
	Benchmark bond	CTD bond	Benchmark bond	CTD bond	Benchmark bond
	113510	113505	571432	570665	
Bund future	0.850/0.777	0.865/0.837	0.862/0.825	0.851/0.845	0.824/0.618
Euro Notional future	0.951/0.955	0.958/0.966	0.966/0.961	0.964/0.978	0.910/0.878
Euro swaps	0.908/0.958	0.915/0.956	0.907/0.974	0.899/0.963	0.923/0.970

Daily period: 06.01.99-05.03.99. Weekly period: 15.01.99-05.03.99. Correlation is measured for futures by the effective daily/weekly price changes between futures and bonds, and for swaps by the effective daily/weekly yield changes between swaps and bonds.

Source: Bloomberg.

Annex 8.4

10Y Euro Bund futures contract (EUREX) vs 10Y Euro Notional futures contract (MATIF): June 1999 delivery

10Y Euro Bund futures contract June 1999 (09.03.99-08.06.99; delivery 10.06.99)

Deliverable bonds	Start of accrued interest	Outstanding amount (Million Euro)	Coupon	Maturity	Conv. factor	Deliverable volume (Million Euro)	Open interest (high)	Days being CTD	Mod. duration	Yield
113505	09.01.1998	15.339	5.25	04.01.2008	0.950792	5,441.3 (35.5% of outst. amount)	1,057,000 (01.06.99)	59	6.75	4.226
113507	10.07.1998	8.692	4.75	04.07.2008	0.914979			0	7	4.23
113509	30.10.1998	13,805	4.125	04.07.2008	0.872468			0	7.14	4.246
113510	08.01.1999	14,000	3.750	04.01.2009	0.840315			0	7.73	4.225
113511	26.03.1999	11,000	4.000	04.07.2009	0.852798				8.06	4.228
Total deliv. volume		62,836								

10Y Euro Notional futures contract June 1999 (16.03.99-14.06.99; delivery: 18.06.99)

Deliverable bonds	Start of accrued interest	Outstanding amount (Million Euro)	Coupon	Maturity	Conv. factor	Deliverable volume (Million Euro)	Open interest (high)	Days being CTD	Mod. duration	Yield
Bund 113505	09.01.1998	15,339	5.25	04.01.2008	1.127267		101,309 (26.05.99)	0	6.71	4.355
OAT FR0000570632	25.04.1998	25,292	5.25	25.04.2008	1.131264			6	7	4.375
Bund 113507	10.07.1998	8,692	4.75	04.07.2008	1.095524			0	6.96	4.358
OAT FR0000570665	25.10.1997	16,245	8.5	25.10.2008	1.393006			0	6.6	4.38
Bund 113509	30.10.1998	13,805	4.125	04.07.2008	1.047747			5	7.11	4.367
Bund 113510	08.01.1999	14,000	3.750	04.01.2009	1.019853			0	7.7	4.329
OAT FR0000571432	25.04.1998	22,522	4.000	25.04.2009	1.041014	1,251.1 (5.56% of outst. amount)		38	7.9	4.454
Bund 113511	26.03.1999	11,000	4.000	04.07.2009	1.041412			15	8.03	4.312
Total deliv. volume		126,895								

Basket of deliverable bonds changed by MATIF on June 1999 delivery: dual issuer basket with French and German issues. In addition, notional coupon lowered from 5.5% to 3.5%.

Sources: Bloomberg; Ministere de l'Economie des Finances et de l'Industrie: Monthly Report; Eurex: Monthly Report (Internet page: www.exchange.de); Clearnet: Bulletin for the delivery months.

Correlations (daily/weekly)

	Germany		France		Italy
	Benchmark bond	CTD bond	Benchmark bond	CTD bond	Benchmark bond
	113511	113505	571432	571432	
Euro Bund future	0.791/0.929	0.817/0.968	0.808/0.933	0.808/0.933	0.715/0.928
Euro Notional future	0.910/0.918	0.908/0.944	0.938/0.943	0.938/0.943	0.916/0.937
Euro swaps	0.715/0.866	0.720/0.884	0.732/0.897	0.732/0.897	0.667/0.897

Daily period: 23.03.99-14.06.99. Weekly period: 02.04.99-11.06.99. Correlation is measured for futures by the effective daily/weekly price changes between futures and bonds, and for swaps by the effective daily/weekly yield changes between swaps and bonds.

Source: Bloomberg.

Annex 8.5

10Y Euro Bund futures contract (EUREX) vs 10Y Euro Notional futures contract (MATIF): September 1999 delivery

10Y Euro Bund futures contract September 1999 (09.06.99-08.09.99; delivery: 10.09.99)

Deliverable bonds	Start of accrued interest	Outstanding amount (Million Euro)	Coupon	Maturity	Conv. factor	Deliverable volume (Million Euro)	Open interest (high)	Days being CTD	Mod. duration	Yield
113507	10.07.1998	8,692	4.75	04.07.2008	0.916530	1,050.3 (12.1% of outst. amount)	872,127 (13.07.99)	60	6.97	5.009
113509	30.10.1998	13,805	4.125	04.07.2008	0.874958	20 (0.14% of outst. amount)		4	7.1	5.016
113510	08.01.1999	14,000	3.750	04.01.2009	0.843546			0	7.37	5.005
113511	26.03.1999	11,000	4.000	04.07.2009	0.855312			0	7.7	4.992
113512	09.07.1999	20,000	4.500	04.07.2009	0.891403			0	7.65	5.008
Total deliv. volume		67,497								

10Y Euro Notional futures contract September 1999 (15.06.99-13.09.99; delivery: 17.09.99)

Deliverable bonds	Start of accrued interest	Outstanding amount (Million Euro)	Coupon	Maturity	Conv. factor	Deliverable volume (Million Euro)	Open interest (high)	Days being CTD	Mod. duration	Yield
OAT FR0000570632	25.04.1998	25,292	5.25	25.04.2008	1.127991		63,305 (03.08.99)	0	6.67	5.129
Bund 113507	10.07.1998	8,692	4.75	04.07.2008	1.093188			0	6.95	5.115
OAT FR0000570665	25.10.1997	16,245	8.5	25.10.2008	1.384281			0	6.24	5.112
Bund 113509	30.10.1998	13,805	4.125	04.07.2008	1.046547			0	7.08	5.118
Bund 113510	08.01.1999	14,000	3.750	04.01.2009	1.019432			0	7.35	5.109
OAT FR0000571432	25.04.1998	22,522	4.000	25.04.2009	1.040059			0	7.56	5.189
Bund 113511	26.03.1999	11,000	4.000	04.07.2009	1.040488			0	7.68	5.089
Bund 113512	09.07.1999	20,000	4.500	04.07.2009	1.081669			0	7.63	5.109
OAT FR0000186199	25.10.1999	13,697	4	25.10.2009	1.041905	1,685.6 (12.3% of outst. amount)		65	7.69	5.24
Total deliv. volume		145,253								

Sources: Bloomberg; Ministere de l'Economie des Finances et de l'Industrie: Monthly Report; Eurex: Monthly Report (Internet page: www.exchange.de); Clearnet: Bulletin for the delivery months.

Correlations (daily/weekly)

	Germany		France		Italy
	Benchmark bond	CTD bond	Benchmark bond	CTD bond	Benchmark bond
	113512	113507	186199	186199	
Euro Bund future	0.847/0.932	0.842/0.947	0.867/0.929	0.867/0.929	0.656/0.924
Euro Notional future	0.936/0.986	0.940/0.993	0.944/0.987	0.944/0.987	0.803/0.984
Euro swaps	0.834/0.943	0.827/0.936	0.863/0.950	0.863/0.950	0.627/0.942

Daily period: 07.07.99-13.09.99. Weekly period: 16.07.99-10.09.99. Correlation is measured for futures by the effective daily/weekly price changes between futures and bonds, and for swaps by the effective daily/weekly yield changes between swaps and bonds.

Source: Bloomberg.

Annex 8.6

10Y Euro Bund futures contract (EUREX) vs 10Y Euro Notional futures contract (MATIF): December 1999 delivery

10Y Euro Bund futures contract December 1999 (09.09.99-08.12.99; delivery: 10.12.99)

Deliverable bonds	Start of accrued interest	Outstanding amount (Million Euro)	Coupon	Maturity	Conv. factor	Deliverable volume (Million Euro)	Open interest (high)	Days being CTD	Mod. duration	Yield
113507	10.07.1998	8.692	4.75	04.07.2008	0.917801	748.2 (8.6% of outst. amount)	682,910 (05.11.99)	61	6.73	5.039
113509	30.10.1998	13,805	4.125	04.07.2008	0.876915	0.2 (0.001% of outst. amount)		2	6.86	5.042
113510	08.01.1999	14,000	3.750	04.01.2009	0.846008			0	7.13	5.034
113511	26.03.1999	11,000	4.000	04.07.2009	0.856929			0	7.46	5.033
113512	09.07.1999	20,000	4.500	04.07.2009	0.892856			0	7.4	5.07
113513	22.10.1999	11,000	5.375	04.01.2010	0.953223				7.62	5.063
Total deliv. volume		78,497								

10Y Euro Notional futures contract December 1999 (14.09.99-13.12.99; delivery: 17.12.99)

Deliverable bonds	Start of accrued interest	Outstanding amount (Million Euro)	Coupon	Maturity	Conv. factor	Deliverable volume (Million Euro)	Open interest (high)	Days being CTD	Mod. duration	Yield
Bund 113507	10.07.1998	8,692	4.75	04.07.2008	1.090849		53,975 (26.10.99)	0	6.73	4.989
OAT FR0000570665	25.10.1997	16,245	8.5	25.10.2008	1.375275			0	6.45	4.946
Bund 113509	30.10.1998	13,805	4.125	04.07.2008	1.045350			0	6.86	4.988
Bund 113510	08.01.1999	14,000	3.750	04.01.2009	1.019088			0	7.13	4.982
OAT FR0000571432	25.04.1998	22,522	4.000	25.04.2009	1.039181			0	7.34	5.066
Bund 113511	26.03.1999	11,000	4.000	04.07.2009	1.039643			0	7.46	4.983
Bund 113512	09.07.1999	20,000	4.500	04.07.2009	1.079848			0	7.41	5.015
OAT FR0000186199	25.10.1999	20,821	4	25.10.2009	1.041025	1,122 (5.39% of outst. amount)		65	7.81	5.12
Bund 113513	22.10.1999	11,000	5.375	04.01.2010	1.156354			0	7.62	5.015
Total deliv. volume		138,085								

Sources: Bloomberg; Ministere de l'Economie des Finances et de l'Industrie: Monthly Report; Eurex: Monthly Report (Internet page: www.exchange.de); Clearnet: Bulletin for the delivery months.

Correlations (daily/weekly)

	Germany		France		Italy
	Benchmark bond	CTD bond	Benchmark bond	CTD bond	Benchmark bond
	113513	113507	186199	186199	
Euro Bund future	0.939/0.985	0.938/0.979	0.931/0.978	0.931/0.978	0.835/0.965
Euro Notional future	0.965/0.982	0.971/0.978	0.973/0.987	0.973/0.987	0.930/0.972
Euro swaps	0.933/0.966	0.938/0.958	0.932/0.951	0.932/0.951	0.848/0.937

Daily period: 20.10.99-13.12.99. Weekly period: 29.10.99-10.12.99. Correlation is measured for futures by the effective daily/weekly price changes between futures and bonds, and for swaps by the effective daily/weekly yield changes between swaps and bonds.

Source: Bloomberg.

Annex 8.7

10Y Euro Bund futures contract (EUREX) vs 10Y Euro Notional futures contract (MATIF): March 2000 delivery

10Y Euro Bund futures contract March 2000 (09.12.99-08.03.00; delivery: 10.03.00)

Deliverable bonds	Start of accrued interest	Outstanding amount (Million Euro)	Coupon	Maturity	Conv. factor	Deliverable volume (Million Euro)	Open interest (high)	Days being CTD	Mod. duration	Yield
113510	08.01.1999	14,000	3.750	04.01.2009	0.849146	107.6 (0.77% of outst. amount)	703,749 (03.02.00)	2	7.13	5.443
113511	26.03.1999	11,000	4.000	04.07.2009	0.859902	5 (0.45% of outst. amount)		0	7.16	5.445
113512	09.07.1999	20,000	4.500	04.07.2009	0.894982	1,366 (6.83% of outst. amount)		59	7.11	5.46
113513	22.10.1999	20,000	5.375	04.01.2010	0.953876			0	7.32	5.449
Total deliv. volume		65,000								

10Y Euro Notional futures contract March 2000 (14.12.99-13.03.00; delivery: 17.03.00)

Deliverable bonds	Start of accrued interest	Outstanding amount (Million Euro)	Coupon	Maturity	Conv. factor	Deliverable volume (Million Euro)	Open interest (high)	Days being CTD	Mod. duration	Yield
OAT FR0000570665	25.10.1997	16,799	8.5	25.10.2008	1.366054		155,639 (14.02.00)	0	6.17	5.298
Bund 113510	08.01.1999	14,000	3.750	04.01.2009	1.018574			0	7.14	5.313
OAT FR0000571432	25.04.1998	22,522	4.000	25.04.2009	1.038381			0	7.06	5.395
Bund 113511	26.03.1999	11,000	4.000	04.07.2009	1.038875			0	7.17	5.319
Bund 113512	09.07.1999	20,000	4.500	04.07.2009	1.078107			0	7.12	5.331
OAT FR0000186199	25.10.1999	23,874	4	25.10.2009	1.040069	1,125.4 (4.71% of outst. amount)		64	7.53	5.421
Bund 113513	22.10.1999	11,000	5.375	04.01.2010	1.152988			0	7.34	5.321
Total deliv. volume		119,195								

Sources: Bloomberg; Ministere de l'Economie des Finances et de l'Industrie: Monthly Report; Eurex: Monthly Report (Internet page: www.exchange.de); Clearnet: Bulletin for the delivery months.

Correlations (daily/weekly)

	Germany		France		Italy
	Benchmark bond	CTD bond	Benchmark bond	CTD bond	Benchmark bond
	113513	113512	186199	186199	
Euro Bund future	0.839/0.895	0.897/0.906	0.903/0.928	0.903/0.928	0.807/0.804
Euro Notional future	0.877/0.962	0.961/0.966	0.956/0.960	0.956/0.960	0.898/0.899
Euro swaps	0.824/0.824	0.890/0.843	0.897/0.884	0.897/0.884	0.768/0.683

Daily period: 10.12.99-13.03.00. Weekly period: 17.12.99-10.03.00. Correlation is measured for futures by the effective daily/weekly price changes between futures and bonds, and for swaps by the effective daily/weekly yield changes between swaps and bonds.

Source: Bloomberg.

Annex 8.8

10Y Euro Bund futures contract (EUREX) vs 10Y Euro Notional futures contract (MATIF): June 2000 delivery

10Y Euro Bund futures contract June 2000 (09.03.00-08.06.00; delivery: 12.06.00)

Deliverable bonds	Start of accrued interest	Outstanding amount (Million Euro)	Coupon	Maturity	Conv. factor	Deliverable volume (Million Euro)	Open interest (high)	Days being CTD	Mod. duration	Yield
113510	08.01.1999	14,000	3.750	04.01.2009	0.852420	4,329.2 (30.9% of outst.amount)	842,199 (19.05.00)	36	6.92	5.233
113511	26.03.1999	11,000	4.000	04.07.2009	0.863172			0	6.95	5.221
113512	09.07.1999	20,000	4.500	04.07.2009	0.897383			25	6.9	5.222
113513	22.10.1999	20,000	5.375	04.01.2010	0.954764			0	7.12	5.196
113515	05.05.2000	8,000	5.250	04.07.2010	0.944136			0	7.64	5.178
Total deliv. volume		73,000								

10Y Euro Notional futures contract June 2000 (14.03.00-19.06.00; delivery: 23.06.00)

Deliverable bonds	Start of accrued interest	Outstanding amount (Million Euro)	Coupon	Maturity	Conv. factor	Deliverable volume (Million Euro)	Open interest (high)	Days being CTD	Mod. duration	Yield
Bund 113510	08.01.1999	14,000	3.750	04.01.2009	1.018025		159,373 (23.03.00)	0	6.91	5.145
OAT FR0000571432	25.04.1998	22,522	4.000	25.04.2009	1.037395	0.2 (0.0009% of outst. amount)	637,010 (06.06.00)	0	7.13	5.276
Bund 113511	26.03.1999	11,000	4.000	04.07.2009	1.038136			0	6.94	5.128
Bund 113512	09.07.1999	20,000	4.500	04.07.2009	1.076324			0	6.9	5.127
OAT FR0000186199	25.10.1999	23,874	4	25.10.2009	1.039126	867.5 (3.63% of outst. amount)		8	7.3	5.272
Bund 113513	22.10.1999	11,000	5.375	04.01.2010	1.149461			0	7.11	5.121
OAT FR0000186603	25.04.1999	13,201	5.5	25.04.2010	1.164066	0.1 (0.0008% of outst. amount)		58	7.42	5.271
Bund 113515	05.05.2000	8,000	5.250	04.07.2010	1.145740			1	7.63	5.104
Total deliv. volume		123,597								

Calculation of open interest changed by MATIF on 23.05.00 from net open interest to gross open interest; EUREX calculates net open interest.
Example: There are two clients for one member: First client: 10 long, 20 short, Second client: 50 long, 30 short, Sum: 60 long, 50 short; Net open interest: 10 long=10; Gross open interest: 10 short and 20 long=30.

Sources: Bloomberg; Ministere de l'Economie des Finances et de l'Industrie: Monthly Report; Eurex: Monthly Report (Internet page: www.exchange.de); Clearnet: Bulletin for the delivery months.

Correlations (daily/weekly)

	Germany		France		Italy
	Benchmark bond	CTD bond	Benchmark bond	CTD bond	Benchmark bond
	113515	113510	186603	186603	
Euro Bund future	0.946/0.999	0.956/0.995	0.926/0.995	0.926/0.995	0.908/0.952
Euro Notional future	0.971/0.995	0.976/0.997	0.970/0.999	0.970/0.999	0.959/0.968
Euro swaps	0.925/0.908	0.928/0.939	0.935/0.936	0.935/0.936	0.940/0.990

Daily period: 03.05.00-19.06.00. Weekly period: 12.05.00-16.06.00. Correlation is measured for futures by the effective daily/weekly price changes between futures and bonds, and for swaps by the effective daily/weekly yield changes between swaps and bonds.

Source: Bloomberg.

Annex 8.9

10Y Euro Bund futures contract (EUREX) vs 10Y Euro Notional futures contract (MATIF): September 2000 delivery

10Y Euro Bund futures contract September **2000 (09.06.00-07.09.00; delivery: 11.09.00)**

Deliverable bonds	Start of accrued interest	Outstanding amount (Million Euro)	Coupon	Maturity	Conv. factor	Deliverable volume (Million Euro)	Open interest (high)	Days being CTD	Mod. duration	Yield
113511	26.03.1999	11,000	4.000	04.07.2009	0.865974		614,649 (10.08.00)	1	7.09	5.306
113512	09.07.1999	20,000	4.500	04.07.2009	0.899414	2,127.7 (10.63% of outst. amount)		61	6.99	5.305
113513	22.10.1999	20,000	5.375	04.01.2010	0.955835			1	6.88	5.267
113515	05.05.2000	18,000	5.250	04.07.2010	0.944942			0	7.39	5.264
Total deliv. volume		69,000								

10Y Euro Notional futures contract September 2000 (20.06.00-18.09.00; delivery: 22.09.00)

Deliverable bonds	Start of accrued interest	Outstanding amount (Million Euro)	Coupon	Maturity	Conv. factor	Deliverable volume (Million Euro)	Open interest (high)	Days being CTD	Mod. duration	Yield
OAT FR0000571432	25.04.1998	22,522	4.000	25.04.2009	1.036411		644,715 (28.07.00)	0	6.87	5.474
Bund 113511	26.03.1999	11,000	4.000	04.07.2009	1.037161			0	7.06	5.372
Bund 113512	09.07.1999	20,000	4.500	04.07.2009	1.074422			0	6.95	5.369
OAT FR0000186199	25.10.1999	23,874	4.000	25.10.2009	1.038331	112.3 (0.47% of outst. amount)		19	7.03	5.495
Bund 113513	22.10.1999	20,000	5.375	04.01.2010	1.146277			0	6.84	5.341
OAT FR0000186603	25.04.1999	17,692	5.500	25.04.2010	1.160453	630.3 (3.56% of outst. amount)		46	7.15	5.495
Bund 113515	05.05.2000	18,000	5.250	04.07.2010	1.142579			0	7.35	5.344
Total deliv. volume		133,088								

Open interest is calculated by MATIF as gross open interest, by EUREX as net open interest.

Sources: Bloomberg; Ministere de l'Economie des Finances et de l'Industrie: Monthly Report; Eurex: Monthly Report (Internet page: www.exchange.de); Clearnet: Bulletin for the delivery months.

Correlations (daily/weekly)

	Germany		France		Italy
	Benchmark bond	CTD bond	Benchmark bond	CTD bond	Benchmark bond
	113515	113512	186603	186603	
Euro Bund future	0.888/0.931	0.888/0.941	0.894/0.95	0.894/0.95	0.894/0.943
Euro Notional future	0.943/0.975	0.942/0.981	0.956/0.998	0.956/0.998	0.946/0.975
Euro swaps	0.780/0.919	0.781/0.919	0.783/0.95	0.783/0.95	0.797/0.934

Daily period: 12.06.00-18.09.00. Weekly period: 16.06.00-15.09.00. Correlation is measured for futures by the effective daily/weekly price changes between futures and bonds, and for swaps by the effective daily/weekly yield changes between swaps and bonds.

Source: Bloomberg.

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Monetary policy signalling and movements in the Swedish term structure of interest rates

Malin Andersson, Hans Dillén and Peter Sellin,[1]
Sveriges Riksbank

Abstract

This paper examines how various monetary policy signals such as repo rate changes, inflation reports, speeches and minutes of monetary policy meetings affect the term structure of interest rates. We find that unexpected movements in the short end of the yield curve are mainly driven by unexpected changes in the repo rate, while speeches are a more important determinant for the longer interest rates. Hence, we conclude that central bank communication is an essential part of the conduct of monetary policy.

1. Introduction

The effectiveness of monetary policy is strongly related to monetary policy signalling, ie the way policymakers indicate their intentions through policy reports, speeches and other communication channels. The reason for this is that important variables such as the exchange rate and long-term interest rates reflect expectations of future monetary policy. Thus, the monetary policy stance should be assessed in terms of expected future monetary policy intentions rather than the current setting of the central bank's instrument (normally a short-term nominal interest rate).[2] Indeed, there are examples of models in which the intended future level of the official interest rate rather than its current level is considered to be the instrument for the central bank, see Svensson (2001).

The theoretical considerations above suggest that policymakers should try to steer a (very) long-term interest rate by signalling the intentions of future monetary policy and adjust the short-term interest rates that confirm and support such a signalling policy. However, in practice there are several problems with such a policy device. First, it is hardly meaningful to indicate policy intentions more than a few years ahead since future monetary policy depends on future economic conditions, which become very hard to predict as the forecast horizon increases. Second, the controllability of interest rates declines with maturity since movements in long-term interest rates to a large extent reflect exogenous factors such as global interest rate trends and fluctuating term premia. It is therefore an open empirical issue to determine to what extent monetary policy signalling can affect medium-term and long-term interest rates. The aim of this paper is to shed some light on this issue by examining the relationship between monetary policy signalling by the Riksbank (the Swedish central bank) and movements in the Swedish term structure of interest rates.

The literature that analyses term structure effects of monetary policy actions includes Cook and Hahn (1989), Buttiglione et al (1997), Lindberg et al (1997), Favero et al (1996), Haldane and Read (2000)

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[1] Monetary Policy Department, Sveriges Riksbank S-103 37 Stockholm, Sweden. E-mail: malin.andersson@riksbank.se, hans.dillen@riksbank.se and peter.sellin@riksbank.se. We are grateful for useful comments from Robert Chirinko, Peter Englund, Torsten Persson, Lars E O Svensson, Ulf Söderström, Anders Vredin and seminar participants at Sveriges Riksbank and Bank for International Settlements. Of course, we are responsible for all remaining errors. The views expressed in this paper are solely the responsibility of the authors and should not be interpreted as reflecting the views of the Executive Board of Sveriges Riksbank.

[2] See eg Svensson (2000) who shows that aggregate demand in an open economy depends on the sum of expected future short real interest rates in excess of the natural real interest rate, which under the expectations hypothesis can be approximated by a long-term real interest rate (in excess of the natural real interest rate) times its maturity.

and Kuttner (2001).[3] This paper extends the analysis in the literature cited above in at least two important directions. First, it relates unexpected term structure movements not only to unexpected monetary policy actions, but also to unexpected changes in other important factors such as foreign interest rates, surprises in the outcome of inflation and GDP and unexpected portfolio effects. This paper is hence also to some extent related to studies analysing macroeconomic announcement effects (Fleming and Remolona (1999)). Second, the paper broadens the concept of monetary policy actions to include (in addition to the changes in the official interest rate) signals from speeches, inflation reports and minutes of monetary policy meetings.[4] These additional channels for monetary policy action turn out to be important. Like Buttiglione et al (1997), and Haldane and Read (2000), we find that unexpected changes in the official interest rate have quite small and often insignificant impacts on longer market interest rates (five-year maturity). However, unexpected signals from speeches appear to have significant effects on longer interest rates that are potentially larger than those from unexpected changes of the official rate. In addition, other monetary policy signals provided by inflation reports and the publication of minutes also seem to be of some importance.[5] The main conclusion of this paper is that central bank communication is an essential part of the conduct of monetary policy - an aspect that has recently started to receive attention in the literature (see eg Guthrie and Wright (2000) and Woodford (2001)).

The paper is organised in the following way. In Section 2 the interaction between economic shocks, monetary policy signalling, monetary policy decision-making and movements in the term structure of interest rates are discussed using features from the policy process at the Riksbank. Section 3 presents a model of the Swedish term structure of interest rates, which incorporates factors discussed in Section 2. A description of the data used is provided in Section 4 and the model is evaluated in Section 5. Section 6 summarises and concludes.

2. Monetary policy process and signalling at the Riksbank

In this section, we discuss the role of monetary policy signalling and its effects on the term structure of interest rates. The discussion will be based on the policy process at the Riksbank but we believe that many of the mechanisms can be found in the policy process at other central banks as well. We will consider four different types of signalling channels: (i) speeches, (ii) judgments about future inflation, (iii) announcements of repo rate decisions and (iv) publication of the minutes of Executive Board meetings where repo rate decisions were taken.

Figure 1 presents a simplified example of how the policy process works at the Riksbank and the role of the different signalling channels. Assume that economic news arrives at time t_0. The implications for future inflation are then analysed internally and a decision-maker indicates in a speech (at time t_1) how future inflation prospects might have changed. A more detailed analysis including an explicit inflation forecast is then published in the inflation report at time t_2. A repo rate decision is announced at time t_3 and different views among decision-makers about the appropriate monetary policy stance as well as individual voting behaviour of the decision-makers are published as minutes at time t_4. Then the policy process cycle is repeated.[6]

3 Term structure effects of changes in the monetary policy instrument have also been analysed in VAR models, see eg Evans and Marshall (1998).

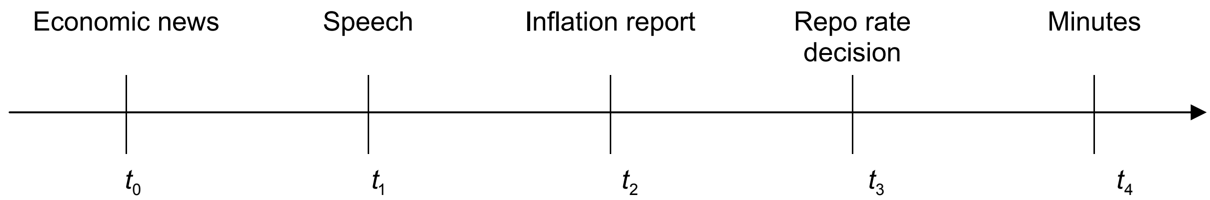
4 Signalling via speeches and inflation reports was also considered in Lindberg et al (1997). Moreover, the effects of central bank statements have been analysed by Guthrie and Wright (2000).

5 A problem is that only unexpected signals should affect interest rates, which requires a measure of expected values. The expected signals from inflation reports and minutes are, however, difficult to measure.

6 As will become apparent later on in the text, the term "policy process cycle" is most relevant in the new policymaking regime in place since January 1999. In this regime, the period between two policy meetings (at which repo rate decisions are taken) constitutes a cycle.

Figure 1

The policy process cycle at the Riksbank - an illustrative example



This description of the policy process at the Riksbank is of course a simplification in many respects. For instance, economic news arrives almost continuously over time and several speeches are often given during the policy process cycle. On the other hand, inflation reports are not published during every cycle. Moreover, the policy process at the Riksbank has changed over time. The most important change took place in January 1999, when the new Riksbank Act became effective. Before 1999 monetary policy decisions were taken by the Governor, who set the repo rate in accordance with general guidelines provided by a Governing Board consisting of parliament members. However, the new Riksbank Act states that an Executive Board consisting of six professional members is responsible for the overriding monetary policy objective of achieving price stability.[7] This change in the policy process has several implications that are important to bear in mind.

First, pre-1999 speeches were signalling the intentions of the Riksbank whereas speeches post-1999 reflect views held by individual members of the Executive Board. Second, pre-1999 monetary policy conclusions were discussed in the inflation report and a repo rate decision in accordance with these conclusions was normally announced some time later (in cases where an adjustment of the repo rate was judged to be appropriate). Post-1999 the inflation report presents an inflation forecast that the majority of the Executive Board supports and the policy conclusions can be found in a press release published at the same time as the inflation report announcing the repo rate decision (ie t_2 coincides with t_3). Third, the introduction in 1999 of the Executive Board as the decision-making body was accompanied by other new features of the decision-making process such as preannounced monetary policy meetings (held eight to 10 times per year), the minutes of which are published with a delay of a few weeks.[8]

How does signalling through these different channels affect the term structure of interest rates? First, it is important to note that in the extreme case when the central bank slavishly follows a policy rule, say a Taylor type rule, signalling will have no effect on interest rates. As soon as relevant economic news arrives market participants adjust their expectations according to the rule and subsequent signalling will only serve as a confirmation of this policy rule. In reality, central banks do not follow simple rules perfectly and monetary policy considerations are based on a large number of indicators that are subject to interpretations and judgments. An important function of speeches is to signal decision-makers' interpretations of new economic information.

Moreover, a central bank that is successful in signalling its monetary policy intentions should experience rather small term structure effects from changes in the official interest rate. It can therefore be misleading, as pointed out by Woodford (2001), to associate the effectiveness of monetary policy with the ability to obtain large term structure effects by surprising the market.

One may argue that signalling speeches given before 1999 should have had more impact on interest rates than the ones held after 1999 since the speaker (normally the Governor or one of the Deputy Governors), who knew what monetary action was planned, was able to give rather precise information about future intentions. Today, members of the Executive Board can only indicate individual views

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7 In 1999 the Governing Board was replaced by the Governing Council (also consisting of members of parliament), that retains general supervisory functions and appoints members of the Executive Board. For a fuller discussion, see Berg and Lindberg (2000).

8 Two clarifications can be made: first, at the beginning of 1999 the delay was several weeks but since October 1999 minutes have been published with a delay of about two weeks. Second, in *Press Release no 66* of 6 November 1999, it was announced that repo rate decisions will normally only be made at the preannounced monetary policy meetings. However, this is in line with the practice established at the beginning of 1999.

concerning the appropriate stance of monetary policy in speeches whereas the actual decision will be the outcome of a voting process that cannot be predicted for certain by anyone, including the members of the Executive Board. One could also argue that the arrangement with a collective of decision-makers who decide by voting may tend to make monetary policy less predictable in the short run compared with the case of a single decision-maker. On the other hand, a collective of decision-makers, whose members are gradually replaced over time, may imply more continuity in the policy process and therefore increased predictability of monetary policy in a longer perspective. The replacement of a single policy-maker can be a more drastic event associated with substantial uncertainty, which might sometimes generate credibility problems.

Monetary policy statements of the kind analysed by Guthrie and Wright (2000) are not considered to be an important part of the Riksbank's communication policy and are therefore not included in the analysis. Instead, we focus on speeches that are not assumed to have signalling value by Guthrie and Wright. This difference in methodology reflects differences in communication policy between the Riksbank and the Reserve Bank of New Zealand.

As indicated above, the inflation reports published post-1999 may not contain very much additional information concerning policy intentions in the near future given that a press release with policy conclusions and a repo rate decision is published the same day, especially when an adjustment of the repo rate is announced.[9] However, the inflation report does contain a detailed inflation forecast as well as a quantitative risk assessment that should be indicative of monetary policy intentions in the future. In this context it should be noted that inflation forecasts have been published since the 1997:4 inflation report. Moreover, the inflation report does sometimes signal changes concerning the analytical framework, which may have some impact on investors' monetary policy expectations in a longer perspective.

Minutes of the Executive Board's monetary policy meetings have been published since 1999 with a delay of a few weeks. Minutes present the range of views held within the Executive Board about the appropriate monetary policy stance as well as the voting behaviour of individual members. Minutes show the support for the latest repo rate decision among the members of the Executive Board, which should be indicative of future repo rate adjustments (Gerlach-Kristen (2001)). For instance, if all members have voted for an unchanged repo rate, investors may assign a lower probability to further increases of the repo rate than when there is a minority that favours an increase of the repo rate.

This review of the policy process at the Riksbank raises several interesting issues. What are the effects from various signalling channels on the term structure of interest rates? How large are the impacts on short-term and long-term interest rates? And how important is it to control for the publication of relevant economic news? In the next section we will develop a model for the Swedish term structure of interest rates in order to quantitatively assess these kind of issues.

3. A model for the Swedish term structure of interest rates

3.1 Determinants of unexpected movements in the term structure

The basic mechanism we want to study is how monetary policy signalling will affect expectations of future short-term interest rates. Economic theory tells us that unexpected movements in the term structure are driven by changes in expectations of future short-term interest rates and unexpected changes in the term premia. Moreover, when analysing the interest rate effects of monetary policy signalling it is crucial to control for other factors affecting the term structure of interest rates. Hence we find it natural to attribute movements in the Swedish term structure to unexpected movements in the foreign term structure, unexpected monetary policy signals, unexpected economic news and unexpected changes in market conditions:

$$\Delta i(t,\tau) - E_{t-1}[\Delta i(t,\tau)] = \kappa(\tau)\,\{\Delta i^*(t,\tau) - E_{t-1}[\Delta i^*(t,\tau)]\} + \Delta i^{sig}(t,\tau) + \Delta i^{news}(t,\tau) + \varepsilon^{\rho}(t,\tau) \tag{1}$$

[9] In other words, the fact that several monetary signals are given simultaneously gives rise to multicollinearity problems.

where $i(t,\tau)$ is the continuously compounded interest rate at time t on a nominal Swedish zero coupon bond maturing τ periods ahead, $i^*(t,\tau)$ is a corresponding foreign interest rate, $\kappa(\tau)$ is a parameter, $\Delta i^{sig}(t,\tau)$, $\Delta i^{news}(t,\tau)$ and $\varepsilon^{\rho}(t,\tau)$ represent unexpected term structure movements caused by new monetary policy signals, relevant economics news and changed market conditions (formally unexpected changes in term premia) respectively. The notation $\Delta x(t)$ denotes $x(t)–x(t–1)$ and $E_{t–1}[.]$ is the expectation operator conditional on information available at time t–1. We will next turn to the non-trivial task of defining the above concepts in terms of observable variables.

3.2 Measuring unexpected changes in the term structure

When specifying the unexpected movements in the term structure, we make use of the fact that an implicit forward interest rate at time t for a loan with maturity τ and settlement s periods ahead, $f(t,\tau,s)$, can be written as

$$f(t,\tau,s) = [i(t,\tau + s)\ (\tau + s) – i(t,s)s]/\tau \tag{2}$$

In what follows, we will consider settlement s = 1 period ahead. We also have that

$$f(t–1,\tau,1) = E_{t–1}[i(t,\tau)] + \rho^f(t–1,\tau,1) \tag{3}$$

where $\rho^f(t–1,\tau,1)$ is a forward term premium that should be very small.[10] Thus, an expectation adjustment term, $v(t–1,\tau)$, defined as

$$v(t–1,\tau) \equiv f(t–1,\tau,1) – i(t–1,\tau) = i(t–1,\tau+1) – i(t–1,\tau) + (i(t–1,\tau+1) – i(t–1,1))/\tau \tag{4}$$

should be a natural proxy for $E_{t–1}[\Delta i(t,\tau)]$. In the expression above, we have used the fact that one period in our study corresponds to one week, implying that τ should also be measured in weeks.[11] Substituting (2), (3) and (4) into (1), using the corresponding expressions for foreign interest rates and rearranging yields

$$\Delta i(t,\tau) – v(t–1,\tau) = c(t–1,\tau) + \kappa(\tau)\ \{\Delta i^*(t,\tau) – v^*(t–1,\tau)\} + \Delta i^{sig}(t,\tau) + \Delta i^{news}(t,\tau) +\varepsilon^{\rho}(t,\tau) \tag{5}$$

where

$$c(t–1,\tau) = \kappa(\tau)\ \rho^{f*}(t–1,\tau,1) – \rho^f(t–1,\tau,1) \tag{6}$$

We will base our empirical analysis on (5), which differs from (1) only by the term $c(t–1,\tau)$, which is likely to be small. The expectation adjustment term, $v(t–1,\tau)$, can be interpreted in the following way. The interest rates $i(t–1,\tau)$ and $i(t,\tau)$ reflect expectations of monetary policy during the time intervals $[t–1,t+\tau–1]$ and $[t,t+\tau]$ respectively, and the difference in monetary policy expectations between these two intervals is captured by the term $v(t–1,\tau)$. One realises that the expectation adjustment term is negligible when τ is large. When τ is small it is of potential importance to take this term into account.[12] In particular, if the next preannounced policy meeting is scheduled just after the maturity of a three-month T-bill at time t–1, the expected change in the one-month interest rate might be substantial since the three-month T-bill observed at time t will include a potential repo rate adjustment within the maturity.

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[10] The forward term premium, $\rho^f(t–1,\tau,1)$, should reflect the uncertainty concerning the spot rate, $i(t,\tau)$, in the next period (in our case the next week).

[11] The general expression for the expectation adjustment term is actually $v(t–s,\tau,s) = i(t–s,\tau+1) – i(t–s,\tau) + (i(t–s,\tau+1) – i(t–s,1))s/\tau$. We use weekly data and let one period correspond to one week, implying that s = 1.

[12] One should be aware that for small τ there are measurement problems. Good estimates of the term $v(t–1,\tau)$ require good estimates of short-term interest rates that differ very little in time to maturity. This in turn requires many observations of different short-term interest rates at the short end of the yield curve, which we do not have. Thus, the term $v(t–1,\tau)$ should be viewed as a rough indicator of how monetary policy expectations change.

3.3 Foreign interest rate

The foreign interest rate is constructed as a weighted average of estimated zero coupon yields from Germany (GE), the United Kingdom (UK) and the United States (US) according to:

$$i^*(t,\tau) = 0.5i^{GE}(t,\tau) + 0.25i^{UK}(t,\tau) + 0.25i^{US}(t,\tau) \qquad (7)$$

This construction can be seen as a rough proxy for a TCW-weighted interest rate, with the weights for the three largest currencies scaled up.[13] Unexpected movements in the foreign term structure are measured in the same way as in Section 3.2.

It is important to realise that unexpected movements in the foreign term structure reflect unexpected news in the global economy that affects monetary policy expectations more or less in all countries as well as changes in global market conditions (ie term premia). This means that the other terms on the right-hand side in (1) only capture domestic factors. In particular, the term $\varepsilon^{\rho}(t,\tau)$ will only reflect the domestic component of the unexpected changes in market conditions. For instance, the drastic fall of Swedish long-term interest rates during the second half of 1998 was partly the result of a downward adjustment of global monetary policy expectations caused by the Asian crises and partly the result of a decrease of the global component of the Swedish term premium.[14] A closer inspection reveals that Swedish long-term interest rates did not fall as much as in Germany, the United Kingdom and the United States, indicating a possible increase of the domestic component of the Swedish term premium.

3.4 Domestic monetary policy signalling component

The monetary policy signalling component, $\Delta i^{sig}(t,\tau)$, is assumed to be of the form

$$\Delta i^{sig}(t,\tau) = \mu_1(\tau)D^{sp}(t) + \mu_2(\tau)(repo(t) - E_{t-1}[repo(t)]) + \mu_3(\tau)[\pi_2^f(t) - 2] + \mu_4(\tau)m(t) \qquad (8)$$

where $D^{sp}(t)$ is a dummy variable taking the value +1 (–1) when a speech at time t contains an unexpected signal of a more contractionary (expansionary) monetary policy and zero otherwise, $repo(t) - E_{t-1}[repo(t)]$ is the change in the repo rate announced at time t relative to its expected value at time t–1, $[\pi_2^f(t) - 2]$ is the Riksbank's inflation forecast two years ahead relative to the inflation target of 2%,[15] $m(t)$ is a minority view indicator that will be described below and the $\mu_i(\tau)$ are parameters. The expected future repo rate at time t–1, $E_{t-1}[\Delta repo(t)]$, is approximated by the two-week forward interest rate at time t–1.

Since 1999, decisions not to change the repo rate have been announced to the public. Such announcements should of course be considered as monetary policy signals but one may argue that they differ from announcements of non-zero repo rate changes. Announcements of zero adjustments of the repo rate are not likely to contain information of substantial revisions of the Riksbank's view of the appropriate stance of monetary policy. Announcements of no change in the repo rate are treated

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13 The Riksbank uses the Total Competitive Weights (TCW) index as a measure of the krona's effective exchange rate. According to TCW, the Deutsche mark has a weight of 0.22 whereas sterling and the US dollar both have weights of 0.12. We have examined other ways of defining the foreign interest rate without any substantial changes of the results.

14 The decrease of the global term premium probably reflects an increased demand for liquid assets such as government bonds.

15 Several clarifications concerning the nature of the inflation forecast should be made. (i) The inflation forecast is conditional on an unchanged repo rate. Consequently, an inflation forecast above (below) the inflation target signals the need for a future increase (decrease) of the repo rate. (ii) Before 1999, the inflation forecast was based on the annual change in the CPI. However, at the beginning of 1999, Deputy Governor Heikensten issued the clarification message that monetary policy for the time being would not respond to transitory inflation effects such as interest rate expenditures and effects from subsidies and taxes, see Heikensten (1999) for details. This clarification was generally interpreted to mean that monetary plicy would mainly be guided by the prospects for underlying inflation (measured by UND1X), and we use the inflation forecast for UND1X from 1999 and onwards. (iii) Before the fourth inflation report of 1997, the Riksbank did not publish an explicit inflation forecast. In five of the six preceding inflation reports, it was stated that the inflation rate was judged to be 2% at the end of the forecast period, which we interpret as if the inflation forecast two years ahead were on target. In the first inflation report of 1997, it was stated that the inflation rate was judged to be below the target and in this case we set the inflation forecast to 1.9%. In Jansson and Vredin (2001), it is revealed that the actual forecast was 1.9%.

as a separate signalling variable in order to examine if they differ from announcements of non-zero repo rate adjustments.

The inflation forecast in the inflation report is defined as the *mode* of the conditional distribution for the inflation rate two years ahead, which can be viewed as the most likely outcome for inflation.[16]

It is a non-trivial task to determine when a speech contains an unexpected monetary policy signal, as illustrated by the following example. Assume that monetary policy expectations are neutral, ie the short end of the yield curve is flat. A speech signalling an increase of the repo rate will then lead to expectations of future rises of the repo rate and a positively sloped yield curve. A subsequent speech with the same monetary policy signal will then have no effect since the yield curve has already responded to a similar signal. Based on the insights gained from this example, we will use the following two-step procedure to calculate the dummy variable $D^{sp}(t)$. In a first step, a dummy variable $D^{sign}(t)$ is constructed such that it takes the value 1 (–1) when an increase (decrease) is signalled in a speech and zero if an unchanged monetary policy stance is signalled. Then in a second step, the dummy variable $D^{sp}(t)$ is defined as:

$$D^{sp}(t) = \begin{cases} 1 \text{ if } D^{sign}(t) = 1 \text{ and slope}(t\text{–}1) < d \text{ or } D^{sign}(t) = 0 \text{ and slope}(t\text{–}1) \le -d \\ -1 \text{ if } D^{sign}(t) = 0 \text{ and slope}(t\text{–}1) \ge d \text{ or } D^{sign}(t) = -1 \text{ and slope}(t\text{–}1) > -d \\ 0 \quad \text{otherwise} \end{cases} \tag{9}$$

where d is set to 0.05 in the base model, and the variable slope(t–1) is measured as the difference between the 30-day T-bill rate and the repo rate at time t–1. Thus, if $D^{sp}(t)$ takes the value 1 (–1) the speech is judged to contain an unexpected signal of a more contractionary (expansionary) monetary policy whereas a zero value indicates a monetary policy signal in accordance with market expectations. This method of characterising speeches is similar to the dummy variable method applied by Guthrie and Wright (2000) for characterising monetary policy statements. The main difference is that we control for monetary policy expectations, as reflected in the slope variable, in order to determine whether the signal is unexpected. Guthrie and Wright assume that all statements indicating a need for tighter or looser monetary policy conditions are unexpected (excluding preannounced speeches and statements that are part of regular information releases).

The construction of the variable $D^{sp}(t)$ is problematic and subjective judgments must be used in several steps. First, it must be decided if a speech contains a monetary policy signal as well as the nature of the signal (ie the value of $D^{sign}(t)$). In the Appendix there is a list of speeches containing signals as well as quotations motivating the assigned nature of the speeches. Thereafter it must be decided if the signal was expected or not according to expression (9), which is based on the assumption that investors have expectations of increases (decreases) of the repo rate in the near future only if the slope variable is greater (less) than 5 (–5) basis points. The consequences of changing parameter d will be examined.[17]

The minority view indicator is defined as

$$m(t) = \frac{1}{6}\sum_{k=1}^{6} \Delta repo^{k}(t) - \Delta repo(t-n) \tag{10}$$

where $\Delta repo^{k}(t)$ is the preferred repo rate adjustment of Executive Board member k according to the minutes published at time t, and $\Delta repo(t\text{–}n)$ is the actual repo rate adjustment that took place n weeks earlier at the monetary policy meeting to which the minutes refer.[18] A positive value of the indicator $m(t)$, which can be viewed as the *average* preferred repo rate adjustment relative to the preferred repo

16 Formally, the mode is the outcome that maximises the density function of the underlying (conditional) distribution. The mode forecast will typically differ from the adjusted forecast (ie the mathematically expected value) in the presence of asymmetric risks to the forecast. For details, see Blix and Sellin (1998).

17 An interesting possibility is to estimate the parameter d, eg using maximum likelihood estimation. We have refrained from this rather complex procedure.

18 For example, in the minutes published on 29 November 1999 it can be read that Executive Board member Mr Bergström voted for an unchanged repo rate whereas the majority voted for an increase of 35 basis points. In this case we have that $m(t)$ = –0.35/6.

rate adjustment *of the majority*, signals that there are preferences for a tighter monetary policy within the Executive Board and hence we expect a positive relationship between $m(t)$ and unexpected movements in the term structure of interest rates. Indeed, Gerlach-Kristen (2001), who analyses the voting behaviour of the Monetary Policy Committee at the Bank of England, constructs a model in which the indicator $m(t)$ is indicative of future monetary policy actions. It is worth emphasising that the purpose of publishing minutes is not to signal monetary policy intentions, but to provide a transparent description of the monetary policy views that are held within the Executive Board.

It should be noted that the signalling variables $\left[\pi_2^f(t)-2\right]$ and $m(t)$ are not defined in terms of deviations from expected values. The problem is that we do not have measures of investors' expectations concerning these variables.[19] Alternatively, one can say that we have approximated the expected values for $\left[\pi_2^f(t)-2\right]$ and $m(t)$ with zeros. Anyhow, we expect that if the inflation report or the minutes contain unexpected monetary policy signals then they will show up in $\left[\pi_2^f(t)-2\right]$ and $m(t)$ respectively.

3.5 Economic news term

Interest rate movements caused by unexpected economic news $\Delta i^{news}(t,\tau)$ are modelled as

$$\Delta i^{news}(t,\tau) = \eta^{\pi}(\tau)\big(\pi(t) - \pi^{e}(t)\big) + \eta^{y}(\tau)\big(y(t) - y^{e}(t)\big) \tag{11}$$

where $\pi(t)$ ($y(t)$) is the official outcome of actual inflation (GDP) announced at time t and $\pi^e(t)$ ($y^e(t)$) is the outcome for inflation (GDP) expected by market participants just before time t. It is of course possible to include other variables but we restrict the analysis to news of inflation and GDP since these variables are judged to be the most important determinants of future inflation.

3.6 Unexpected changes in market conditions

Finally, we have to address unexpected movements in the term structure that cannot be attributed to unexpected international term structure movements, monetary policy signals or economic news. These are contained in the last term in (1): $\varepsilon^{\rho}(t,\tau)$. It is natural to think of these remaining effects as a result of changes in market conditions such as changes in the demand for liquidity or portfolio adjustments. Formally, this kind of movements can be seen as unexpected shocks to term premia. Moreover, since term premia often exhibit autocorrelation we also expect term premia factors to enter our equations with a lag.[20] We assume that the term premium includes a domestic portfolio component of the form

$$\rho^{d}(t,\tau) = \varphi(\tau)\,\delta^{L}(t) \tag{12}$$

where $\delta^L(t)$ is the spread between Swedish and foreign yields on long (10-year) bonds. We think of the term $\rho^d(t,\tau)$ as representing portfolio adjustment effects in the following way. If investors want to substitute from Swedish to foreign bonds, this should tend to increase Swedish interest rates relative to foreign. Such effects are often present during periods of international financial turmoil, eg in the autumn of 1998. Moreover, in the mid-1990s portfolio effects of this kind were large in Sweden and driven by the imperfect (and fluctuating) credibility of Swedish economic policy that the worrisome development of the national debt caused. Dillén and Hopkins (1998) have shown that long-term

[19] There exist measures of inflation expectations and inflation forecasts but there are no measures of expectations concerning the conditional forecast published in the inflation reports. This forecast is conditional on an unchanged repo rate and must be distinguished from traditional forecasts.

[20] To realise this, assume that the term premium (expressed as a deviation from its stationary value) follows an AR(n) process: $\rho(t,\tau) = \theta_1\,\rho(t-1,\tau) + ... + \theta_n\rho(t-n,\tau) + \varepsilon^{\rho}(t,\tau)$. The unexpected change in the term premia can then be written as: $\varepsilon^{\rho}(t,\tau) = \Delta\rho(t,\tau) + \mu_1\,\rho(t-1,\tau) + \ldots + \mu_{n-1}\,\Delta\rho(t+1-n,\tau) + \mu_n\,\rho(t-n,\tau)$, where $\mu_i = 1-(\theta_1+\ldots+\theta_i)$). We see that lagged changes in the term premium have a positive impact on unexpected term structure movements that is also smaller than the contemporaneous change in the term premia ($\mu_1<1$).

interest rate differentials play an important role in explaining term structure movements in Sweden that are not related to monetary policy expectations.[21]

In addition, we acknowledge the possibility that there is a global component in the term premium incorporated in foreign interest rates. For instance, it is reasonable that the drastic fall in international market interest rates during the second half of 1998 partly reflected a reduction in term premia caused by increased demand for liquid assets, such as government bonds. To the extent that this component exhibits serial correlation, we would expect lagged changes in the foreign interest rates to enter significantly in our empirical model.

Finally, we include lagged values of the other regressors (monetary policy signals and economic news) in order to examine the specification. The hypothesis is that investors immediately and correctly evaluate unexpected monetary policy signals and economic news, implying that lagged values of these variables should not be significant determinants of term structure movements. However, if it takes time for investors to evaluate news of a particular kind this should lead to a positive lagged effect. A variant of this argument is that influential commentators (including politicians) comment on news, eg a repo rate decision, with some delay, which in turn leads to subsequent movements in interest rates. Another possibility is that investors overreact to news, in which case there should be a negative lagged effect.[22]

4. Data

We use weekly data from 16 April 1996 to 25 September 2001. There are two main reasons why we do not extend the analysis backwards in time. First, it is hard to find relevant measures of inflation and GDP expectations prior to 1996. Second, during the first half of the 1990s Swedish interest rates were often high and very volatile due to the presence of credibility problems. Even though it is possible to control for some of these effects, the inclusion of data from the first half of the 1990s is likely to blur the analysis. Swedish and foreign interest rates are estimated as continuously compounded zero coupon yields using (with a few exceptions) interest rate quotations from Tuesdays. These quotations should be viewed as end-week observations and all events that occur between Wednesday morning and the following Tuesday afternoon are considered as week *t* events. Market participants' inflation and GDP expectations have been taken from surveys by Reuters.

Details about the data used can be found in the Appendix. As regards the monetary policy signalling variables, a first look at the data is warranted in order to facilitate the interpretation of the regression analysis in the next section. Table 1 depicts the numerical values of all monetary policy signalling variables used in the analysis. Several interesting observations can be made. Sixteen out of 28 non-zero repo rate adjustments in the sample period were made during 1996.[23] Since 1997 the repo rate has been adjusted only a few times per year (four times or less). The total number of speeches with unexpected monetary policy signals has been relatively constant over the years. The monetary policy signals provided by inflation forecasts in inflation reports and minutes are quite well aligned with the speech signals.

When we compare actual and unexpected repo rate changes, it is noticeable that the predictability of repo rate changes has not increased over time. In fact, the unexpected component of repo rate changes in 1996 was usually substantially smaller than in 2000 and 2001. To a large extent, this is natural since a policy with quite small and frequent repo rate adjustments as in 1996 should tend to reduce the unexpected part of repo rate changes in comparison with a policy with larger but less

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[21] Dillén and Hopkins (1998) derive the presence of the long-term interest rate differential in a term premium (expression) from a theoretical regime switching model in which investors fear that the low-inflation policy will be abandoned in the future. Strictly speaking, the long-term interest rate differential reflects an expectational error (unfulfilled expectations of a switch to a high-inflation regime). Moreover, a German long-term interest rate was used as the foreign interest rate in this study.

[22] Note that there are basically two different arguments for deviations from the expectations hypothesis: (i) investors demand term premia for holding bonds or (ii) expectations are not fully rational due to eg delayed evaluation of news or overreaction.

[23] The repo rate was lowered 22 times during 1996: six of these cuts took place before the start of the sample period (16 April 1996).

frequent changes. One could also argue that the economic situation in 1996 in some sense was easier to evaluate from the perspective of monetary policymaking. It is fair to say that monetary policy in 1996 reflected an adjustment towards lower levels of interest rates associated with the increased credibility of Swedish economic policy, and that the direction of future monetary policy was quite obvious. Since 1997, monetary policy has mainly been guided by future inflation prospects and events such as the Asian crises in 1998, and the surprisingly high productivity growth in recent years has made monetary policy a difficult task.

Table 1

Monetary policy signals

Date[1]	Speech	Report	Repo change	Unexp repo	Minutes
1996-04-23			– 0.25	0.08	
1996-05-07			– 0.20	0.06	
1996-05-21			– 0.20	– 0.03	
1996-06-04			– 0.20	– 0.10	
1996-06-18			– 0.20	– 0.04	
1996-07-02			– 0.20	0.06	
1996-07-16			– 0.20	0.03	
1996-07-30			– 0.15	– 0.06	
1996-08-13			– 0.15	– 0.06	
1996-08-27			– 0.15	– 0.06	
1996-09-10			– 0.10	– 0.00	
1996-09-24			– 0.10	0.05	
1996-10-08			– 0.10	0.01	
1996-10-22			– 0.35	– 0.23	
1996-11-12	– 1.00				
1996-11-26			– 0.25	– 0.18	
1996-12-17			– 0.25	– 0.14	
1997-01-28	1.00				
1997-02-04	1.00				
1997-03-25		– 0.10			
1997-05-06	1.00				
1997-06-17	1.00				
1997-10-21	– 1.00				
1997-11-25	1.00				
1997-12-09		0.50			
1997-12-16			0.25	0.17	
1998-06-02	– 1.00				
1998-06-09		– 0.40	– 0.25	– 0.24	
1998-08-25	– 1.00				
1998-09-29		– 0.10			
1998-11-03			– 0.25	– 0.24	
1998-11-17	– 1.00				
1998-11-24			– 0.25	– 0.21	
1998-12-08		– 0.60			
1998-12-15			– 0.20	– 0.17	
1999-02-16			– 0.25	– 0.17	
1999-03-30	– 1.00	– 0.20	– 0.25	– 0.22	

[1] Refers to the Tuesday of the week in which the signal was given.

Table 1 (cont)					
Date[1]	**Speech**	**Report**	**Repo change**	**Unexp repo**	**Minutes**
1999-06-08					– 0.04
1999-09-21					0.06
1999-10-12		0.10			
1999-10-26					0.08
1999-11-16			0.35	0.26	
1999-11-30					– 0.06
1999-12-14		0.20			
2000-02-08			0.50	0.40	
2000-03-21	– 1.00				
2000-03-28	– 1.00	0.10			
2000-04-18					0.08
2000-05-23	1.00				
2000-06-13		– 0.10			
2000-06-27					0.08
2000-07-25					0.08
2000-09-05					0.08
2000-10-10		– 0.10			
2000-10-24					0.08
2000-11-14	1.00				
2000-11-28	– 1.00				
2000-12-12		– 0.10	0.25	0.18	
2000-12-26					– 0.04
2001-03-27		– 0.10			
2001-06-05		0.10			
2001-06-19	1.00				
2001-07-10			0.25	0.17	
2001-07-24					– 0.13
2001-09-18			– 0.50	– 0.49	

1 Refers to the Tuesday of the week in which the signal was given.

However, it cannot be ruled out that the new arrangement with an Executive Board that collectively makes repo rate decisions has rendered repo rate changes less predictable. On the other hand, it would be premature to conclude that monetary policy intentions as reflected in the term structure have become less predictable. There are no indications that unexpected movements in long-term interest rates have become larger since 1999 according to Table 2. Indeed, 2000 exhibits the smallest movements in one- and two-year interest rates. The overall impression from Table 2 is, however, that the predictability of term structure movements has not changed significantly since 1996.

5. Results and evaluation

5.1 Results in the basic model

Table 3 displays estimates of the model for unexpected movements in the Swedish term structure of interest rates described in Section 3. Four interest rates are examined; a short interest rate (maturity of 90 days), two medium-term interest rates (maturities of one and two years), and a long interest rate (maturity of five years).

Table 2

Unexpected weekly movements in the Swedish term structure of interest rates

(mean, standard deviation)

Sample	90-day bill	1-year bond	2-year bond	5-year bond
1996-04-16 to 2001-09-25	– 0.0089, 0.0769	– 0.0085, 0.0885	– 0.0092, 0.1082	– 0.0098, 0.1216
1996-4-16 to 1996-12-31	– 0.0704, 0.0865	– 0.0623, 0.0837	– 0.0588, 0.1091	– 0.0467, 0.1334
1997	0.0159, 0.0642	0.0161, 0.0957	0.0100, 0.1292	– 0.0090, 0.1420
1998	– 0.0217, 0.0591	– 0.0303, 0.0744	– 0.0334, 0.0818	– 0.0334, 0.0894
1999	0.0033, 0.0619	0.0163, 0.0900	0.0264, 0.1151	0.0332, 0.1376
2000	0.0106, 0.0747	0.0001, 0.0687	– 0.0108, 0.0780	– 0.0190, 0.1029
2001-01-01 to 2001-09-25	– 0.0100, 0.0918	– 0.0067, 0.1097	0.0056, 0.1189	0.0067, 0.1097

5.2 Non-policy factors

Note first that the impact of foreign term structure movements increases with time to maturity as expected, and that foreign interest rates appear to be the dominant factor for longer interest rates (Table 4). This is natural since global economic shocks should affect long-term monetary policy intentions in different countries in a similar way, whereas policy actions in the short run, ie the timing of policy actions, are related to foreign policy intentions only to a limited extent. Moreover, lagged foreign interest rates also enter significantly (with one exception) in the regressions, but with a lesser magnitude, which is consistent with the presence of a serially correlated global term premium.

Changes in market conditions (measured by changes in the long-term forward rate differential between domestic and foreign bonds) exhibit a significant impact on medium- and long-term interest rates, indicating that weekly changes in interest rates are to some extent driven by noisy market effects. The absence of lagged effects indicates that these market effects are probably not serially correlated. The term structure effects from the long forward rate differential are also small in comparison with Dillén and Hopkins (1998).

Economic news concerning GDP and inflation seems to have significant effects on longer interest rates but the modest coefficients are hard to reconcile with the view that the market believes that the Riksbank follows a Taylor rule closely. It appears that economic news does not play an important role for monetary policy in the near future but mainly affects expectations regarding monetary policy in the medium term. Moreover, the impact on monetary policy expectations depends on how economic news is interpreted. If GDP surprises are interpreted to be the result of productivity shocks rather than changes in demand conditions (the output gap), then we expect limited effects on monetary policy expectations and market interest rates.

5.3 Policy factors

Turning to the policy signalling variables, we see from Tables 3 and 4 that announcements of repo rate changes are not fully discounted with a substantial effect on the 90-day T-bill rate. The quantitative effects on short-term interest rates are broadly similar to the findings of Cook and Hahn (1989), Favero et al (1996) and Kuttner (2001). The impact from unexpected repo rate changes on longer market interest rates is smaller and declines with maturity. This observation, which is in line with the findings of Favero et al (1996), Buttiglione et al (1997) and Haldane and Read (2000), suggests that interest rate policy is mainly used to implement rather than signal long-run monetary policy intentions. Note also that there appears to be a lagged effect from unexpected repo changes on medium-term market rates. This may indicate that it takes some time for investors to fully appreciate the signal or that the repo rate change triggers some kind of delayed reaction from influential commentators, which in turn affects market rates.

Table 3

Yield curve impact of news, monetary policy and market factors

Variable	90-day bill	1-year bond	2-year bond	5-year bond
Constant	– 0.006 (1.624)	– 0.004 (0.873)	– 0.004 (0.766)	– 0.003 (0.567)
GDP	0.014 (0.766)	0.036 (1.530)	**0.058** (2.059)	**0.063** (2.162)
lagged effect	0.021 (1.113)	– 0.013 (0.576)	– 0.013 (0.475)	– 0.008 (0.276)
CPI	0.037 (1.048)	**0.151** (3.452)	**0.157** (2.960)	0.085 (1.555)
lagged effect	0.058 (1.640)	**0.086** (1.970)	0.062 (1.173)	0.088 (1.600)
REPO	**0.589** (9.940)	**0.341** (4.642)	**0.268** (3.014)	0.127 (1.390)
lagged effect	0.043 (0.736)	**0.134** (1.853)	0.101 (1.146)	0.058 (0.644)
NOREPO	**0.856** (3.096)	0.192 (0.562)	– 0.175 (0.422)	0.094 (0.219)
lagged effect	**0.610** (2.187)	– 0.025 (0.073)	– 0.005 (0.011)	– 0.179 (0.417)
REPORT	0.064 (0.850)	**0.161** (1.723)	0.136 (1.203)	0.104 (0.890)
lagged effect	0.017 (0.218)	– 0.081 (0.855)	– 0.104 (0.903)	– 0.048 (0.404)
SPEECH	**0.043** (3.111)	**0.054** (3.124)	**0.056** (2.661)	**0.038** (1.779)
lagged effect	**0.027** (1.911)	0.018 (1.030)	0.009 (0.437)	0.008 (0.375)
MINUTES	0.342 (1.631)	0.039 (0.151)	0.085 (0.271)	0.223 (0.687)
lagged effect	– 0.033 (0.158)	0.166 (0.647)	0.161 (0.519)	0.166 (0.517)
*R**	**0.234** (4.896)	**0.305** (7.496)	**0.420** (11.128)	**0.632** (15.950)
lagged effect	**0.085** (1.858)	0.053 (1.285)	**0.072** (1.898)	0.110 (2.764)
RDIFF	0.028 (1.345)	**0.125** (4.867)	**0.158** (5.057)	**0.119** (3.682)
lagged effect	– 0.011 (0.523)	0.010 (0.380)	0.027 (0.867)	0.007 (0.208)
RDIFF	0.028 (1.345)	0.125 (4.867)	0.158 (5.057)	0.119 (3.682)
lagged effect	– 0.011 (0.523)	0.010 (0.380)	0.027 (0.867)	0.007 (0.208)
R^2	0.407	0.350	0.372	0.471
R^2adj	0.367	0.306	0.329	0.435
DW	2.027	1.837	1.815	1.943

Coefficients significant at the 10% level are in bold. t-values are in parentheses. The equations have been estimated using SURE. *GDP* is the actual minus the expected percentage change in GDP, *CPI* is the actual minus the expected change in CPI inflation, *REPO* is the announced change in the repo rate minus the expected change, *NOREPO* corresponds to *REPO* in the case where no change in the repo rate is announced, *REPORT* is the two-year inflation forecast minus 2%, *SPEECH* is a dummy variable indicating the monetary policy stance of the speaker, *MINUTES* reflects the minority view relating to a repo rate change as revealed in the minutes of the Executive Board, *R** is the change in the foreign interest rate with matching maturity to the dependent variable, and *RDIFF* is the change in the difference between domestic and foreign forward interest rates. DW is the Durbin-Watson test for first-order autocorrelation.

Table 4

Variance decomposition of changes in interest rates, as a share of total explained interest rate variance

(in percentages)

Component	90-day bill	1-year bond	2-year bond	5-year bond
News variance	2.7	13.0	9.7	4.6
Policy variance	82.9	43.7	23.5	9.9
*DR** variance	12.3	22.0	39.5	70.7
DRDIFF variance	1.4	18.0	18.9	7.2

News includes the *GDP* and *CPI* variables, while policy encompasses *REPO*, *NOREPO*, *REPORT*, *SPEECH* and *MINUTES*. The contributions from the covariance components (not reported in the table) were all quite small (less than 3% in absolute values).

Announcements of no change in the repo rate only affect short-term interest rates. Thus, in this case investors are mainly somewhat surprised by the timing of monetary policy actions but the decision not to change the repo rate does not appear to contain signals concerning monetary policy in a longer perspective. Moreover, there is an additional and significant lagged effect on short-term interest rates, which may indicate that investors adjust their monetary policy expectations for the near future with some delay when the Riksbank surprises the market by not changing the repo rate.

The overall impression is that repo rate changes only cause investors to revise their expectations regarding the Riksbanks' monetary policy intentions in a longer perspective to a limited extent, but that investors are sometimes surprised by the timing of monetary policy actions. The economic consequences of postponing a repo rate adjustment until the next monetary policy meeting are often very limited and the actual timing of a decision depends to a large extent on the decision-makers' views concerning the appropriate tactics, which are hard to predict.

The observation that repo rate changes only signal long-run monetary policy intentions to a limited extent gives rise to further questions; if shocks to the economy call for a substantial change in the monetary policy stance, which according to theory means changes in the longer segment of the yield curve, how can this be achieved? In other words, how are monetary policy intentions in a longer perspective signalled? It is natural in this context to examine which roles other channels for monetary policy signalling play.

Inflation forecasts published in the inflation report may have some impact on the Swedish term structure, especially on the one-year interest rate. The quantitative term structure reaction appears to be much smaller than the actual repo rate response to changes in inflation forecasts, see Jansson and Vredin (2001).[24] This indicates that a substantial proportion of future monetary policy actions were expected by investors before the publication of the inflation forecast. Indeed, we do not expect a strong effect from the publication of the inflation forecast since its main role is to support the repo rate decision announced at the same time rather than to provide the market with additional signals. We have also examined various methods to incorporate the risk assessment in the inflation report without obtaining any effects on the Swedish term structure of interest rates.[25]

24 Jansson and Vredin (2001) find that an upward revision of the inflation forecast of 1 percentage point is associated with a short-run response of the repo rate of about 66 basis points.

25 We have tried to use the risk-adjusted inflation forecast (corresponds to the mathematically expected inflation), which if anything had weaker effects on Swedish interest rates. When we added separate variables representing the risk assessment in the inflation report, small insignificant effects of the wrong sign were obtained.

There are several reasons for our cautious interpretation of the effects from the inflation forecast. One problem is that the impact of the inflation forecast is quite sensitive to outliers and in the baseline model we exclude the inflation forecast published on 8 December 1998.[26] Moreover, there is some evidence of overreaction in the form of a negative lagged effect from publications of the inflation forecast that to some extent balances the contemporaneous effect. If we do not exclude the inflation report published on 8 December 1998, this negative lagged effect actually dominates. Moreover, the fact that the unexpected component of the Riksbank's inflation forecast relative to the target is measured with error, since we do not know the expected value, also blurs the analysis. Finally, there is also a multicollinearity problem since the publication of inflation reports normally coincides with the announcement of a repo rate decision. The inflation report may contain some uncertain signalling effects that are difficult to extract due to measurement and statistical problems.

The minority view appears to have some impact only on Swedish short-term interest rates, indicating that investors adjust their monetary policy expectations towards the minority view to some extent. The coefficient of 0.35 is not very far from corresponding estimates reported by Gerlach-Kristen (2001).[27] It should, however, be remembered that the unexpected component of the minority view (as defined by expression (9)) is measured with an error since we do not know the expected values, and that the motive behind the publication of minority views is not to affect monetary policy expectations but to give a more detailed description of the decision-making process.

Finally, Table 3 indicates that unexpected signals from speeches have significant but at first sight small effects on Swedish interest rates. However, of all policy variables only speeches have a significant effect on the five-year interest rate. Moreover, a closer examination reveals that the effect on the five-year interest rate from an unexpected signal given in a speech corresponds to an unexpected repo rate change of 30 basis points, which is quite large. Our tentative conclusion is that speeches have provided the market with the strongest signals for monetary policy intentions in a longer perspective.

5.4 A closer look at speeches

The analysis above indicates that speeches appear to be an important channel for monetary policy signalling. At the same time, it is a non-trivial task to extract unexpected signals from speeches and therefore we find it appropriate to examine alternative methods. First, we analyse the consequences of assigning a very low value of 0.005 to the slope variable *d* in (9). This means that investors very seldom have neutral monetary policy expectations, implying that most non-neutral speeches deliver expected signals. As can be seen from panel A in Table 5, this leads to a reduction of the estimated coefficients[28] for the speech signals as well as R^2. A similar pattern also emerges (to a lesser degree) if we increase the slope variable *d* to 0.10.[29] The problem in this case is that investors are judged to have neutral monetary expectations most of the time, implying that too many non-neutral unexpected speech signals are included.[30] Our choice of the slope variable *d* is probably not very far from the value that would have emerged if this variable were estimated.

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[26] The inflation forecast published on 8 December 1998 was special in several respects. The forecast exhibits the largest deviation from the target in the sample and it also represents a rather large downward revision in comparison to the forecast published about two months earlier (29 September 1998). Moreover, the low inflation forecast of 1.4% is measured in terms of CPI whereas the inflation forecast for underlying inflation (UND1X) was substantially higher (1.8%) and it is not unreasonable to suppose that investors believed future monetary policy would be guided by the outlook for UND1X - a practice that was announced at the beginning of 1999, see footnote 15.

[27] Gerlach-Kristen (2001) reports significant coefficients in the range 0.24-0.28 for changes in the three-months interest rate, whereas the impact on longer interest rates is smaller and insignificant.

[28] Changes in the definition of the *SPEECH* variable had very small effects on estimates of the coefficients of the other regressors and they are therefore not reported.

[29] If we increase the parameter *d* to a sufficiently large number, all non-neutral speeches become unexpected. The result in this case is quite similar to that presented in panel B of Table 5.

[30] When the parameter *d* is set to a very high number (ie no adjustment for monetary policy expectations as reflected in the slope of the yield curve), the size and significance of the estimated coefficients weaken further.

Table 5

Variable	90-day bill	1-year bond	2-year bond	5-year bond
A. d = 0.005 in (9)				
SPEECH	0.008 (0.593)	0.013 (0.813)	0.014 (0.723)	– 0.005 (0.227)
lagged effect	**0.031** (2.278)	0.005 (0.322)	– 0.009 (0.472)	– 0.009 (0.446)
R^2/ R^2adj	0.390/0.348	0.326/0.280	0.356/0.312	0.465/0.428
B. d = 0.10 in (9)				
SPEECH	**0.031** (2.526)	**0.033** (2.176)	**0.031** (1.653)	0.012 (0.651)
lagged effect	0.009 (0.761)	0.021 (1.400)	0.022 (1.206)	0.022 (1.125)
R^2/ R^2adj	0.393/0.352	0.343/0.298	0.367/0.323	0.468/0.432
C. Include only speeches given within three weeks before repo rate adjustment				
SPEECH	**0.047** (1.781)	**0.076** (2.366)	0.056 (1.447)	0.030 (0.744)
lagged effect	0.034 (1.240)	0.011 (0.315)	0.052 (1.300)	0.088 (2.122)
R^2/ R^2adj	0.386/0.344	0.334/0.288	0.360/0.317	0.471/0.435
D. Impact of speeches given by the Governor before and after 1999				
SPEECH-pre99	**0.067** (2.935)	**0.047** (1.672)	0.022 (0.655)	-0.007 (0.186)
lagged effect	0.033 (1.451)	**0.050** (1.779)	0.051 (1.480)	**0.078** (2.198)
SPEECH-post99	**0.061** (2.305)	**0.105** (3.214)	**0.124** (3.136)	0.052 (1.275)
lagged effect	0.002 (0.078)	0.006 (0.187)	– 0.029 (0.720)	– 0.035 (0.821)
R^2/ R^2adj	0.410/0.365	0.362/0.313	0.383/0.336	0.477/0.437
E. Speeches with unexpected contractionary or expansionary monetary policy signals				
SPEECH-contractionary	**0.0944** (4.706)	**0.091** (3.651)	**0.116** (3.835)	**0.116** (3.736)
lagged effect	0.011 (0.557)	0.024 (0.713)	– 0.003 (0.102)	– 0.009 (0.294)
SPEECH-expansionary	– 0.002 (0.117)	0.020 (0.822)	0.001 (0.048)	– 0.031 (1.058)
lagged effect	**0.041** (2.113)	0.012 (0.500)	0.019 (0.656)	0.022 (0.736)
R^2/ R^2adj	0.433/0.389	0.360/0.311	0.389/0.342	0.494/0.455

t-values are in parentheses.

Next we restrict the analysis to speeches that were followed by a non-zero repo rate change within three weeks. In this case, the signals should be stronger since these signals were typically followed up by a corresponding policy move. In panel C, we see that this is indeed the case for interest rates up to one year. For longer maturities, this is true only in the sense that the sum of the contemporaneous and lagged coefficients increases, but these coefficients are on the other hand insignificant with one exception (a quite strong delayed effect on the five-year interest rate). Moreover, speech signals constructed in this way cannot be used in real-time analysis.

We also examine whether speeches by the Governor had a bigger impact before the introduction of collective decision-making by the Executive Board in 1999 than after. However, the evidence presented in panel D of Table 5 provides no support for this hypothesis. Indeed, speeches given post-1999 have a larger contemporaneous impact on medium- and long-term interest rates, but if we include lagged effects the picture is not clear. We cannot reject the hypothesis of equal impact in the two subperiods using a formal F-test.

In panel E of Table 5, it is evident that unexpectedly contractionary speeches have had a much larger impact on Swedish interest rates than unexpectedly expansionary speeches. A mirror image of this result is that unexpected repo rate decreases have had a much larger impact than unexpected repo rate increase (see Table 6). Indeed, it appears that unexpected increases of the repo rate have had no effects on medium- and long-term interest rates. The observations above suggest that investors have had difficulties identifying unexpected signals in speeches about future decreases of the repo rate and therefore view repo rate decreases as a rather drastic change of policy intentions when they occur.

We do not, a priori, think that there should be any asymmetric response to repo rate increases and decreases. The estimated asymmetry is probably to some extent a small sample problem in the sense that the sample only includes five upward adjustments of the repo rate and on several occasions these adjustments were associated with substantial interest rate *reductions*. However, one cannot exclude the possibility that this reflects an asymmetric credibility effect, ie that repo rate increases lead to lower nominal interest rates thanks to lower inflation expectations but not the other way around (ie repo rate decreases lead to higher inflation expectations).[31] Another possible explanation for the asymmetry is that most of the repo rate decreases since 1996 have been against the long-run trend, ie the repo rate has been cut when its current level has been below its long-run equilibrium level. It is conceivable that such policy moves are harder to communicate, which may explain the lack of impact from speeches signalling unexpected repo rate decreases, and therefore leading to a substantial revision of monetary policy expectations when they occur.

Table 6

Impact of unexpected increases and decreases in the repo rate

Variable	90-day bill	1-year bond	2-year bond	5-year bond
REPO increases	0.571 (5.559)	0.084 (0.671)	– 0.049 (0.323)	– 0.049 (0.306)
lagged effect	– 0.100 (0.994)	0.163 (1.313)	0.155 (1.034)	0.091 (0.579)
REPO decreases	0.604 (8.052)	0.479 (5.223)	0.436 (3.946)	0.220 (1.916)
lagged effect	0.124 (1.668)	0.117 (1.285)	0.068 (0.622)	0.039 (0.342)
R^2/ R^2adj	0.413/0.368	0.363/0.315	0.385/0.338	0.474/0.433

6. Conclusions

This paper examines how various monetary policy signals from the Riksbank (the Swedish central bank) affect the Swedish term structure of interest rates. The paper extends the existing literature in two important ways. First, it relates unexpected term structure movements not only to unexpected monetary policy actions, but also to unexpected changes in other factors such as foreign interest rates, surprises in the outcome of inflation and GDP and unexpected portfolio effects. Second, the paper broadens the concept of monetary policy actions to include (in addition to the changes in the official interest rate) unexpected signals from speeches, inflation reports and minutes of monetary policy meetings.

[31] The observation that long-term interest rates tend to decrease when the repo rate is increased can also be interpreted in terms of changed central bank preferences (see Ellingsen and Söderström (1998)).

The overall picture is that the policy variables, especially unexpected changes in the repo rate (the official instrumental rate of the Riksbank), are the most important factors behind movements at the short end of the yield curve (the nominal three-month interest rate) but they still contribute significantly (in a statistical as well as an economic sense) to movements in medium-term interest rates with maturities of one and two years. Surprises in the outcome of inflation and GDP and unexpected changes in market conditions (term premia) also had some impact on medium-term interest rates. However, the foreign interest rate is probably the most important factor in the sense that it is the dominant factor for interest rates with a maturity of two years or more.

A closer inspection of the policy variables reveals that the impact on market interest rates of unexpected changes in the repo rate declines as the maturity increases. The results are in line with the results in other papers analysing how changes in the official rate affect the term structure of interest rates. However, announcements of no change in the repo rate only affect short-term interest rates. The published inflation forecast two years ahead may have some impact on medium-term interest rates but this result should be interpreted with caution due to statistical and measurement problems. There is also evidence that the minority view as reflected in the minutes published a few weeks after monetary policy meetings affects investors' expectations concerning repo rate decisions in the subsequent meetings.

Unexpected signals from speeches appear to be as important as unexpected repo rate changes for Swedish term structure movements. Indeed, one can argue that speeches are more important in the sense that they, in contrast to repo rate changes, significantly affect the long-term (five-year) interest rate. Moreover, there is weak evidence that the impact is larger when the analysis is restricted to speeches that were followed by a non-zero repo rate change within three weeks. However, it can be misleading to compare repo rate changes and speeches as separate policy variables without taking the interaction between them into account. As an example of this interaction, it is shown that speeches signalling repo rate increases had a far stronger impact than speeches signalling repo rate decreases. Consequently, unexpected decreases in the repo rate had a much stronger impact than repo rate increases.

Finally, one should recall that there is an implicit and fundamental role for the repo rate in the sense that other channels for signalling future monetary policy intentions would be useless if there were no repo rate (or other instrument) that could implement these intentions. This does not, however, alter the main conclusion of this paper, namely that central bank communication is an essential part of the conduct of monetary policy - an aspect that should be examined further in future research.

Appendix: Description of data

Interest rate data

With the exception of the repo rate, which is expressed as a simple annual rate, interest rates are continuously compounded zero coupon rates estimated with the extended Nelson-Siegel method (see Svensson (1995)). Interest rates obtained in this way are displayed in Figures A1 and A2.

Figure A1
Swedish (SE) and Foreign (FOR) zero coupon interest rates

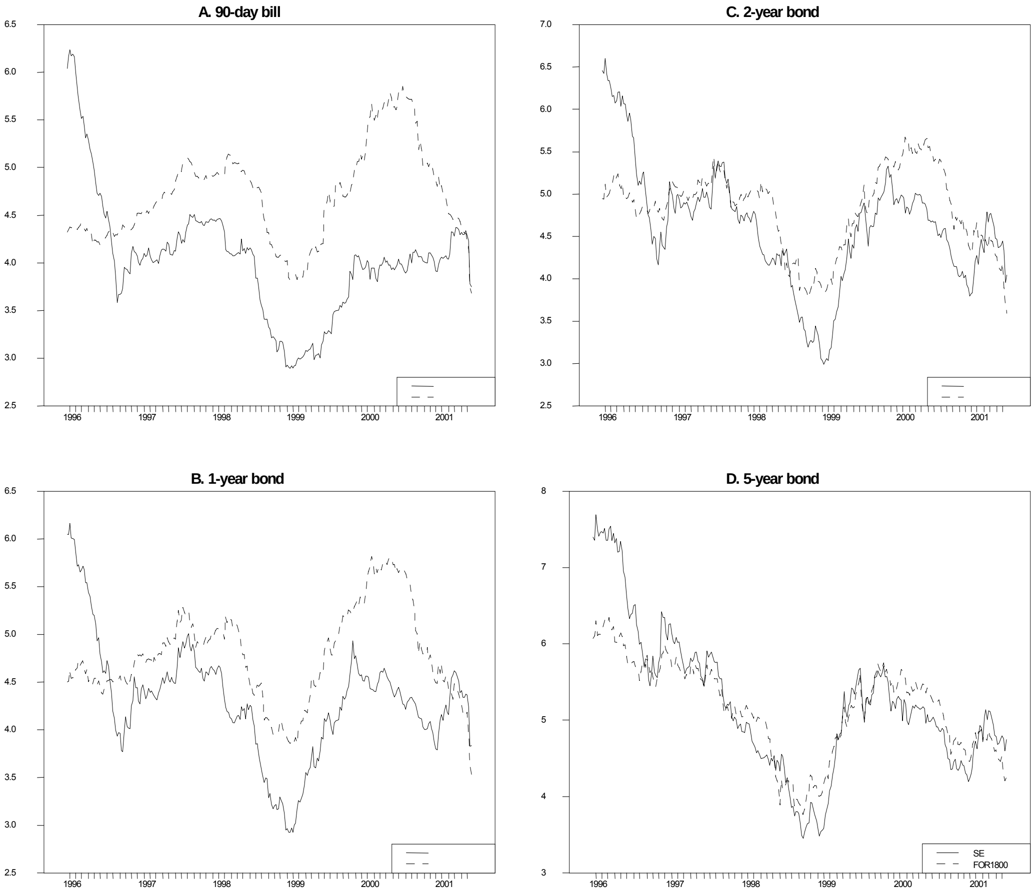

Figure A2
Repo rate and 10-year forward interest rate differential

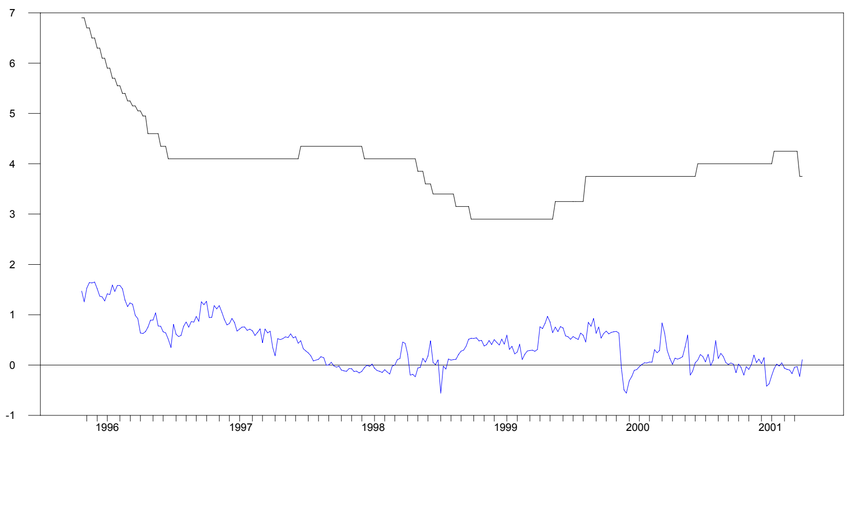

Table A1

Speeches and quotes with monetary policy content

Date	Speaker (number of press release)	Title and place of speech	$D^{sign}(t)$	Quote
1996-04-19	Urban Bäckström	Sweden's economy and monetary policy; Handelsbanken Seminar in New York	– 1	"All in all, this background suggests that there may be some scope for a further easing of interest rate policy. The real economic trends and the related outlook for future inflation will provide guidance in the task of assessing how large this scope may be. This assessment starts from sustained confidence in Sweden's economic policy, measured in terms of inflation expectations and exchange rate movements, viewed over a somewhat longer period."
1996-05-09	Urban Bäckström	The current situation for monetary policy; Standing Committee on Finance, Stockholm	– 1	"Regardless of which of the two alternatives for the real economy proves most probable, the Riksbank considers that there may continue to be some room for repo rate reductions. But the room for manoeuvre is contingent on the alternative that materialises, on the attendant inflation outlook, and on the confidence in economic policy."
1996-06-03	Urban Bäckström	Monetary policy perspective; Monetary Policy Forum, Stockholm	– 1	"The Riksbank's own assessment of the outlook for inflation in the coming years, which includes an appraisal of tendencies in the real economy, likewise indicates that the possibility of fulfilling the inflation target is good. Under these circumstances, therefore, there may continue to be some scope for easing the monetary stance."
1996-08-15	Urban Bäckström (18)	Interest rate corridor lowered 0.5 percentage points; Stockholm	– 1	"During 1996 the repo rate has been lowered comparatively quickly. The pace of the Riksbank's recent cuts has been somewhat slower. It is essential that the conditions for future monetary policy are carefully analysed in the light of incoming information. There may still continue to be some room for easing the monetary stance."
1996-10-09	Lars Heikensten	Monetary policy; autumn conference arranged by SNS (Centre for Business and Policy Studies)	– 1	"Our assessment from the middle of September, which still stands, was that the available information pointed to some remaining room for cuts in the repo rate. It should not be expected, on the other hand, that in the period ahead monetary policy will follow a particular pattern. The future path will depend on new information and on how this relates to the analysis in the Riksbank's latest inflation report."
1996-10-09	Urban Bäckström	Current issues in monetary policy; Örebro	– 1	"Under these circumstances the Riksbank considers that there is a good prospect of inflation being in line with the inflation target in the coming years. The available information accordingly suggests that some room may remain for cuts in the repo rate. It should not be expected, on the other hand, that in the period ahead the Riksbank will follow a particular pattern. The future path will depend on new information and on how this relates to the analysis in the Riksbank's latest inflation report."
1996-11-07	Urban Bäckström	The current situation for monetary policy; opening remarks at hearing by the Standing Committee on Finance.	– 1	"The background to this is that while we perceive some limited room for a further lowering of the repo rate, the picture is not entirely unambiguous. We need time in which to follow and analyse incoming statistics. The conclusion to be drawn from the assessments that are made may also be an unchanged repo rate."

Table A1 (cont)

Date	Speaker (number of press release)	Title and place of speech	$D^{sign}(t)$	Quote
1996-11-07	Lars Heikensten	The Swedish Economy; SE-Banken in New York	– 1	“In the light of the available information, the Riksbank considers that there is still some limited room for lowering the repo rate. But the picture is not unambiguous. This means that additional time is needed to follow and analyse incoming information. The conclusion to be drawn from the assessments that are made may also turn out to be an unchanged repo rate.”
1997-01-28	Urban Bäckström	Maintaining price stability; address at Handelsbanken seminar in London	0	“All in all, the picture of future inflation does not appear to have changed from the assessment in the December inflation report. The conclusion in that report - that monetary policy is relatively well balanced - therefore holds good.”
1997-01-29	Lars Heikensten	Inflation and the interest rate; conference arranged by the Stockholm Chamber of Commerce and Veckans Affärer.	0	“The picture I have outlined does not warrant any change in the conclusions presented in the December inflation report. Our main scenario suggests that at present the monetary stance is relatively well balanced.”
1997-04-30	Urban Bäckström	Sweden’s economy and monetary policy; New York	0	“The conclusion in the latest inflation report was that monetary policy is well balanced. That conclusion still holds true.”
1997-05-14	Urban Bäckström	The Swedish economy; Skånska Sparbanks-föreningen	0	“The repo rate was lowered most recently last December. Since then we have frequently declared that the monetary stance is well balanced. My message today is the same. On the whole, economic tendencies confirm the picture in the Riksbank’s latest inflation report. So at present we see no need to alter the repo rate.”
1997-05-15	Lars Heikensten	The economy and monetary policy; Real-Estate Day, Grand Hotel, Stockholm	0	“The repo rate was lowered most recently last December. Since then we have frequently declared that the monetary stance is well balanced. This still applies.”
1997-05-15	Urban Bäckström	The current situation for monetary policy: opening remarks to the Standing Committee on Finance	0	“The repo rate was lowered most recently last December. Since then we have frequently declared that the monetary stance is well balanced. This still applies. At present the Riksbank sees no need to alter the repo rate.”
1997-06-15	Lars Heikensten	The economic situation; Centre Party Economic Seminar, Haparanda	0	“The conditions for monetary policy in the years ahead will then be improved and greater freedom of action will be created for economic policy in the longer term.”
1997-10-15	Lars Heikensten	Inflation and the interest rate; Sweden Financial Forum, Örebro	0	“The overall assessment in the inflation report is that the monetary stance is well balanced. Today there is no reason to modify that conclusion. In the past month there has been no appreciable change in the outlook for inflation.”

Table A1 (cont)

Date	Speaker (number of press release)	Title and place of speech	$D^{sign}(t)$	Quote
1997-10-22	Lars Heikensten	Monetary policy; autumn conference arranged by Centre for Business and Policy Studies, Stockholm	1 (0)	Part 1: "As activity in the economy strengthens and the monetary policy perspective is moved forward in time, monetary policy has to be gradually adjusted so that instead of giving a certain expansive effect, it has a more neutral effect on the economy." Part 2: "Most indications are that the level of activity and resource utilisation has risen further during the autumn. However, according to the Riksbank's assessment, there is still available capacity to meet an upswing. Therefore our assessment is that monetary policy at present is well balanced."
1997-10-23	Urban Bäckström	The current situation for monetary policy; Standing Committee on Finance	1	"As economic activity becomes stronger and monetary policy adjusts its sights on the future picture, the Riksbank's monetary stance will have to gradually move away from its current expansionary position. The timing of such a move has to be assessed in the light of new information and today one cannot say when it will happen."
1997-11-19	Urban Bäckström	Sweden's economy and monetary policy; Swedish Shareholders' Association, Stockholm	1	"From what I have said about demand, resource utilisation and other factors, it is clear that some time in the future monetary policy will have to be given a somewhat less expansionary direction."
1998-01-27	Urban Bäckström	Inflation and the interest rate; Stockholm Chamber of Commerce and Veckans Affärer	0	"The conclusion is that at present there is no reason to alter the repo rate."
1998-03-12	Urban Bäckström	The current situation for monetary policy; Standing Committee on Finance	0	"All in all, in the inflation report the Riksbank concluded that the repo rate should not be altered at present. With the uncertainties in the assessment, however, there are strong reasons for appraising the construction of monetary policy continuously as new information becomes available. Since the presentation of the inflation report, some new statistics have been produced. They do not motivate an altered conclusion about the monetary stance."
1998-03-21	Lars Heikensten	Inflation and monetary policy; Swedish Shareholders' Association, Trelleborg	0	"The conclusion in the latest inflation report was that the repo rate should not be altered at present but that a cautious tightening would probably be considered in the year ahead. The information that has been obtained since the publication of the inflation report does not alter that conclusion."
1998-05-27	Lars Heikensten	Economic policy and inflation; Meeting of Almega-affiliated employers' associations, Stockholm	– 1	"With the bright inflation prospects and a strict interpretation of the Riksbank's rule for monetary policy decisions, today there may even be grounds for considering a minor downward repo rate adjustment. What the Riksbank now has reason to consider is whether such an adjustment would lead to good conditions for stable economic development in the future."

Table A1 (cont)

Date	Speaker (number of press release)	Title and place of speech	$D^{sign}(t)$	Quote
1998-08-25	Urban Bäckström	The present situation; Näringslivets Fonds annual meeting	– 1	"Some new information that has been obtained during the summer does not appreciably alter the picture we painted in June. If anything, the statistics on overall real economic activity and inflation point more in the direction of a future inflation tendency that is weaker than in the main scenario in our June report, though in that case the revisions would be only marginal."
1998-10-07	Urban Bäckström	The Swedish economy; Svenska Handelsbanken Seminar, New York	0	"Inflation prospects and the future path of monetary policy accordingly depend on two - contrary - factors: on the one hand, the international economic trend could be weaker than we have counted on and thereby lead to lower inflation; on the other, a sustained weak exchange rate that has no counterpart in a weaker real economy could generate increased inflationary pressure. Our monetary policy conclusion is that we will go on analysing the course of events and appraise monetary policy continuously in the light of new information. Hopefully, the analysis in the inflation report should give an indication of our line of reasoning about the inflation outlook in Sweden and the future path of monetary policy that is as clear as possible in the global economy's present state of uncertainty."
1998-10-14	Lars Heikensten	Monetary policy; autumn conference arranged by Centre for Business and Policy studies	0	"At present there are no grounds for altering the direction of interest rate policy."
1998-10-20	Urban Bäckström	Monetary policy during financial unrest; Swedish Bond Promotion	0	"The monetary policy conclusion is that we must keep a close watch on the real economy, the financial system and the financial markets. At present we are waiting with a change in the repo rate but that decision may need to be altered in time as the picture becomes clearer."
1998-11-13	Urban Bäckström	The current situation for monetary policy; Standing Committee on Finance, Stockholm	– 1	"The course of the Asian crisis and its contagious effects in the industrialised countries is having a larger impact than we counted on earlier. I cannot rule out the possibility that in order to fulfil the inflation target, further adjustments of the monetary stance will be called for in the same direction as recently. A weaker development in the rest of the world also affects conditions in Sweden."
1999-01-22	Lars Heikensten	The new currency and the Swedish economy; Swedish Shareholders' Association, Stockholm	– 1	"Since the publication of the December report, international economic activity can hardly be said to have changed appreciably for the better. […] The economic statistics for Sweden suggest that industrial activity may go on weakening. [….] The assessment of future inflationary pressure has to take these and other factors into account. At the same time, the downward path of market interest rates in recent months represents a demand stimulus further ahead."
1999-02-02	Urban Bäckström	The krona and the interest rate; Stockholm Chamber of Commerce and Veckans Affärer	– 1	"Thus, the international outlook can hardly be said to have improved since the publication of the December report and there still seem to be risks of a development that is weaker. […] The Executive Board's monetary policy discussion on 11 February will thus focus to a large extent on assessing global economic prospects and their consequences for Sweden's economy. "

Table A1 (cont)

Date	Speaker (number of press release)	Title and place of speech	$D^{sign}(t)$	Quote
1999-03-25	Urban Bäckström	The current situation for monetary policy; Standing Committee on Finance, Stockholm	– 1	"The conclusion from the Riksbank's inflation forecast is that, even when transitory effects from changes in indirect taxes, subsidies and interest rates are disregarded, the rate of inflation 12 to 24 months ahead will be below the Riksbank's target. Moreover, as I just said, the risk of lower inflation compared with the main scenario is greater than the upside risk."
1999-09-01	Urban Bäckström	The economic situation in Sweden; Föreningsspar-banken, Ulricehamn	0 (1)	"In my opinion, there is no reason as yet to reduce the expansionary effect on the Swedish economy that monetary policy is currently exerting. A monetary policy adjustment will indeed be called for at some time in the economic upswing but I still see its timing as an open question."
1999-10-06	Urban Bäckström	The current situation for monetary policy; Standing Committee on Finance, Stockholm	1	"Thus, there are still no signs of more widespread shortages that might generate unsettling inflationary impulses; but the risk spectrum has shifted. Moreover, the situation can change at short notice and the Riksbank has to be alert to this. We must be ready to take preventive action."
1999-10-12	Lars Heikensten	Monetary policy and the new Executive Board; autumn conference, Centre for Business and Policy Studies, Stockholm	1	"In connection with the publication of the inflation report we made it clear that the repo rate will need to be increased in the future if there is no new information that clearly alters the perspective. Even if inflation expectations continue to be low and there are certain signs that the economy is functioning more efficiently, the growth rate will have to be brought into line with the long-term potential. That we shall do in good time. We can thereby contribute to good, stable growth in the Swedish economy for a long time to come."
1999-10-25	Lars Heikensten	Competition, trade and inflation; Örebro Association of Building Contractors	1	"The inflation report earlier this month allowed for the effects of increased competition and so on that we could identify. So the Riksbank's conclusion in connection with the publication of the report - that the repo rate will need to be increased if nothing unforeseen happens - holds."
1999-10-26	Lars Heikensten	Economic conditions for wage formation; National Institute of Working Life, Stockholm	1	"At the same time, it is important that current assessments and policy are discussed continuously. Along with most other observers, we now count on an acceleration of inflation in the coming years. Assessments of the rate at which inflation will move up may vary, of course. But when the underlying rate of inflation is 1.8%, it is obvious that a repo rate increase ought not to wait particularly long, given that nothing unforeseen alters the economic assessment. Timely action creates the best conditions for a stable development with a longer upward phase."
1999-12-01	Lars Heikensten	Repo rate increase reconfirmed by new information; Swedish Shareholders' Association in Folkets Hus, Stockholm	1 (0)	"The new information since then strengthens my conviction that the interest rate increase was needed. If the economic upswing continues as expected, further interest rate increases will be called for in order to adjust growth to the rate that the Swedish economy can maintain with a continuation of low inflation. There are reasons for returning to this after the turn of the year."

Table A1 (cont)

Date	Speaker (number of press release)	Title and place of speech	$D^{sign}(t)$	Quote
2000-03-14	Kerstin Hessius	Controller Congress 2000	1	"Growth prospects in Sweden at present are robust and during an upward cyclical phase monetary policy must be gradually realigned in a less relaxed direction but the rate at which we have to proceed is by no means self-evident."
2000-03-17	Urban Bäckström	Swedish monetary policy; Monetary Policy Forum	0	"After the latest repo rate increase in February, against this background I consider that the inflation risks still seem to be fairly balanced."
2000-03-23	Urban Bäckström	The current situation for monetary policy; Standing Committee on Finance	0 (1)	"The strong economic activity and gradually growing inflationary pressure point to a future need for a further repo rate increase. The timing and size of the increase are considered in the light of, for example, new information and its significance for the Riksbank's overall inflation assessment. Our current assessment is that in the greater part of the coming one to two years, inflation is expected to be below 2%. This speaks in favour of leaving the repo rate unchanged for now."
2000-05-18	Lars Heikensten (28)	Present inflation prospects good; Fastighetsvärlden conference in Stockholm	1	"Although inflation prospects seem to be better, in my view there is reason to count on a need for further interest rate hikes. The rate at which they may be introduced has become more uncertain. That depends, as always, on our ongoing appraisal of inflation."
2000-06-06	Eva Srejber	The role of monetary policy for growth; Förenings Spar-banken's Economics Day in Vellinge	1	"I am more concerned about what can happen with inflation and growth after the forecast period if demand increases at the rate we have anticipated. […T]he consequences that the economic development can have for macroeconomic stability and inflation beyond the forecast horizon must also be weighed in. The risk of financial imbalances now being built up when indebtedness is increasing and of inflationary pressure accumulating at the same time must in my view therefore be taken into account in the monetary policy decisions. […] The quantity of money and lending, especially to households, are for instance increasing at present at a rate which is probably not sustainable in the long term."
2000-08-22	Lars Heikensten (48)	Domestic inflation surprisingly low; Öhmans Fondkommission, Stockholm	1	"There are many indications that the growing competition, deregulations and so on may continue to aid the Riksbank in combatting inflation. But even if they do, growth above the long-term potential will presumably generate rising inflationary pressure. With our present assessment of economic activity - an average growth rate in the coming years of over 3% - it is thus natural to count on further interest rate increases."
2000-09-04	Eva Srejber	Price stability and growth; SEB Malmö	1	"Caution indicates that monetary policy should at least be neutral in the present situation. I regard monetary policy as being expansive at present. I therefore consider that the interest rate should be increased."

Table A1 (cont)

Date	Speaker (number of press release)	Title and place of speech	$D^{sign}(t)$	Quote
2000-09-06	Villy Bergström (52)	Sweden's economy performing strongly; Aktie Torget's and Almi's "Market Day" at Uppsala University	1	"This has enabled us to defer an increase in the interest rate but the fact remains that if the economy continues to grow at the same good rate, an increase will come sooner or later. Production capacity is calculated to grow at an annual rate of 2-2.5%, while demand growth is on a higher path. More and more unutilised resources are being brought into production. Sooner or later demand growth will have to be curbed."
2000-10-10	Urban Bäckström	The current situation for monetary policy; Standing Committee on Finance, Stockholm	1	"The picture of a strong upswing in the Swedish economy still holds, with rising resource utilisation in the labour market, for example. That suggests that the repo rate may need to be raised in the future."
2000-11-07	Lars Heikensten	Six monetary policy issues; Umeå School of Business and Economics	1	"For my part, there seems to be no reason at present for any appreciable change in the assessment I made in October, namely that a repo rate increase will probably be needed in the future in order to safeguard the continuation of a favourable and stable development, with low inflation and rising output."
2000-11-08	Urban Bäckström	The Swedish economy's future path; Association of Swedish Chambers of Commerce & Industry, Stockholm	1	"In the absence of a sufficient slowdown in demand, an adjustment to the long-term growth path will need to be achieved with interest rate increases by the Riksbank. […] Consideration will also have to be paid, of course, to the inflation risks associated with the high price of oil and the high dollar rate. These were some of the risks we highlighted in the October inflation report."
2000-11-17	Lars Heikensten	Monetary policy autumn conference; Centre for Business and Policy Studies, Stockholm	1	"Still, there are now many indications that resource utilisation is relatively high and will go on rising. That implies that, little by little, inflationary pressure will grow. […] Although it is still too early to specify when, there will presumably be grounds for increasing the repo rate in the future."
2001-11-21	Villy Bergström (74)	Conflicting trends in the Swedish economy; Swedish Shareholders' Association in Örebro	1	"Demand is still growing more quickly than long-term sustainable growth, which means that available resources are being utilised. If the increase in demand continues at a rapid rate, sooner or later inflation will begin to rise and force increases in interest rates. However, the growth in demand is probably on the verge of slowing down somewhat."
2000-11-28	Urban Bäckström	The Swedish economy; Swedish Shareholders' Association, Stockholm	1	"To some extent, therefore, the situation for monetary policy has changed. That is also why I began by saying that the time will soon come to raise the repo rate. Not because I have dramatically revised my assessment of inflation prospects but rather because resource utilisation is still rising and a shift can be discerned in the risk spectrum."
2000-11-28	Villy Bergström (75)	The economic scope for wage increases; seminar in Industrihuset organised by the Mediation Institute, Stockholm	1	"However, considering the strong development in demand we anticipate for the coming two years, the signs of bottlenecks and labour shortages will probably increase and resource utilisation will become more strained. It will probably also be apparent in the form of some upward pressure on prices and wages. Sooner or later, the Riksbank will have to increase the rate if a spontaneous slowdown does not occur."

Table A1 (cont)

Date	Speaker (number of press release)	Title and place of speech	$D^{sign}(t)$	Quote
2001-02-28	Villy Bergström	The Riksbank's role in the economy; Swedish Shareholders' Association, Jönköping	0	"It is still too early to say anything about the conclusions for monetary policy that can be drawn from this reasoning about future cyclical developments. The Riksbank's overall assessment will be included in the next inflation report on 27 March. There will then be a clearer basis for assessing whether resource use is expected to be under such strain that a more stringent policy is required or whether the cyclical outlook has weakened so much that stimulation is called for. One thing is clear, however. Downward adjustments of growth assessments mean that the large number of interest rate increases that most analysts expected during the spring will hardly be necessary to keep inflation on target!"
2001-03-27	Urban Bäckström	The current situation for monetary policy; Standing Committee on Finance	0	"All in all, however, the Executive Board of the Riksbank considers that the spectrum of risks is asymmetric, so that inflation somewhat below the main forecast is more probable than a higher rate. With the risks taken into account, inflation in the coming years is forecast to be around two tenths of a percentage point below the targeted level of 2%. At the same time, the margins are so small that we have decided not to adjust the repo rate at this time."
2001-06-14	Urban Bäckström	Currency interventions cannot be ruled out; Inter-Alpha's Steering Committee Press release no 38	71	"The weak exchange rate at present is a deviation from the path in the main scenario that served as the basis for the latest inflation report. This means that if the krona remains weak for a longer period, there may be a risk of inflation being higher one to two years from now. If there are grounds for believing that the krona will continue to be weak - and nothing else happens to alter inflation prospects - that will have consequences for monetary policy."
2001-06-15	Lars Heikensten	The krona has shifted the risk spectrum; Trevises Economic Club in Malmö	1	"If the exchange rate were to remain weak and nothing untoward happens in other respects, it would have consequences for monetary policy."

Note: $D^{sign}(t)$ = 1 (–1) implies that the quote is interpreted as indicating a forthcoming tightening (easing) of the monetary policy stance by the Riksbank, whereas 0 indicates a neutral signal concerning coming monetary policy moves. Alternative values for the dummy variable are provided within parentheses for some speeches, as discussed below. The following principles have guided the assignment of values for the dummy variables. (i) If a general need to increase (decrease) the repo rate is expressed and/or if there are judgments about inflation prospects that clearly imply the need of a future increase (decrease) of the repo rate, then the dummy variable is assigned the value 1 (-1). (ii) If the speech does not signal an adjustment of the repo rate in a specific direction, the dummy variable takes the value zero. (iii) If a need for a repo rate adjustment is accompanied with a clear declaration that the repo rate does not need to be adjusted in the near future, the dummy variable takes the value zero. This is the reason why the speeches given on 21 March 1998, 1 September 1999 and 23 March 2000 are judged to be neutral even if the last two of these speeches can be viewed as borderline cases where a tightening signal is also possible. Another borderline case is the speech given on 1 December 1999, where it is clear that a repo rate adjustment not will occur before the turn of the millennium. Since there are technical rather than economic grounds for this position, we assign a tightening signal even if a strict application of principle (iii) may suggest a neutral signal. (iv) If several speeches are given during the same week, then an overall assessment is made and the speeches are given a common value which also constitutes that week's value of the variable $D^{sign}(t)$ (only one speech signal per week is allowed). Principle (iv) explains why the speech given on 22 October 1997 is given a value of 1 even if part 2 of that speech calls for a zero value according to principle (iii). Taking the speech given on 23 October 1997, we make the overall assessment that the signals from speeches given that week indicate in future increase in the repo rate. Finally, we have examined alternative characterisations of the borderline speeches mentioned above with no significant changes of the results.

Table A2

CPI and GDP news releases with unexpected component

Date	CPI	Unexp CPI	GDP	Unexp GDP
1996-04-15	0.50	0.20		
1996-05-13	0.30	– 0.20		
1996-07-15	– 0.40	– 0.20		
1996-09-16	– 0.50	– 0.50		
1996-10-14	0.60	– 0.30		
1996-10-21			1.40	– 0.30
1996-12-16	– 0.20	– 0.10	0.80	– 0.70
1997-01-20	– 0.20	0.10		
1997-02-24	0.20	– 0.20		
1997-03-17			1.80	0.10
1997-05-19	0.50	0.30		
1997-06-16			1.60	0.00
1997-07-14	0.10	0.20		
1997-08-18	– 0.20	– 0.30		
1997-10-20	0.90	0.30		
1997-10-27			1.20	– 0.90
1997-12-15	– 0.20	– 0.20		
1997-12-22			2.70	0.20
1998-01-19	– 0.10	0.10		
1998-02-23	– 0.30	– 0.30		
1998-03-09			3.30	0.90
1998-03-16	– 0.10	– 0.20		
1998-06-15	0.20	0.30	2.30	– 0.70
1998-07-13	– 0.20	– 0.10		
1998-08-10			4.20	1.20
1998-08-17	– 0.20	0.10		
1998-09-14	– 0.50	– 0.10		
1998-10-05			4.20	0.00
1998-10-19	0.40	– 0.30		
1998-11-16	0.20	0.10		
1998-12-14	– 0.30	– 0.20		
1998-12-21			3.40	0.00
1999-01-18	– 0.20	– 0.10		
1999-02-22	– 0.10	0.20		
1999-03-15			3.20	0.50
1999-04-12	0.40	0.10		
1999-05-10	0.20	– 0.30		
1999-06-14			3.60	0.20
1999-07-12	0.20	0.20		
1999-08-09			3.70	– 0.20
1999-08-30	– 0.40	– 0.30		
1999-09-27			3.20	– 0.50
1999-10-18	0.70	0.10		
1999-11-15	0.10	– 0.10		
1999-12-13	– 0.30	– 0.20		

Table A2 (cont)

Date	CPI	Unexp CPI	GDP	Unexp GDP
1999-12-20			4.10	0.10
2000-01-17	0.20	0.20		
2000-02-28	– 0.40	– 0.30		
2000-03-13	0.50	0.30	3.40	– 0.90
2000-05-15	– 0.10	– 0.30		
2000-06-19	0.50	0.20	3.00	– 1.30
2000-08-07			4.00	– 0.20
2000-08-14	– 0.50	– 0.10		
2000-09-18	0.10	0.20		
2000-10-02			4.30	0.30
2000-10-16	0.70	– 0.10		
2000-11-13	0.20	0.10		
2000-12-18	0.10	0.30	4.00	0.00
2001-01-22	– 0.10	0.10		
2001-02-26	– 0.1	– 0.1		
2001-03-13	0.40	0.20	2.60	0.00
2001-04-17	0.70	0.20		
2001-05-15	0.90	0.50		
2001-06-19	0.70	0.20	2.30	0.00
2001-07-17	– 0.10	0.10		
2001-08-14	– 0.50	– 0.20	1.40	0.00
2001-09-18	0.20	0.10		

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The information content of the yield curve

Hans-Jürg Büttler,[1] Research Group, Swiss National Bank,
and Department of Economics, University of Zurich

Abstract

The goal of this paper is to determine empirically the information content of the nominal yield curve of riskless non-indexed bonds in Switzerland, that is, future expected inflation rates and real interest rates. Applying the three-factor term structure model proposed by Cox, Ingersoll and Ross (CIR), we estimate the model parameters by the full information maximum likelihood method for a sample of pooled time-series and cross-section data. This maximisation is subject to the condition that the theoretical yield curve fits the actual yield curve observed on the trading day under consideration as well as possible.

For a sample of 40 weeks, we obtain the puzzling result that the term structures of real spot interest rates are both upward- and downward-sloping, while the term structures of expected spot inflation rates are always upward-sloping. We attribute this result to the particular assumptions of the CIR model.

We test the model performance indirectly in two ways. First, we compare the future expected nominal spot interest rates with the nominal forward interest rates implied by the observed yield curve over a future time horizon of four years. The outcome of this test is quite satisfactory. Second, we test whether the future expected three-month nominal spot interest rate is an unbiased estimator of the future observed three-month nominal spot interest rate for future time horizons of up to 91 days. This hypothesis is accepted for future time horizons of both one day and seven days. In restricted regressions, however, we accept this hypothesis for all the future time horizons considered in this paper.

Finally, we compare the behaviour of the interest premium or inflation risk premium, respectively, between two different monetary policy regimes. We find that the interest premium has vanished since the beginning of the year 2000, when the Swiss National Bank switched from a regime with medium-term monetary targeting to a concept with inflation forecasts as a main indicator for monetary policy decisions. This reduced risk may indicate that the new concept has further increased the credibility of Swiss monetary policy.

1. Introduction

The goal of this paper is to determine empirically the information content of the nominal yield curve of riskless non-indexed bonds in Switzerland. Applying the three-factor term structure model proposed by Cox, Ingersoll and Ross (henceforth CIR), we obtain estimates of the term structure of expected spot inflation rates as well as of the term structure of real spot interest rates. We test the performance of the CIR model indirectly in two ways using three-month nominal spot interest rates. The model parameters are estimated by the full information maximum likelihood method for a sample of pooled

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Mailing address: Swiss National Bank, PO Box, 8022 Zurich, Switzerland; telephone: +41 1 631 34 17; fax: +41 1 631 39 01; e-mail: hans-juerg.buettler@snb.ch.

time-series and cross-section data. This maximisation is subject to the condition that the theoretical yield curve fits the actual yield curve observed on the trading day under consideration as well as possible.

As regards the term structure of expected spot inflation rates, earlier attempts such as that in Frankel (1982), which relies on a macroeconomic framework, assume that the expected inflation rates are equal to the difference between nominal and real spot interest rates. This is Irving Fisher's hypothesis that the nominal interest rate moves one for one with the expected inflation rate (Fisher (1930)). Probably the first author to show that the Fisher hypothesis does not hold true in an uncertain world was his near namesake Stanley Fischer (1975) in his path-breaking paper on indexed bonds.[2] He shows that the difference between the nominal and real spot interest rate is equal to the expected spot inflation rate minus a term, which I call the "interest premium", which may have either sign.[3] Many other authors, including Bakshi and Chen (1996), Benninga and Protopapadakis (1985), Breeden (1986), Cox, Ingersoll and Ross (1981, 1985a & b), Evans and Wachtel (1992), Fama and Farber (1979) and Lucas (1982), have confirmed this result within quite different frameworks. To my knowledge, the empirical studies, however, have neglected the interest premium so far.[4] There are two exceptions to this observation. One exception is the recent paper by Evans (1998), who is able to estimate the time-varying interest premium in his investigation of index-linked bonds. However, he fails to estimate both the term structure of expected inflation rates and the interest premia endogenously within his framework. Instead, he uses an exogenous variable for the expected inflation rate, namely the Barclay's survey measure of expected inflation.[5] The other exception is the recent paper by Remolona, Wickens and Gong (1998). Using time-series data on both nominal and real discount bond prices, they are able to estimate simultaneously the expected inflation rates and the interest premia in the course of time. They find that the expected inflation rate obtained from their bond price model is an unbiased estimator of future inflation for the period 1982-97. Our approach is different in that we estimate the term structures of both expected inflation rates and interest premia entirely from *nominal* bonds by means of pooled time-series and cross-section data.

In order to calculate the nominal yield curve on the trading days under consideration, we use a non-linear optimisation to determine the nominal instantaneous forward interest rates from observed prices of coupon-bearing government bonds. The objective of the optimisation is nominal instantaneous forward rates as smooth as possible, subject to the condition that the theoretical coupon-bearing bond prices fit the observed coupon-bearing bond prices as well as possible. This optimisation procedure is a modification of the multi-objective goal attainment problem proposed by Delbaen and Lorimier (1992) and Lorimier (1995). The term structure of nominal spot interest rates or the nominal yield curve is deduced from the optimised instantaneous forward rates by numerical integration. This approach has two advantages. First, it is able to explain *any* term structure of interest rates, because no functional form of the instantaneous forward interest rates is assumed. Second, the numerical integration is more exact than the numerical differentiation. To my knowledge, the methods proposed in the literature are inferior to the one put forward by Delbaen and Lorimier. For instance, we have shown by an example that the bootstrap method is not reliable if the yield curve is sufficiently bent, or if there are no discount bonds available in the sample of bonds under consideration (Büttler (2000)). Other methods such as the regression of prices of coupon-bearing bonds on discount factors as proposed in Carleton and Cooper (1976) or various spline methods as proposed in McCulloch (1971, 1975) or in Vasicek and Fong (1982) have many drawbacks as mentioned in Shea (1984, 1985). The recent models proposed by Nelson and Siegel (1987) as well as Svensson (1995) assume an exponential function for the instantaneous forward rates. This approach has two disadvantages: it does not obey the fundamental partial differential equation to value a discount bond (Björk and Christensen (1997)) and it assumes rather than extracts the yield curve from observed data. In a

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2 For a criticism of Fischer's equilibrium condition, see Fama and Farber (1979, p 643).

3 Fischer calls it just "premium". Other authors call it the "inflation risk premium" or the "purchasing power risk of the nominal bond". We prefer the neutral term "interest premium" to the term "risk premium", because the latter associates in general positive values only.

4 For a comprehensive list of empirical studies on index-linked bonds, see Evans (1998). In particular, Brown and Schaefer (1994), although applying the CIR model, do not investigate the term structure of expected inflation rates and interest premia.

5 Evans also uses the ex post realised inflation rate as a proxy for the expected inflation rate.

recent paper, we applied our optimisation procedure, the bootstrap method and the extended Nelson-Siegel method to an arbitrary yield curve. While our optimisation procedure is able to mimic the given yield curve perfectly, both the bootstrap method and the extended Nelson-Siegel method fail (Büttler (2000)).

In view of Fisher's hypothesis, the nominal yield curve contains information on real interest rates, expected inflation rates and the interest premium at least. As long as there are no indexed bonds issued in the country under consideration, we must rely on an economic model, which is able to explain simultaneously nominal and real interest rates. To my knowledge, there are two candidate models to be used, the one proposed by Cox, Ingersoll and Ross (1985a & b) on the one hand, and the one by Bakshi and Chen (1996) on the other hand. We choose the CIR model for the sake of tractability. The CIR model is a three-factor model of the nominal yield curve, the factors or state variables being the real instantaneous spot interest rate, the expected instantaneous spot inflation rate and the consumer price level. The stochastic differential equations of these three factors together with those of a set of nominal discount bond prices in *real* terms constitute the sample of pooled time-series and cross-section data to be estimated by the full information maximum likelihood method. The cross-section data refer to the various terms of the discount bonds.

The plan of the paper is as follows. In Section 2, the basic relationships to be used in the paper are explained. In particular, we define spot and forward inflation rates for a future time horizon, which correspond to the spot and forward interest rates defining the actual yield curve. Since future inflation rates are random, we derive their expected values to be used in the calculation of the term structure of expected inflation rates. In Section 3, we present the three-factor model proposed by Cox, Ingersoll and Ross. The estimation procedure is explained in Section 4 and the results are presented in Section 5, followed by conclusions.

2. Basic relationships

In the following, we will use continuously compounded rates. However, the results presented in all charts are annually compounded rates. To clarify the use of various yields, we start with the definition of the term structure. A list of variables is given in the appendix to the paper. In order to distinguish between nominal and real variables or variables associated with the inflation rate, we use two subscripts, if necessary. The first subscript of a variable, $v = \{n, r, y\}$, denotes nominal values for $v = n$, real values for $v = r$, and values associated with the inflation rate for $v = y$. The second subscript, $k = \{m, c\}$, denotes the compounding frequency with the understanding that m denotes a compounding m times a year and c denotes the continuous compounding ($m \to \infty$).

2.1 Interest rates

The spot interest rate, denoted as $R_v(t, T)$, is defined as the yield of a pure discount bond with spot price $P_v(t, T)$:

$$P_\nu(t, T) = \exp\left(-R_{\nu,c}(t, T)\left[T - t\right]\right), \quad \nu = n, r. \tag{2.1}$$

We assume that the first derivative of the pure discount bond price with respect to time exists and is bounded for any lifetime of the bond. Solving for the spot interest rate yields the following expression:

$$R_{\nu,c}(t, T) = -\frac{\ln\left(P_\nu(t, T)\right)}{T - t}, \quad \nu = n, r. \tag{2.2}$$

The term structure of spot interest rates or the yield curve is defined by equation (2.2). The instantaneous spot interest rate, denoted as $r_v(t)$, is equal to the spot interest rate with a vanishing lifetime:

$$r_{\nu,c}(t) = R_{\nu,c}(t, t) = \lim_{t \to T}\left\{-\frac{\ln\left(P_\nu(t, T)\right)}{T - t}\right\}, \quad \nu = n, r. \tag{2.3}$$

The $(\tau - T)$-year forward interest rate, denoted as $F_v(t, T, \tau)$, corresponds to a forward contract on a pure discount bond with the agreement that the forward price, denoted as $\mathrm{P}_v(t, T, \tau)$, is fixed at date t

and paid at a later date T when the discount bond is delivered. The discount bond matures at a later date τ ($\tau \geqq T \geqq t$).

$$\mathcal{P}_\nu(t, T, \tau) = \exp\left(-F_{\nu,c}(t, T, \tau)\left[\tau - T\right]\right), \quad (t \leqq T \leqq \tau), \quad \nu = n, r. \tag{2.4}$$

In this case, the forward price is equal to the futures price (see Hull (1997), p 95). Again, we assume that the first derivative of the forward pure discount bond price with respect to time exists and is bounded for any lifetime of the bond. Solving for the forward interest rate yields the following expression:

$$F_{\nu,c}(t, T, \tau) = -\frac{\ln\left(\mathcal{P}_\nu(t, T, \tau)\right)}{\tau - T}, \quad \nu = n, r. \tag{2.5}$$

The price of a pure discount bond fixed at date t with maturity date τ should be equal to the price of a portfolio at date t, which consists of a pure discount bond maturing at date T plus a (τ–T)-year forward pure discount bond (see eg Hull (1997)). This leads to the following well known relationship:

$$\begin{aligned} P_\nu(t, \tau) &= P_\nu(t, T)\, \mathcal{P}_\nu(t, T, \tau), \quad (t \leqq T \leqq \tau) \quad \Rightarrow \\ \exp\left(-R_{\nu,c}(t, \tau)\left[\tau - t\right]\right) &= \exp\left(-R_{\nu,c}(t, T)\left[T - t\right]\right) \exp\left(-F_{\nu,c}(t, T, \tau)\left[\tau - T\right]\right) \quad \Rightarrow \\ F_{\nu,c}(t, T, \tau) &= \frac{R_{\nu,c}(t, \tau)\left[\tau - t\right] - R_{\nu,c}(t, T)\left[T - t\right]}{\tau - T} \\ &= R_{\nu,c}(t, \tau) + \frac{R_{\nu,c}(t, \tau) - R_{\nu,c}(t, T)}{\tau - T}\left[T - t\right], \quad \nu = n, r. \end{aligned} \tag{2.6}$$

It holds true that $F_v(t,t,T) = R_v(t,T)$. The instantaneous forward interest rate is obtained for a forward contract that expires in the same instant it has been initiated. Using the above equation, we obtain the following relationship:

$$\begin{aligned} f_{\nu,c}(t, T) &= F_{\nu,c}(t, T, T) \\ &= \lim_{\tau \downarrow T} F_{\nu,c}(t, T, \tau), \quad (\tau \geqq T) \\ &= \lim_{\tau \downarrow T} \left\{R_{\nu,c}(t, \tau) + \frac{R_{\nu,c}(t, \tau) - R_{\nu,c}(t, T)}{\tau - T}\left[T - t\right]\right\} \\ &= R_{\nu,c}(t, T) + \frac{\partial R_{\nu,c}(t, T)}{\partial T}\left[T - t\right], \quad \nu = n, r. \end{aligned} \tag{2.7}$$

It holds true that $f_v(t,t) = R_v(t,t) = r_v(t)$, because we have assumed that the first derivative of the pure discount bond price with respect to time exists and is bounded for any lifetime of the bond. Integration by parts of the above equation leads to the well known relationship that the spot interest rate is equal to the integral of the instantaneous forward interest rate divided by the corresponding period of time:

$$\int_{\tau=t}^{\tau=T} f_{\nu,c}(t, \tau)\, \mathrm{d}\tau = R_{\nu,c}(t, T)\left[T - t\right], \quad \nu = n, r. \tag{2.8}$$

Substituting the above equation into equation (2.1), it follows that the spot price of a pure discount bond can be written in terms of the instantaneous forward interest rate:

$$P_\nu(t, T) = \exp\left(-R_{\nu,c}(t, T)\left[T - t\right]\right) = \exp\left(-\int_{\tau=t}^{\tau=T} f_{\nu,c}(t, \tau)\, \mathrm{d}\tau\right), \quad \nu = n, r. \tag{2.9}$$

Differentiation of the logarithm of the above equation with respect to the maturity date leads to the following relationship for the instantaneous forward interest rate:

$$f_{\nu,c}(t, T) = -\frac{\partial \ln\left(P_\nu(t, T)\right)}{\partial T} = -\frac{\dfrac{\partial P_\nu(t, T)}{\partial T}}{P_\nu(t, T)}, \quad \nu = n, r. \tag{2.10}$$

If the price of a pure discount bond is given in a functional form, then the above equation can be used to determine the whole term structure of the instantaneous forward interest rate.

2.2 Inflation rates

We define the spot and forward inflation rates in an analogous way to the interest rates. Although we are dealing now with random variables, it turns out that all the previous relationships for the interest rates carry over to the various inflation rates. Let $P_y(t, T)$ denote the purchasing power of money at the future date T in nominal terms at current prices as seen from date t, and let $p(t)$ denote the consumer price level at date t, then we define the spot inflation rate, $R_{y,c}(t, T)$, and the instantaneous forward inflation rate, $f_{y,c}(t, \tau)$, as follows:

$$P_y(t, T) \equiv \frac{p(t)}{p(T)} = \exp(-R_{y,c}(t, T)[T-t]) = \exp\left(-\int_{\tau=t}^{\tau=T} f_{y,c}(t, \tau)\,\mathrm{d}\tau\right), \quad t \leqq T. \tag{2.11}$$

Since the future consumer price level $p(T)$ is a random variable, both the spot inflation rate, $R_{y,c}(t, T)$, and the instantaneous forward inflation rate, $f_{y,c}(t, \tau)$, are random variables, too. Taking the logarithm of the above equation, the spot inflation rate becomes

$$R_{y,c}(t, T) = -\frac{\ln(P_y(t, T))}{T-t} = \frac{\ln(p(T)) - \ln(p(t))}{T-t} \tag{2.12}$$

The instantaneous spot inflation rate, denoted as $r_{y,c}(t)$, is equal to the spot inflation rate with a vanishing time horizon, which turns out - as it should - to be equal to the relative change of the consumer price level.

$$r_{y,c}(t) \equiv R_{y,c}(t, t) = \lim_{t \leftarrow T}\left\{\frac{\ln(p(T)) - \ln(p(t))}{T-t}\right\} = \frac{\left(\frac{\mathrm{d}p(t)}{\mathrm{d}t}\right)}{p(t)} \tag{2.13}$$

In the general equilibrium framework of Bakshi and Chen (1996), the instantaneous spot inflation rate, $r_{y,c}(t)$, consists of a random drift and a volatility term, both driven by macroeconomic variables. The same structure has been assumed by CIR (1985b).

The $(\tau-T)$-year forward inflation rate, denoted as $F_y(t, T, \tau)$, corresponds to a $(\tau-T)$-year forward purchasing power of money, denoted as $\mathcal{P}_y(t, T, \tau)$, at date τ at prices of the earlier date T as seen from date t ($\tau \geqq T \geqq t$). By definition, $\mathcal{P}_y(t, T, \tau) \equiv p(T) / p(\tau)$:

$$\mathcal{P}_y(t, T, \tau) = \frac{p(T)}{p(\tau)} \equiv \exp(-F_{y,c}(t, T, \tau)[\tau - T]), \quad (t \leqq T \leqq \tau) \tag{2.14}$$

Solving for the forward interest rate yields the following expression:

$$F_{y,c}(t, T, \tau) = -\frac{\ln(\mathcal{P}_y(t, T, \tau))}{\tau - T} = \frac{\ln(p(\tau)) - \ln(p(T))}{\tau - T} \tag{2.15}$$

By definition, the purchasing power of money at the future date τ is equal to the purchasing power of money at an intermediate date T multiplied by the $(\tau-T)$-year forward purchasing power of money. This leads to the following relationship for the $(\tau-T)$-year forward inflation rate:

$$\begin{aligned}
P_y(t, \tau) &= P_y(t, T)\,\mathcal{P}_y(t, T, \tau), \quad (t \leqq T \leqq \tau) \quad \Rightarrow \\
\exp(-R_{y,c}(t, \tau)[\tau - t]) &= \exp(-R_{y,c}(t, T)[T-t])\exp(-F_{y,c}(t, T, \tau)[\tau - T]) \quad \Rightarrow \\
F_{y,c}(t, T, \tau) &= \frac{R_{y,c}(t, \tau)[\tau - t] - R_{y,c}(t, T)[T-t]}{\tau - T} \\
&= R_{y,c}(t, \tau) + \frac{R_{y,c}(t, \tau) - R_{y,c}(t, T)}{\tau - T}[T-t]
\end{aligned} \tag{2.16}$$

It holds true that $F_y(t,t,T) = R_y(t,T)$. The instantaneous forward inflation rate is obtained for a vanishing time horizon. Using the above equation, we obtain the following relationship:

$$\begin{aligned} f_{y,c}(t,T) &= F_{y,c}(t,T,T) \\ &= \lim_{\tau \downarrow T} F_{y,c}(t,T,\tau), \quad (\tau \geqq T) \\ &= \lim_{\tau \downarrow T} \left\{ R_{y,c}(t,\tau) + \frac{R_{y,c}(t,\tau) - R_{y,c}(t,T)}{\tau - T} [T-t] \right\} \\ &= R_{y,c}(t,T) + \frac{\mathrm{d}R_{y,c}(t,T)}{\mathrm{d}T} [T-t] \end{aligned} \tag{2.17}$$

It holds true that $f_y(t,t) = R_y(t,t) = r_y(t)$. Integration by parts of the above equation leads to the result that the spot inflation rate is equal to the integral of the instantaneous forward inflation rate divided by the corresponding period of time, which, in turn, is equal to the logarithm of the purchasing power of money.

$$\int_{\tau=t}^{\tau=T} f_{y,c}(t,\tau)\,\mathrm{d}\tau = R_{y,c}(t,T)[T-t] = \ln(p(T)) - \ln(p(t)) \tag{2.18}$$

Hence, we return to the starting definition of equation (2.11). Differentiating the integral on the left-hand side with respect to the "maturity" date T for a fixed date t, we obtain the result that the instantaneous forward inflation rate is equal to the instantaneous spot inflation rate at the future date T.

$$f_{y,c}(t,T) = R_{y,c}(t,T) + \frac{\mathrm{d}R_{y,c}(t,T)}{\mathrm{d}T}[T-t] = \frac{\left(\frac{\mathrm{d}p(T)}{\mathrm{d}T}\right)}{p(T)} = r_{y,c}(T), \quad t \leqq T. \tag{2.19}$$

By this result, we can extend the starting definition (2.11) by the integral of the instantaneous spot inflation rate. Again, it holds true that $f_y(t,t) = r_y(t)$.

In view of Fisher's hypothesis, we need to determine the expected value of the spot inflation rate. Let $\mathscr{E}_t$ denote the expectation operator given the information at date t, then we obtain from the above equation

$$\mathscr{E}_t f_{y,c}(t,\tau) = \mathscr{E}_t r_{y,c}(\tau) = \mathscr{E}_t \left[\frac{\left(\frac{\mathrm{d}p(\tau)}{\mathrm{d}\tau}\right)}{p(\tau)} \right], \quad t \leqq \tau. \tag{2.20}$$

and from equation (2.18)

$$\mathscr{E}_t R_{y,c}(t,T)[T-t] = \int_{\tau=t}^{\tau=T} \mathscr{E}_t f_{y,c}(t,\tau)\,\mathrm{d}\tau = \mathscr{E}_t \ln\left(\frac{p(T)}{p(t)}\right) = -\mathscr{E}_t \ln(P_y(t,T)) \tag{2.21}$$

where we have assumed that the integral of the expectation of the instantaneous forward inflation rate remains finite. Then we can reverse the order of the expectation and the time integral by Fubini's theorem (Duffie (1992)). Hence, we can calculate the expected value of the spot inflation rate, $\mathscr{E}_t R_{y,c}(t,T)$, from equations (2.21) and (2.20), given the expected values of the instantaneous spot inflation rate, $\mathscr{E}_t r_{y,c}(\tau)$, $(T \geqq \tau \geqq t)$.

2.3 Interest premium

Let the interest premium be denoted as $\eta_k(t,T)$, then the relationship between nominal and real interest rates can be written as

$$R_{n,k}(t,T) = R_{r,k}(t,T) + \mathscr{E}_t R_{y,k}(t,T) - \eta_k(t,T), \quad k = m, c. \tag{2.22}$$

The above equation is Fisher's hypothesis in an uncertain world (Stanley Fischer (1975)). In the CIR framework, the interest premium consists of two terms, the variance of the future consumer price level and a term which we call the wealth premium. The latter depends both on the investor's attitude towards risk, as measured by the relative risk aversion, and on the covariance between future real wealth and future inflation, which may have either sign. Hence the interest premium may have either sign, too. If investors expect to gain real wealth from future inflation, then this covariance will be positive. In this case, investors do not ask for a full compensation of the expected spot inflation rate. On the other hand, if investors expect to lose real wealth from future inflation, then this covariance will be negative. In this case, they may ask for compensation in excess of the expected spot inflation rate.

3. The CIR model

In view of Fisher's hypothesis, the nominal yield curve contains information on real interest rates, expected inflation rates and the interest premium at least. As long as there are no indexed bonds issued in the country under consideration, we must rely on an economic model which is able to explain simultaneously nominal and real interest rates. To my knowledge, there are two candidate models to be used, the one proposed by Cox, Ingersoll and Ross (1985a & b) on the one hand, and the one by Bakshi and Chen (1996) on the other hand. We choose the CIR model for the sake of tractability. The CIR model is a three-factor model of the nominal yield curve, the factors or state variables being the real instantaneous spot interest rate, the expected instantaneous spot inflation rate and the consumer price level.

To be specific, CIR propose two competitive models to explain nominal and real interest rates. Again, we choose the simpler one, which is their model 2. In equilibrium, the real instantaneous spot interest rate is given by the following square-root process:

$$\mathrm{d}r_{r,c}(t) = \kappa\left[\theta - r_{r,c}(t)\right]\mathrm{d}t + \sigma\sqrt{r_{r,c}(t)}\,\mathrm{d}z_1(t)\,, \quad 0 < \kappa, \theta, \sigma < \infty \tag{3.1}$$

The above process corresponds to a continuous time first-order autoregressive process where the randomly moving interest rate is elastically pulled towards a long-term equilibrium value, θ. The parameter κ determines the speed of adjustment, and σ denotes the constant volatility parameter, and z_1 a Gauss-Wiener process. With the square-root process, the *real* instantaneous spot interest rate remains non-negative. By means of their fundamental partial differential equation, CIR derive the price of a *real* pure discount bond in *real* terms as follows:

$$P_r\left(t, T \mid r_{r,c}(t)\right) = A(t, T)^{\psi} \exp\left(-B(t, T)\, r_{r,c}(t)\right), \text{ where}$$

$$\begin{aligned} A(t, T) &= \frac{2\,\gamma \exp\left(\dfrac{[\kappa + \lambda + \gamma][T - t]}{2}\right)}{[\kappa + \lambda + \gamma]\left[\exp(\gamma[T - t]) - 1\right] + 2\,\gamma} \\ B(t, T) &= \frac{2\left[\exp(\gamma[T - t]) - 1\right]}{[\kappa + \lambda + \gamma]\left[\exp(\gamma[T - t]) - 1\right] + 2\,\gamma} \\ \gamma &= \sqrt{[\kappa + \lambda]^2 + 2\,\sigma^2}\,, \quad \psi = \frac{2\,\kappa\,\theta}{\sigma^2} \end{aligned} \tag{3.2}$$

The parameter λ denotes the factor risk premium, a negative number in the CIR framework. The payoff of the real pure discount bond in real terms is equal to one unit of consumption goods, ie $P_r(T, T) = 1$.

Let $\bar{r}_{y,c}(t)$ denote the drift of the instantaneous spot inflation rate or the "expected" instantaneous spot inflation rate, respectively, at date t. CIR propose the following two random paths for the "expected" instantaneous spot inflation rate and the consumer price level to be tested empirically:

$$\begin{aligned} \mathrm{d}\bar{r}_{y,c}(t) &= \kappa_2\left[\theta_2 - \bar{r}_{y,c}(t)\right]\mathrm{d}t + \sigma_2\sqrt{\bar{r}_{y,c}(t)}\,\mathrm{d}z_2(t)\,, \quad 0 < \kappa_2, \theta_2, \sigma_2 < \infty\,, \\ r_{y,c}(t)\,\mathrm{d}t &= \frac{\mathrm{d}p(t)}{p(t)} = \bar{r}_{y,c}(t)\,\mathrm{d}t + \sigma_p\sqrt{\bar{r}_{y,c}(t)}\,\mathrm{d}z_3(t)\,, \quad 0 < \sigma_p < 1\,, \\ \mathscr{C}_t\left\{\mathrm{d}\bar{r}_{y,c}(t), \mathrm{d}p(t)\right\} &= \rho\,\sigma_2\,\sigma_p\,\bar{r}_{y,c}(t)\,p(t)\,\mathrm{d}t\,. \end{aligned} \tag{3.3}$$

where $\mathscr{C}$ denotes the covariance operator, ρ denotes the correlation coefficient between the Wiener processes z_2 and z_3, and all other variables have the same meaning as above. Note that $(1/\mathrm{d}\tau)\, \mathscr{C}_t \{\mathrm{d}p(\tau)/p(\tau)\} = \mathscr{E}_t\, r_{y,c}(\tau) = \mathscr{E}_t\, \bar{r}_{y,c}(\tau)$ for $\tau \geqq t$, and $\mathscr{E}_t\, r_{y,c}(t) = \bar{r}_{y,c}(\tau)$. Given $\mathscr{E}_t\, \bar{r}_{y,c}(\tau)$ for $T \geqq \tau \geqq t$, we can apply equations (2.20) and (2.21) to calculate the expected spot inflation rate $\mathscr{E}_t\, R_{y,c}(t,T)$. Cox, Ingersoll and Ross derive the following price of a nominal pure discount bond in nominal terms from their fundamental partial differential equation:

$$P_n\big(t, T \mid r_{r,c}(t), \bar{r}_{y,c}(t)\big) = P_r(t,T)\, C(t,T)^{\psi_2} \exp\big(-D(t,T)\, \bar{r}_{y,c}(t)\big)\text{, where}$$

$$\begin{aligned} C(t,T) &= \frac{2\,\xi \exp\left(\dfrac{[\kappa_2 + \rho\,\sigma_2\,\sigma_p + \xi][T-t]}{2}\right)}{[\kappa_2 + \rho\,\sigma_2\,\sigma_p + \xi]\big[\exp(\xi[T-t]) - 1\big] + 2\,\xi} \\ D(t,T) &= \frac{2\big[\exp(\xi[T-t]) - 1\big]\big[1 - \sigma_p^2\big]}{[\kappa_2 + \rho\,\sigma_2\,\sigma_p + \xi]\big[\exp(\xi[T-t]) - 1\big] + 2\,\xi} \\ \xi &= \sqrt{[\kappa_2 + \rho\,\sigma_2\,\sigma_p]^2 + 2\,\sigma_2^2\big[1 - \sigma_p^2\big]}\,, \quad \psi_2 = \frac{2\,\kappa_2\,\theta_2}{\sigma_2^2} \end{aligned} \tag{3.4}$$

where $P_r(t,T)$ denotes the price of a real discount bond given above. The payoff of the nominal pure discount bond in nominal terms is equal to one unit of money, ie $P_n(T,T) = 1$.

The nominal and real spot interest rates according to the CIR model 2 can be written by equation (2.2) as follows:

$$\begin{aligned} R_{r,c}(t,T) &= \frac{B(t,T)\, r_{r,c}(t) - \psi \ln\big(A(t,T)\big)}{T-t} \\ R_{n,c}(t,T) &= \frac{B(t,T)\, r_{r,c}(t) - \psi \ln\big(A(t,T)\big) - \psi_2 \ln\big(C(t,T)\big) + D(t,T)\, \bar{r}_{y,c}(t)}{T-t} \end{aligned} \tag{3.5}$$

Taking the limit as $T \to t$, we find for the nominal and real instantaneous spot interest rates by means of L'Hopital's rule:

$$\begin{aligned} R_{r,c}(t,t) &= r_{r,c}(t) \\ R_{n,c}(t,t) &= r_{n,c}(t) = r_{r,c}(t) + \big[1 - \sigma_p^2\big]\, \bar{r}_{y,c}(t) \end{aligned} \tag{3.6}$$

The last equation is Fisher's hypothesis (2.22) for instantaneous interest rates, where the instantaneous interest premium is given by $\eta_k(t,t) = \sigma_p^2 \bar{r}_{y,c}(t) = (1/\mathrm{d}t)\, \mathscr{V}_t \{\mathrm{d}p(t) / p(t)\} = \mathrm{d}t\, \mathscr{V}_t\, r_{y,c}(t)$. If there are no indexed bonds issued in the country under consideration, this equation allows you to calculate the real instantaneous spot interest rate; otherwise it determines the volatility parameter σ_p.

Before moving to the estimation of the CIR model, it may be appropriate to add a few remarks. The price of a nominal discount bond in *real* terms, $P_n(t,T) / p(t)$, at date t depends on the *observed* values of three factors or state variables, namely the real instantaneous spot interest rate, $r_{r,c}(t)$, the drift of the instantaneous spot inflation rate, $\bar{r}_{y,c}(\tau)$, and the consumer price level, $p(t)$. However, the price of a nominal discount bond in *nominal* terms, $P_n(t,T)$, as given in equation (3.4) does *not* depend on the consumer price level. In view of the empirical estimation, it is a great advantage of the CIR model that it provides a closed-form solution, which comes at the expense of some unrealistic features of the CIR model. First, there is no correlation between the real interest rate and the inflation rate, that is, monetary impulses are artificially superimposed on real shocks. Second, the inflation process of equation (3.3) does not allow for negative inflation rates (ie deflation rates). It is an empirical fact that moderate deflation rates could be observed for several industrial countries, for instance in the 1950s and 1990s. Third, the adjustment processes for the real instantaneous spot interest rate and the "expected" instantaneous spot inflation rate as given in equations (3.1) and (3.3) do not allow for the phenomenon of overshooting the long-run equilibrium value, nor for the phenomenon of oscillating around the long-run equilibrium value. Again, it is an empirical fact that both phenomena could be observed in the past. Despite these disadvantages, the nominal yield curve according to the CIR model as given in equation (3.5) may exhibit a wide variety of possible shapes, including the well known normal, inverse and humped shapes.

4. Estimation: pooled time-series and cross-section data

In view of the empirical estimation of the model parameters described in the previous section, we wish to use all the information contained in the CIR model. This may best be accomplished by considering pooled time-series and cross-section data. The pooled time-series and cross-section data will consist of a sample of the three stochastic processes for the real instantaneous spot interest rate, the expected instantaneous spot inflation rate and the consumer price level on the one hand as well as of a sample of the stochastic processes for a selected number of prices of nominal pure discount bonds in *real* terms on the other hand. The cross-section data refer to the term structure of the yield curve. (The first three processes mentioned above have, of course, a term of zero years.) The estimation procedure maximises the full information maximum likelihood function of the pooled time-series and cross-section sample subject to the constraint that the sample of theoretical discount bond prices fits the sample of observed discount bond prices as well as possible on the trading day under consideration.

Let us consider the stochastic processes for the discount bond prices first. Let $\Pi(\cdot)$ denote the price of a nominal pure discount bond in *real* terms, ie $\Pi(t,T) = P_n(t,T) \,/\, p(t)$. Applying Ito's lemma to equation (3.4), we derive the following stochastic differential equation for the price of a nominal pure discount bond in real terms:

$$\begin{aligned} d\Pi(\cdot) = {} & \left[1 - \lambda\, B(\cdot)\right] r_{r,c}(t)\, \Pi(\cdot)\, dt - B(\cdot)\, \Pi(\cdot)\, \sigma \sqrt{r_{r,c}(t)}\, dz_1(t) \\ & - D(\cdot)\, \Pi(\cdot)\, \sigma_2 \sqrt{\bar{r}_{y,c}(t)}\, dz_2(t) - \Pi(\cdot)\, \sigma_p \sqrt{\bar{r}_{y,c}(t)}\, dz_3(t) \end{aligned} \tag{4.1}$$

By this equation, the bond price change is driven by the three Wiener processes associated with the real instantaneous spot interest rate, the expected instantaneous spot inflation rate and the consumer price level as given in equations (3.1) and (3.3). The expressions for $\Pi(\cdot)$, $B(\cdot)$ and $D(\cdot)$ are given in equations (3.2) and (3.4).

Next, we consider discrete time steps Δt (which may be variable) and select H discount bonds with remaining life periods (terms) $\tau_j = T_j - t$, $j = 1, 2, \ldots, H$. In the estimation to follow, the terms of the bonds will vary between three and 26 years. Let $\Pi_{j,t}$ denote the bond price for term τ_j at date t, and similarly for B and D. Since we cannot expect that the CIR model perfectly fits the data, we introduce for each bond a new volatility as follows:

$$\begin{aligned} \Delta\Pi_{j,t} = {} & \left[1 - \lambda\, B_j\right] r_{r,c,t-1}\, \Pi_{j,t-1}\, \Delta t - B_j\, \Pi_{j,t-1}\, \sigma \sqrt{r_{r,c,t-1}}\, \Delta z_{1,t} - D_j\, \Pi_{j,t-1}\, \sigma_2 \sqrt{\bar{r}_{y,c,t-1}}\, \Delta z_{2,t} \\ & - \Pi_{j,t-1}\, \sigma_p \sqrt{\bar{r}_{y,c,t-1}}\, \Delta z_{3,t} + \sigma_0\, \Pi_{j,t-1}\, \Delta z_{3+j,t}, \quad j = 1, \ldots, H. \end{aligned} \tag{4.2}$$

where σ_0 is a new volatility parameter which is common to each bond selected. Note that we introduced H new Wiener processes, one for each bond selected, and that the expressions B and D depend on the various terms $\tau_j = T_j - t$, $j = 1, 2, \ldots, H$, but not on a particular date t.

Let $\Delta\mathbf{z}(t)$ denote the column vector of the $(3 + H)$ discrete Wiener processes. This vector has mean zero and the following $((3 + H) \times (3 + H))$ variance-covariance matrix $\mathbf{\Sigma}(t) = \mathcal{C}(\Delta\mathbf{z}(t), \Delta\mathbf{z}(t)) = \mathcal{E}\{\Delta\mathbf{z}(t)\, \Delta\mathbf{z}(t)'\} - \mathcal{E}\Delta\mathbf{z}(t)\, \{\mathcal{E}\Delta\mathbf{z}(t)\}'$.

$$\underset{((3+H)\times 1)}{\Delta \mathbf{z}(t)} = \left[\begin{array}{ccc:cccc} \Delta z_{1,t} & \Delta z_{2,t} & \Delta z_{3,t} & \Delta z_{4,t} & \cdots & \Delta z_{3+H,t} \end{array} \right]'$$

$$\underset{((3+H)\times(3+H))}{\mathbf{\Sigma}(t)} = \left[\begin{array}{ccc:cccc} \Delta t & 0 & 0 & 0 & \cdots & \cdots & 0 \\ 0 & \Delta t & \rho\,\Delta t & 0 & \cdots & \cdots & 0 \\ 0 & \rho\,\Delta t & \Delta t & 0 & \cdots & \cdots & 0 \\ \hdashline 0 & 0 & 0 & \Delta t & 0 & \cdots & 0 \\ \vdots & \vdots & \vdots & 0 & \ddots & \ddots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \ddots & \ddots & 0 \\ 0 & 0 & 0 & 0 & \cdots & 0 & \Delta t \end{array} \right] \tag{4.3}$$

By the properties of the Wiener process, the vector $\Delta \mathbf{z}(t)$ is normally distributed with mean zero and variance-covariance matrix $\mathbf{\Sigma}(t)$, that is,

$$\underset{((3+H)\times 1)}{\Delta \mathbf{z}(t)} \sim \mathcal{N}\left(\underset{((3+H)\times 1)}{\mathbf{0}}, \underset{((3+H)\times(3+H))}{\mathbf{\Sigma}(t)} \right) \tag{4.4}$$

where $\mathcal{N}(\cdot)$ denotes the Gaussian (normal) distribution.

Next, let $\Delta \mathbf{y}(t)$ denote the column vector of the $(3 + H)$ discrete, trend-adjusted increments of the variables considered, that is,

$$\underset{((3+H)\times 1)}{\Delta \mathbf{y}(t)} = \left[\begin{array}{c} \Delta r_{r,c,t} - \kappa\left[\theta - r_{r,c,t-1}\right]\Delta t \\ \Delta \bar{r}_{y,c,t} - \kappa_2\left[\theta_2 - \bar{r}_{y,c,t-1}\right]\Delta t \\ \Delta p_t - \bar{r}_{y,c,t-1}\, p_{t-1}\,\Delta t \\ \hdashline \Delta \Pi_{1,t} - \left[1 - \lambda\, B_1\right] r_{r,c,t-1}\, \Pi_{1,t-1}\,\Delta t \\ \Delta \Pi_{2,t} - \left[1 - \lambda\, B_2\right] r_{r,c,t-1}\, \Pi_{2,t-1}\,\Delta t \\ \vdots \\ \Delta \Pi_{H,t} - \left[1 - \lambda\, B_H\right] r_{r,c,t-1}\, \Pi_{H,t-1}\,\Delta t \end{array} \right] \tag{4.5}$$

Furthermore, let $\mathbf{G}(t)$ denote the $((3 + H) \times (3 + H))$ volatility matrix as follows:

$$\underset{((3+H)\times(3+H))}{\mathbf{G}(t)} = \left[\begin{array}{c:c} \underset{(3\times 3)}{\mathbf{G}_{11}(t)} & \underset{(3\times H)}{\mathbf{0}} \\ \hdashline \underset{(H\times 3)}{\mathbf{G}_{21}(t)} & \underset{(H\times H)}{\mathbf{G}_{22}(t)} \end{array} \right] \tag{4.6}$$

where the first (3 x 3) submatrix is defined as

$$\underset{(3\times 3)}{\mathbf{G}_{11}(t)} = \begin{bmatrix} \sigma\sqrt{r_{r,c,t-1}} & 0 & 0 \\ 0 & \sigma_2\sqrt{\bar{r}_{y,c,t-1}} & 0 \\ 0 & 0 & \sigma_p\, p_{t-1}\sqrt{\bar{r}_{y,c,t-1}} \end{bmatrix} \tag{4.6a}$$

the second (H x 3) submatrix as

$$\underset{(H\times 3)}{\mathbf{G}_{21}(t)} = \begin{bmatrix} -B_1\, \Pi_{1,t-1}\, \sigma\sqrt{r_{r,c,t-1}} & -D_1\, \Pi_{1,t-1}\, \sigma_2\sqrt{\bar{r}_{y,c,t-1}} & -\Pi_{1,t-1}\, \sigma_p\sqrt{\bar{r}_{y,c,t-1}} \\ -B_2\, \Pi_{2,t-1}\, \sigma\sqrt{r_{r,c,t-1}} & -D_2\, \Pi_{2,t-1}\, \sigma_2\sqrt{\bar{r}_{y,c,t-1}} & -\Pi_{2,t-1}\, \sigma_p\sqrt{\bar{r}_{y,c,t-1}} \\ \vdots & \vdots & \vdots \\ -B_H\, \Pi_{H,t-1}\, \sigma\sqrt{r_{r,c,t-1}} & -D_H\, \Pi_{H,t-1}\, \sigma_2\sqrt{\bar{r}_{y,c,t-1}} & -\Pi_{H,t-1}\, \sigma_p\sqrt{\bar{r}_{y,c,t-1}} \end{bmatrix} \tag{4.6b}$$

and the last (H x H) submatrix as

$$\underset{(H\times H)}{\mathbf{G}_{22}(t)} = \begin{bmatrix} \sigma_0\,\Pi_{1,t-1} & 0 & \cdots & 0 \\ 0 & \sigma_0\,\Pi_{2,t-1} & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & \sigma_0\,\Pi_{H,t-1} \end{bmatrix} \tag{4.6c}$$

Taking for the pre-period variables their realised (observed) values, the trend-adjusted increments are then normally distributed as follows (Goldberger (1964)):

$$\underset{((3+H)\times 1)}{\Delta\mathbf{y}(t)} = \underset{((3+H)\times(3+H))}{\mathbf{G}(t)}\ \underset{((3+H)\times 1)}{\Delta\mathbf{z}(t)} \sim \mathcal{N}\Big(\underset{((3+H)\times 1)}{\mathbf{0}}, \underset{((3+H)\times(3+H))}{\mathbf{S}(t)}\Big), \quad \mathbf{S}(t) = \mathbf{G}(t)\,\mathbf{\Sigma}(t)\,\mathbf{G}(t)' \tag{4.7}$$

If we had not introduced new volatility terms for the selected bonds, then the rank of the variance-covariance matrices $\mathbf{\Sigma}(t)$ and $\mathbf{S}(t)$ would be three at most, hence we could only estimate the processes for the real instantaneous spot interest rate, the drift of the instantaneous spot inflation rate and the consumer price level.

Our goal is to maximise the likelihood of a given sample of the vector of trend-adjusted increments $\Delta\mathbf{y}(t)$ for each date t. For computational ease, we wish to reduce the normal distribution as given in equation (4.7) to a standard multivariate normal distribution. This can be accomplished by the following transformation (Goldberger (1964)):

$$\underset{((3+H)\times 1)}{\Delta\mathbf{x}(t)} = \underset{((3+H)\times(3+H))}{\left(\mathbf{Q}(t)^{-1}\right)'}\ \underset{((3+H)\times 1)}{\Delta\mathbf{y}(t)} \sim \mathcal{N}\Big(\underset{((3+H)\times 1)}{\mathbf{0}}, \underset{((3+H)\times(3+H))}{\mathbf{I}}\Big), \quad \mathbf{S}(t) = \mathbf{Q}(t)'\,\mathbf{Q}(t) \tag{4.8}$$

where the ((3 + H) x (3 + H)) upper-triangle matrix $\mathbf{Q}(t)$ is the Cholesky decomposition of the variance-covariance matrix $\mathbf{S}(t)$ as shown in the equation above, and $\mathbf{I}$ denotes the identity matrix. The upper-triangle matrix, $\mathbf{Q}(t)$, and its inverse, $\mathbf{Q}(t)^{-1}$, can easily be computed recursively. The probability density function of the vector $\Delta\mathbf{y}(t)$ is then equal to the standard multivariate normal distribution for the vector $\Delta\mathbf{x}(t)$ divided by the absolute value of the determinant of the Jacobian of the above transformation (4.8), which is equal to the upper-triangle matrix $\mathbf{Q}(t)$. If the volatility matrix $\mathbf{G}(t)$ has full rank, then the variance-covariance matrix $\mathbf{S}(t)$ has full rank, too, and it is positive definite. Since the determinant of a positive definite matrix is positive, it follows that the determinant of the upper-triangle matrix $\mathbf{Q}(t)$ is also positive, that is,

$$|\mathbf{S}(t)| = |\mathbf{Q}(t)'\,\mathbf{Q}(t)| = |\mathbf{Q}(t)'|\,|\mathbf{Q}(t)| = |\mathbf{Q}(t)|^2 > 0 \quad \Rightarrow \quad |\mathbf{Q}(t)| = \sqrt{|\mathbf{S}(t)|} > 0 \tag{4.9}$$

where $|\mathbf{Q}(t)|$ denotes the determinant of $\mathbf{Q}(t)$. Note that, by the transformation (4.8), all the elements of the vector $\Delta\mathbf{x}(t)$ are independent of each other, that is, each element has a univariate standard normal distribution.

Denote the (10 x 1) column vector of the CIR model parameters as $\boldsymbol{\beta} = [\kappa, \theta, \sigma, \lambda, \kappa_2, \theta_2, \sigma_2, \sigma_p, \rho, \sigma_0]'$. Let $L(\Delta\mathbf{y}(t)\,|\,\boldsymbol{\beta})$ denote the logarithm of the likelihood of a given sample $\Delta\mathbf{y}(t)$ in terms of parameters $\boldsymbol{\beta}$. From equations (4.7) to (4.9), the logarithm of the likelihood function can be written as follows:

$$\begin{aligned} \mathcal{L}\{\Delta\mathbf{y}(t)\,|\,\boldsymbol{\beta}\} &= \ln\left(\frac{\prod_{j=1}^{3+H} \frac{1}{\sqrt{2\pi}} \exp\left(-\frac{\Delta x_j^2\{\Delta\mathbf{y}(t)\,|\,\boldsymbol{\beta}\}}{2}\right)}{|\mathbf{Q}(t)|}\right) \\ &= -\left[\frac{3+H}{2}\ln(2\pi) + \frac{1}{2}\sum_{j=1}^{3+H} \Delta x_j^2\{\Delta\mathbf{y}(t)\,|\,\boldsymbol{\beta}\} + \ln(|\mathbf{Q}(t)|)\right] \end{aligned} \tag{4.10}$$

Due to the transformation (4.8), the likelihood function is just the logarithm of the algebraic product of the univariate probability masses of the (3 + H) independent increments Δx_j divided by the determinant of the matrix $\mathbf{Q}(t)$.

Consider next the correlation between the trend-adjusted increments $\Delta\mathbf{y}$ at various dates. By the properties of the Wiener processes, these covariances become zero for any time period s greater than zero, that is,

$$\mathscr{C}\big(\Delta\mathbf{y}(t),\, \Delta\mathbf{y}(t+s)\big) = \mathscr{C}\big(\mathbf{G}(t)\,\Delta\mathbf{z}(t),\, \mathbf{G}(t+s)\,\Delta\mathbf{z}(t+s)\big) = \underset{((3+H)\times(3+H))}{\mathbf{0}}, \quad s > 0. \tag{4.11}$$

By the equation above, all the likelihood functions $\mathscr{L}(\Delta\mathbf{y}(t) \mid \boldsymbol{\beta})$ at different dates are independent of each other. Hence, the overall likelihood function is equal to the sum of the single logarithmic likelihood functions.

Finally, let $P_n^{\text{obs}}(s, T_k)$ denote the observed prices of the nominal pure discount bonds in nominal terms on the trading day under consideration, s, for various term dates T_k, $k = 1, \ldots, K$. These terms need not be the same as the terms considered in the selection of the various bond price processes of equation (4.2). The goal of the estimation is to maximise the overall likelihood function subject to the condition that the theoretical bond prices do not deviate from the bond prices observed on the trading day under consideration by more than a given tolerance ϵ, that is,

$$\begin{aligned} &\max_{\{\boldsymbol{\beta}\}} \sum_{t \leq s} \mathscr{L}(\Delta\mathbf{y}(t) \mid \boldsymbol{\beta}), \quad s \in \mathscr{S}, \quad \text{s. t.} \\ &-\epsilon_k \leq \left(\frac{P_n(s, T_k \mid \boldsymbol{\beta})}{P_n^{\text{obs}}(s, T_k)} - 1 \right) 100 \leq \epsilon_k, \quad k = 1, \ldots, K. \end{aligned} \tag{4.12}$$

where s denotes the actual trading day and $\mathscr{S}$ the set of trading days considered in the paper. Note that a different percentage tolerance may be given for each bond selected on the trading day for which we investigate the actual yield curve.

In this paper, we run the optimisation as given in equation (4.12) above for a sample of 40 trading days between 14 August 2000 and 14 May 2001. These 40 trading days are approximately weekly spaced. Hence, we obtain a set of 40 parameter vectors $\boldsymbol{\beta}$. The observed nominal discount bond prices are obtained from a set of observed coupon-bearing government bonds by means of the constrained optimisation described in the introduction above (Büttler (2000)). For each of the 40 trading days, we consider a sample of pooled time-series and cross-section data which starts at the beginning of February 1998, the earliest date for which bond data with the required information are available from our database. The number of nominal pure discount bonds selected for the cross-section data has been chosen to be five, that is, $H = 5$. Their terms vary between three and 26 years. The number of bonds selected for the constraints in equation (4.12) has been chosen to be 20, that is, $K = 20$. Their terms are equally spaced between zero years and the maximum term of the set of observed discount bond prices which define the actual yield curve on the trading day under consideration. Since indexed bonds are not traded in Switzerland, the time-series data of the real instantaneous spot interest rate have been calculated from equation (3.6); they depend on the parameter set, $\boldsymbol{\beta}$, however.

5. Results

The estimates of the parameters for the 40 trading days are depicted in Figure 1. Except for the speed of adjustment of the real instantaneous spot interest rate process, κ, the parameter estimates are quite stable over time. Note that the long-run equilibrium values, θ and θ_2, are related to their corresponding speeds of adjustment, κ and κ_2, respectively. For a speed of adjustment of zero, say, any long-run equilibrium value is compatible.

Given the estimated parameters, $\boldsymbol{\beta}$, for each trading day considered, the real yield curve, $R_r(t, T)$, has been calculated from equation (3.5). The 40 real yield curves and the 40 observed nominal yield curves are depicted in Figure 2. Although the nominal yield curves are upward-sloping (ie normal) or U-shaped, the real yield curves turn out to be upward-sloping during the first half of the sample period, but downward-sloping (ie inverse) during the second half of the sample period. Since downward-sloping real yield curves are puzzling in view of the falling trend of recent inflation rates, we checked whether we had encountered a local rather than a global maximum of the logarithmic likelihood function. Indeed, we found many local maxima of the logarithmic likelihood function, which result mostly in an *upward*-sloping real yield curve, and consequently in a *downward*-sloping term structure of expected spot inflation rates, but we could not find other maxima with greater function values than the ones reported here. We conclude, therefore, that the downward-sloping real yield curves result, most likely, from the assumptions of the CIR model, namely from the impossibility of the future expected inflation rate overshooting its long-run equilibrium value. Furthermore, the real instantaneous spot interest rate is not correlated with the drift of the instantaneous spot inflation rate in the CIR model.

In order to calculate the term structure of the expected spot inflation rates, $\mathscr{E}_t R_{y,c}(t,T)$, for a given trading date t, we need to know the expected instantaneous spot inflation rate, $\mathscr{E}_t r_{y,c}(\tau) = \mathscr{E}_t \bar{r}_{y,c}(\tau)$ for $T \geqq \tau \geqq t$, by equations (2.20) and (2.21). The future expected instantaneous spot inflation rate can be derived in three different ways at least. First, since the transition probability density function of the drift of the instantaneous spot inflation rate is given by the non-central chi square probability density function, the expected values of the drift of the instantaneous spot inflation rate can be calculated straightforwardly from this distribution (Cox et al (1985b)). Second, the drift of the instantaneous spot inflation rate at date t can be written as an integral over time of the respective process as given in equation (3.3). Taking the expectation on the one hand and differentiating the integral equation on the other hand yields a first-order ordinary differential equation for the expected instantaneous spot inflation rate (Duffie (1992)). Third, the discrete-time version of the stochastic differential equation of the drift of the instantaneous spot inflation rate as given in equation (3.3) leads to a stochastic finite difference equation. Taking the expectation on the one hand and the limit as the time step goes to zero on the other hand, the same ordinary differential equation as mentioned in the second way can be derived. Similarly, we derive the first-order ordinary differential equations for the variance and the covariance of the drift of the instantaneous spot inflation rate. The solutions of these three differential equations are given below.

$$\begin{aligned}
&\mathscr{E}_s \bar{r}_{y,c}(t) = \theta_2 + \left[\mathscr{E}_s \bar{r}_{y,c}(s) - \theta_2\right] e^{-\kappa_2 [t-s]}, \quad t \geqq s, \\
&\mathscr{V}_s \bar{r}_{y,c}(t) = \frac{\sigma_2^2\, \mathscr{E}_s \bar{r}_{y,c}(s)}{\kappa_2}\left[e^{-\kappa_2[t-s]} - e^{-2\kappa_2[t-s]}\right] + \frac{\sigma_2^2\, \theta_2}{2\,\kappa_2}\left[1 - e^{-\kappa_2[t-s]}\right]^2, \quad t \geqq s, \\
&\mathscr{C}_s\left(\bar{r}_{y,c}(t), \bar{r}_{y,c}(t+\tau)\right) = e^{-\kappa_2 \tau}\, \mathscr{V}_s \bar{r}_{y,c}(t), \quad \tau \geqq 0, \quad t \geqq s
\end{aligned} \tag{5.1}$$

where $\mathscr{V}$ denotes the variance operator. Note that t and s denote two arbitrary dates, whereas τ denotes a non-negative time period. As seen from date s, the initial value is equal to the realised value, that is, $\mathscr{E}_s \bar{r}_{y,c}(s) = \bar{r}_{y,c}(s)$. By the third equation above, the auto-covariances decline exponentially with the speed of adjustment and time. Using equations (5.1), (2.20) and (2.21), the expected value of the spot inflation rate becomes as follows:

$$\begin{aligned}
&\mathscr{E}_t R_{y,c}(t,T) = \theta_2 + \frac{\left[\mathscr{E}_t \bar{r}_{y,c}(t) - \theta_2\right]}{\kappa_2}\, \frac{\left[1 - e^{-\kappa_2[T-t]}\right]}{T-t}, \quad T \geqq t, \\
&\lim_{T\to\infty} \mathscr{E}_t R_{y,c}(t,T) = \theta_2, \quad \lim_{t\leftarrow T} \mathscr{E}_t R_{y,c}(t,T) = \mathscr{E}_t \bar{r}_{y,c}(t) = \bar{r}_{y,c}(t).
\end{aligned} \tag{5.2}$$

The term structures of the expected spot inflation rates, $\mathscr{E}_t R_{y,c}(t,T)$, for the 40 trading days considered are depicted in Figure 3. Note that the expected spot inflation rates with terms zero are equal to the realised drifts of the instantaneous spot inflation rates on the trading day considered. The overall picture suggests that the term structure of expected spot inflation rates is quite stable over time.

Next, we calculate the future expected three-month nominal spot interest rate over a future time horizon of four years from the estimated parameters. (We choose the three-month interest rate because three-month Libor is the operational target rate of the Swiss National Bank.) From equation (3.5), the expected three-month nominal spot interest rate is given by

$$\begin{aligned}
&\mathscr{E}_s R_{n,c}(t,T) = \frac{B(t,T)\, \mathscr{E}_s r_{r,c}(t) - \psi \ln\left[A(t,T)\right] - \psi_2 \ln\left[C(t,T)\right] + D(t,T)\, \mathscr{E}_s \bar{r}_{y,c}(t)}{T-t} \\
&t \geqq s, \quad T = t + \tfrac{1}{4}.
\end{aligned} \tag{5.3}$$

where the expected instantaneous spot inflation rate is given in equation (5.1). The expected real instantaneous spot interest rate is given below.

$$\begin{aligned}
&\mathscr{E}_s r_{r,c}(t) = \theta + \left[\mathscr{E}_s r_{r,c}(s) - \theta\right] e^{-\kappa[t-s]}, \quad t \geqq s, \quad \mathscr{E}_s r_{r,c}(s) = r_{r,c}(s), \\
&\mathscr{V}_s r_{r,c}(t) = \frac{\sigma^2\, \mathscr{E}_s r_{r,c}(s)}{\kappa}\left[e^{-\kappa[t-s]} - e^{-2\kappa[t-s]}\right] + \frac{\sigma^2\, \theta}{2\,\kappa}\left[1 - e^{-\kappa[t-s]}\right]^2, \quad t \geqq s, \\
&\mathscr{C}_s\left(r_{r,c}(t), r_{r,c}(t+\tau)\right) = e^{-\kappa \tau}\, \mathscr{V}_s r_{r,c}(t), \quad \tau \geqq 0, \quad t \geqq s.
\end{aligned} \tag{5.4}$$

We compare the future expected three-month nominal spot interest rate with the three-month nominal forward interest rate which we calculate from the *observed* nominal yield curve by equation (2.6). Apart from a risk premium, these two interest rates should exhibit the same forecasting profile over the future time horizon. This may be taken as a plausibility test of the CIR model. The sample of the 40 trading days considered is depicted in Figures 4a-4h. As you can see in these figures, the forecasting profiles are quite similar in most cases.

As another indirect test of the performance of the CIR model, we address the question of whether future expected three-month Libor, calculated from the estimated model parameters according to equation (5.3), is an unbiased estimator of future three-month Libor. Let $R^{obs}_{n,c}(t,T)$ denote the nominal spot interest rate which is observed at date t and which has a term of three months ($T-t = 1/4$ years), then the ordinary least-squares regressions are written as follows:

$$R^{obs}_{n,c}(t,T) = \alpha_0 + \alpha_1 \mathscr{E}_s R_{n,c}(t,T) + u(s), \quad s \in \mathscr{S}, \quad t > s, \quad T = t + \tfrac{1}{4}, \qquad t - s = 1, 7, 14, \ldots, 91 \text{ days.} \tag{5.5}$$

where again $\mathscr{S}$ denotes the set of the 40 trading dates considered. It is assumed that the disturbances, $u(s)$, are identically and independently distributed normal variates with a zero mean value and a constant variance. We consider 14 different time horizons of up to 91 days into the future. If expected three-month Libor is an unbiased estimator of future three-month Libor, then $\alpha_0 = 0$ and $\alpha_1 = 1$. The regression results are shown in Table 1 and depicted in Figures 5a-5d. For future time horizons of both one day and seven days, we accept the hypothesis that expected three-month Libor is an unbiased estimator of future three-month Libor. As one can see in Figures 5a-5d, the observations are clustered in a rather small range which is due to the small sample period. If we could consider a sample period of 10 years, say, then the observations would vary between 0 and 10%. Hence, it might be reasonable to argue that the 14 regressions would look different for a larger sample period. To account for this phenomenon, we rerun the 14 regressions subject to the condition that the coefficient of the constant term is equal to zero, that is, $\alpha_0 = 0$. The results of these restricted least-squares regressions are shown in Table 2 and depicted in Figures 5a-5d. For all 14 future time horizons considered, we now accept the hypothesis that expected three-month Libor is an unbiased estimator of future three-month Libor.

Finally, we compare the behaviour of the interest premium or inflation risk premium, respectively, between two monetary regimes. At the beginning of the year 2000, the Swiss National Bank switched from a concept of medium-term monetary targeting to a concept with inflation forecasts as a main indicator for guiding monetary policy decisions. The old monetary policy mentioned above was operated mainly by foreign exchange swaps, whereas the new concept relies on repurchase agreements (repos) with commercial banks for short terms of one day up to several weeks. By these operations, the Swiss National Bank keeps three-month Libor - its operational target rate - within a particular band. Due to the limited database, we cannot estimate the CIR model by the full information maximum likelihood (FIML) method described in this paper before 2000. For the period 1999-2001, however, we applied the CIR model to observed yield curves by means of a multi-objective goal attainment (MOGA) method described elsewhere (Büttler (2000)). The MOGA method does not use time-series data at all, because it only requires that the theoretical yield curve fits the actual yield curve observed on a particular trading day as well as possible, given two other objective functions. The parameters estimated by the MOGA method are less stable than those estimated by the FIML method. Furthermore, some estimates are associated with a local rather than a global maximum in terms of the likelihood function. Although the term structures of expected inflation rates estimated from the MOGA method may deviate considerably from those obtained from the FIML method, the interest premia are close to each other during the period from January to May 2001, given weekly spaced data. The difference in the interest premium between these two methods is depicted in Figure 6. The maximum difference in absolute value is 31 basis points. The interest premia obtained from the MOGA method for the period between 1999 and 2001 are depicted in Figure 7. As you can see, the interest premia for all the terms considered between zero and 25 years are declining over this period. Since the middle of 2001, they have been almost zero. This reduced risk may indicate that the new concept has further increased the credibility of Swiss monetary policy.

6. Conclusions

Applying the CIR model, we determine empirically the term structure of expected spot inflation rates and the term structure of real spot interest rates from the nominal yield curves of 40 consecutive weeks. The smooth evolution of these curves over the course of time suggests that the empirical estimation is quite stable. We find the puzzling result that half the real yield curves are upward-sloping, while the other half are downward-sloping, but all the expected inflation rate curves are upward-sloping. We attribute this phenomenon to the fact that the future expected inflation rate cannot overshoot its long-run equilibrium value in the CIR model. We test the performance of the CIR model indirectly in two ways. First, we compare the time profile of the future expected nominal three-month spot interest rate with that of the three-month nominal forward interest rate implied by the observed nominal yield curve on the trading day under consideration. This test is quite satisfactory. Second, we test whether expected three-month Libor, calculated from the estimated model parameters, is an unbiased estimator of future three-month Libor for 14 different time horizons of up to 91 days into the future. We accept this hypothesis for future time horizons of both one day and seven days. With a restriction on the coefficient of the constant term, however, we accept this hypothesis for all 14 future time horizons considered. Finally, we compare the behaviour of the interest premium or inflation risk premium, respectively, between two different monetary policy regimes. We find that the interest premium has vanished since the beginning of the year 2000, when the Swiss National Bank switched from a regime with medium-term monetary targeting to a concept with inflation forecasts as a main indicator for monetary policy decisions. This reduced risk may indicate that the new concept has further increased the credibility of Swiss monetary policy.

Appendix: list of variables, functions and symbols

Subscripts:

$x_{v,k}(\cdot)$	The first subscript of the variable x, $v = \{n, r, y\}$, denotes nominal values for $v = n$, real values for $v = r$, and values associated with the inflation rate for $v = y$. If necessary, we use a second subscript, $k = \{m, c\}$, which denotes the compounding frequency with the understanding that m denotes a compounding m times a year and c denotes the continuous compounding ($m \to \infty$).

Variables in Roman letters:

$A(t,T)$	See equation (3.2).
$B(t,T)$	See equation (3.2).
$C(t,T)$	See equation (3.4).
$D(t,T)$	See equation (3.4).
$F_v(t,T,\tau)$	$v = \{n, r\}$. The $(\tau - T)$-year forward interest rate corresponding to a forward contract on a pure discount bond with the agreement that the forward price is fixed at date t and paid at a later date T when the discount bond will be delivered. The discount bond matures at a later date τ ($\tau \geqq T \geqq t$). It holds true that $F_v(t,t,T) = R_v(t,T)$.
$F_y(t,T,\tau)$	The $(\tau - T)$-year forward inflation rate corresponding to future consumer price levels at future dates τ and T as seen from date t ($\tau \geqq T \geqq t$). It holds true that $F_y(t,t,T) = R_y(t,T)$.
$f_v(t,T)$	$\equiv F_v(t,T,T)$; $v = \{n, r\}$. The instantaneous forward interest rate corresponding to a forward contract on a pure discount bond with the agreement that the forward price is fixed at date t and paid at a later date T when the discount bond will be delivered. The discount bond matures at the same instant it is delivered. It holds true that $f_v(t,t) = r_v(t)$.
$f_y(t,T)$	$\equiv F_y(t,T,T)$. The instantaneous forward inflation rate corresponding to a consumer price level at the future date T as seen from date t ($T \geqq t$). It holds true that $f_y(t,t) = r_y(t)$.
$\mathbf{G}(t)$	Volatility matrix. See equation (4.6).
H	Number of bonds selected for the cross-section data. See equation (4.2).
$\mathbf{I}$	Identity matrix. See equation (4.8).
K	Number of bonds selected for the constraints. See equation (4.12).
$p(t)$	The price level of consumer goods or the cost of living index, respectively, at date t.
$P_v(t,T)$	$v = \{n, r\}$. The spot price of a pure discount bond, which is fixed and paid at the settlement date t. The debtor of the pure discount bond redeems one monetary unit when the bond matures at date T, but does not pay out any coupons during the bond's life.
$P_y(t,T)$	$\equiv p(t) \,/\, p(T)$, ($T \geqq t$). The purchasing power of money at the future date T in nominal terms at current prices as seen from date t.
$P_n^{\text{obs}}(s,T_k)$	Observed prices of the nominal pure discount bonds in nominal terms on the trading day under consideration, s, for various term dates T_k, $k = 1, \ldots, K$.
$\mathsf{P}_v(t,T,\tau)$	$v = \{n, r\}$. The $(\tau - T)$-year forward price of a forward contract on a pure discount bond with the agreement that the forward price is fixed at date t and paid at a later date T when the pure discount bond will be delivered. The pure discount bond matures at a later date τ ($\tau \geqq T \geqq t$). In this case, the forward price is equal to the futures price of a discount bond (see Hull (1997), p 95). It holds true that $\mathsf{P}_v(t,t,T) = P_v(t,T)$.
$\mathsf{P}_y(t,T,\tau)$	$\equiv p(T) \,/\, p(\tau)$. The $(\tau - T)$-year forward purchasing power of money at date τ at prices of the earlier date T as seen from date t ($\tau \geqq T \geqq t$). It holds true that $\mathsf{P}_y(t,t,T) = P_y(t,T)$.

$\mathbf{Q}(t)$	Upper-triangle matrix. See equation (4.8).
$R_v(t,T)$	$v = \{n, r\}$. The spot interest rate of a pure discount bond with its price fixed at date t and which matures at date T ($T \geqq t$). The spot interest rate is also denoted as the yield of the discount bond.
$R_{n,c}^{\text{obs}}(t,T)$	The nominal spot interest rate which is observed at date t and whose contract matures at date T.
$R_y(t,T)$	The spot inflation rate corresponding to a consumer price level at the future date T as seen from date t ($T \geqq t$).
$r_v(t)$	$\equiv R_v(t,t)$; $v = \{n, r\}$. The instantaneous spot interest rate of a pure discount bond with its price fixed at date t and which matures at the same instant.
$r_y(t)$	$\equiv R_y(t,t)$. The instantaneous spot inflation rate at date t.
$\bar{r}_y(t)$	The drift of the instantaneous spot inflation rate or the "expected" instantaneous spot inflation rate, respectively, at date t. $\mathcal{E}_t\, r_y(t) = \mathcal{E}_t\, \bar{r}_y(t) = \bar{r}_y(t)$.
$\mathbf{S}(t)$	Variance-covariance matrix. See equation (4.7).
$x_j(t)$	Transformed, trend-adjusted variables considered in the sample of pooled time-series and cross-section data, $j = 1, \ldots, 3 + H$. See equation (4.8).
$y_j(t)$	Trend-adjusted variables considered in the sample of pooled time-series and cross-section data, $j = 1, \ldots, 3 + H$. See equation (4.5).
$z_j(t)$	Wiener processes, $j = 1, \ldots, 3 + H$. A Wiener process has normally distributed increments with mean zero and variance dt. Any two increments at two different dates are independent. See equations (3.1), (3.3), (4.2) and (4.3).
$u(s)$	Disturbance on the trading day s in linear regression. See equation (5.5).

Variables in Greek letters:

α_0, α_1	Regression coefficients. See equation (5.5).
$\boldsymbol{\beta}$	$\equiv [\kappa, \theta, \sigma, \lambda, \kappa_2, \theta_2, \sigma_2, \sigma_p, \rho, \sigma_0]'$. Parameter vector to be estimated. See equation (4.10).
ψ	See equation (3.2).
ψ_2	See equation (3.4).
$\in$	Error tolerance. See equation (4.12).
γ	See equation (3.2).
η_k	$k = \{m, c\}$. The interest premium.
ξ	See equation (3.4).
κ	Speed of adjustment of the increments of the real instantaneous spot interest rate. See equation (3.1).
κ_2	Speed of adjustment of the increments of the instantaneous spot inflation rate. See equation (3.3).
λ	Factor risk premium. See equation (3.2).
$\Pi(t,T)$	$\equiv P_n(t,T)\ /\ p(t)$. The spot price of a pure nominal discount bond in real terms which is fixed and paid at the settlement date t.
ρ	Correlation coefficient. See equation (3.3).
σ	Volatility parameter of the increments of the real instantaneous spot interest rate. See equation (3.1).
σ_2	Volatility parameter of the increments of the instantaneous spot inflation rate. See equation (3.3).

σ_p	Volatility parameter of the increments of the consumer price level. See equation (3.3).
σ_0	Volatility parameter of the increments of the nominal discount bond prices in real terms. See equation (4.2).
$\mathbf{\Sigma}(t)$	Variance-covariance matrix. See equation (4.3).
θ	Long-run equilibrium value of the real instantaneous spot interest rate. See equation (3.1).
θ_2	Long-run equilibrium value of the instantaneous spot inflation rate. See equation (3.3).

Functions:

$\mathcal{N}(\mu, \mathbf{\Sigma})$	Gaussian or normal distribution with mean vector μ and variance-covariance matrix $\mathbf{\Sigma}$. For the (n x 1) column vector $\mathbf{x}$, the notation $\mathbf{x} \sim \mathcal{N}(\mu, \mathbf{\Sigma})$ means that $\mathbf{x}$ has normal distribution. The normal probability density function is given by $$f(\mathbf{x}) = [2\pi]^{-n/2} \, |\mathbf{\Sigma}|^{-1/2} \exp\left(-\tfrac{1}{2}[\mathbf{x}-\boldsymbol{\mu}]' \mathbf{\Sigma}^{-1} [\mathbf{x}-\boldsymbol{\mu}]\right).$$
$L(\mathbf{x} \mid \boldsymbol{\beta})$	Logarithm of the likelihood function for a given sample $\mathbf{x}$ in terms of parameters $\boldsymbol{\beta}$.
exp	$\equiv$ e. The exponential function.
ln	The natural logarithm.

Symbols:

$\mathcal{E}$	The expectation operator. For a variable x with probability density function $f(x)$, the expectation of x is defined as $\mathcal{E}x \equiv \int f(x)\,dx$.
$\mathcal{C}$	The covariance operator. For variables x and y, the covariance between x and y is defined as $\mathcal{C}(x,y) \equiv \mathcal{E}\{(x-\mathcal{E}x)\,(y-\mathcal{E}y)\}$.
$\mathcal{V}$	The variance operator. For a variable x, the variance is defined as $\mathcal{V}x \equiv \mathcal{E}\{(x-\mathcal{E}x)^2\}$.
$\lvert\cdot\rvert$	Determinant of a matrix.
$'$	Transposition mark of a vector or of a matrix.
Δ	Backward difference operator in discrete time, ie $\Delta x(t) = x(t) - x(t-1)$.
$\mathcal{S}$	The set of trading days or settlement days considered in the paper. The 40 trading days are approximately weekly spaced between 14 August 2000 and 14 May 2001.

Figure 1a: Parameter estimates

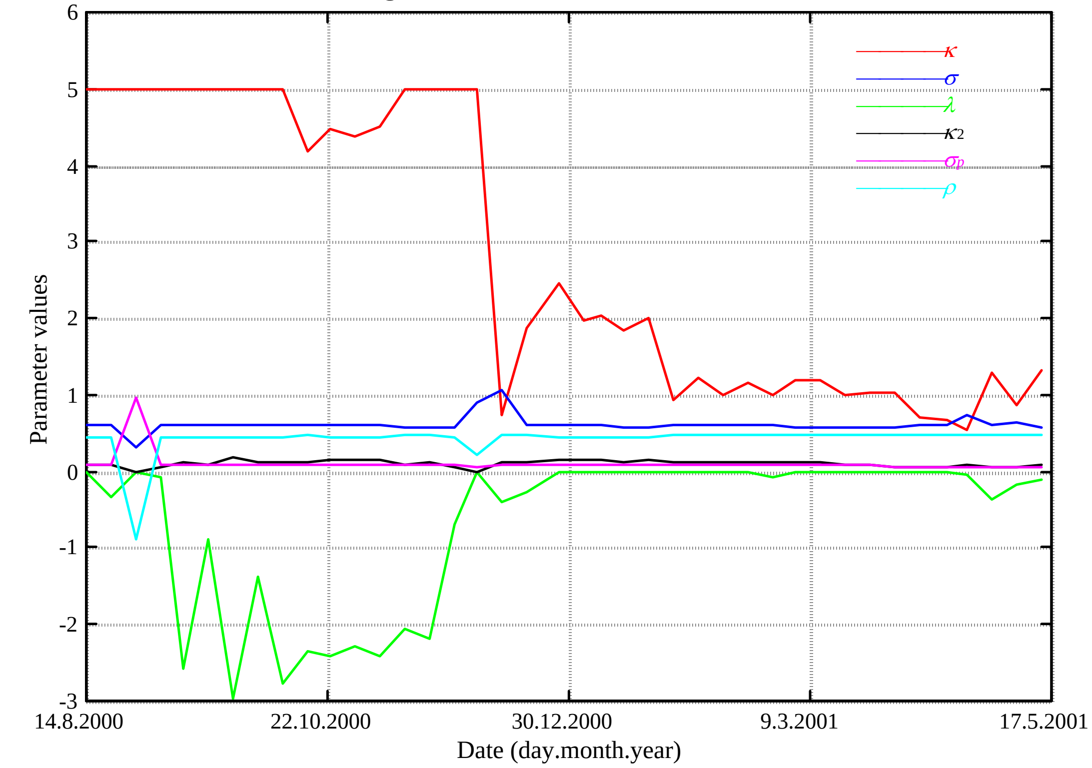


Figure 1b: Parameter estimates continued

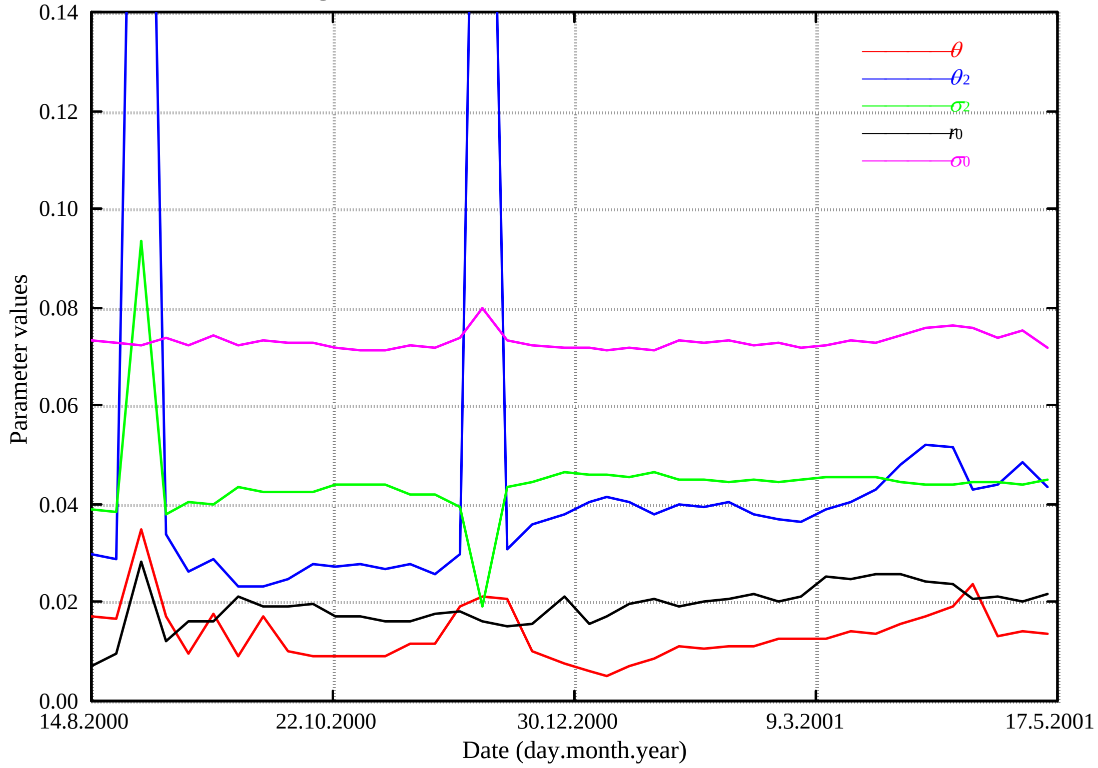


Figure 2: Nominal and real yield curves in percent per annum

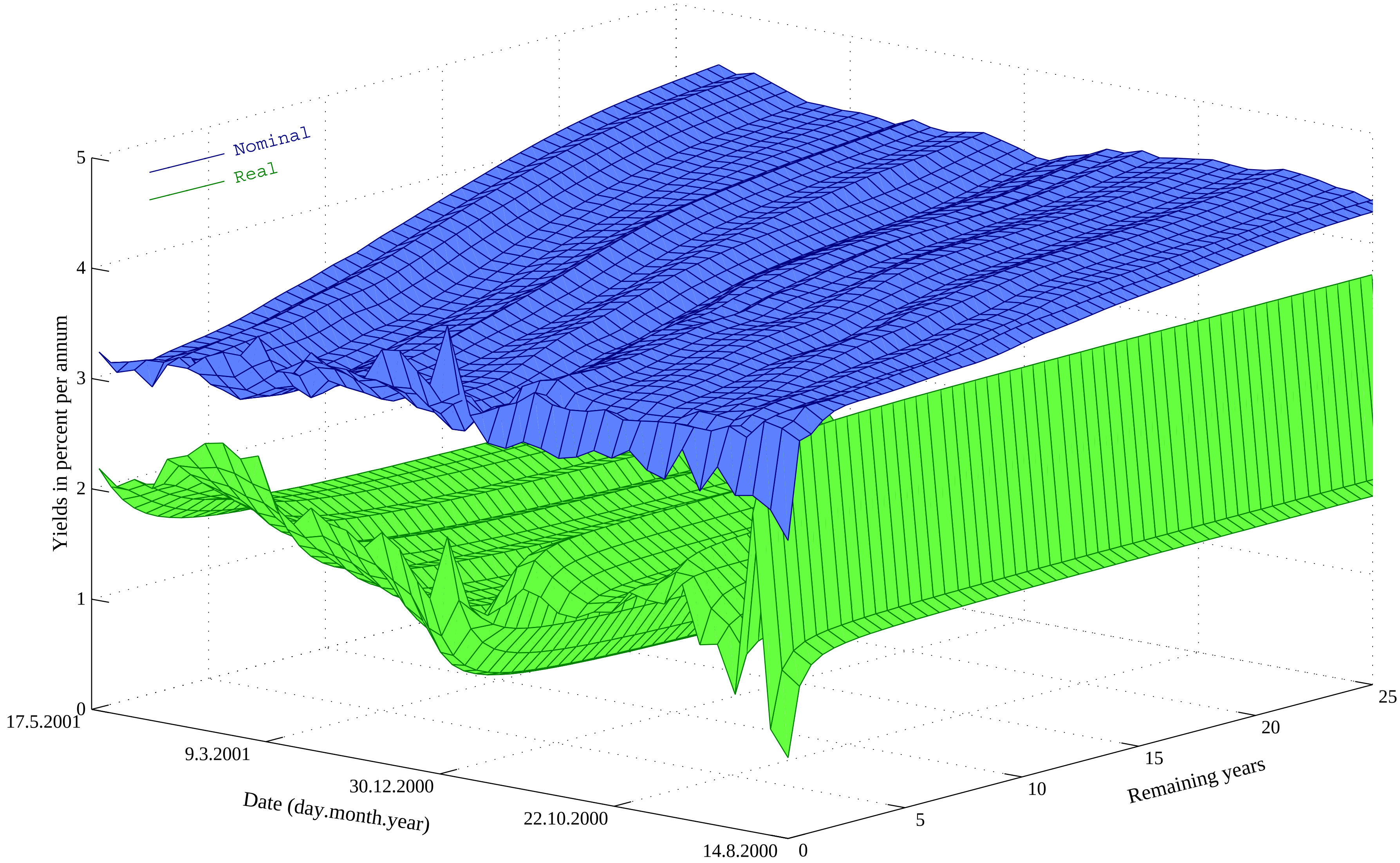


Figure 3: Expected spot inflation rates in percent per annum

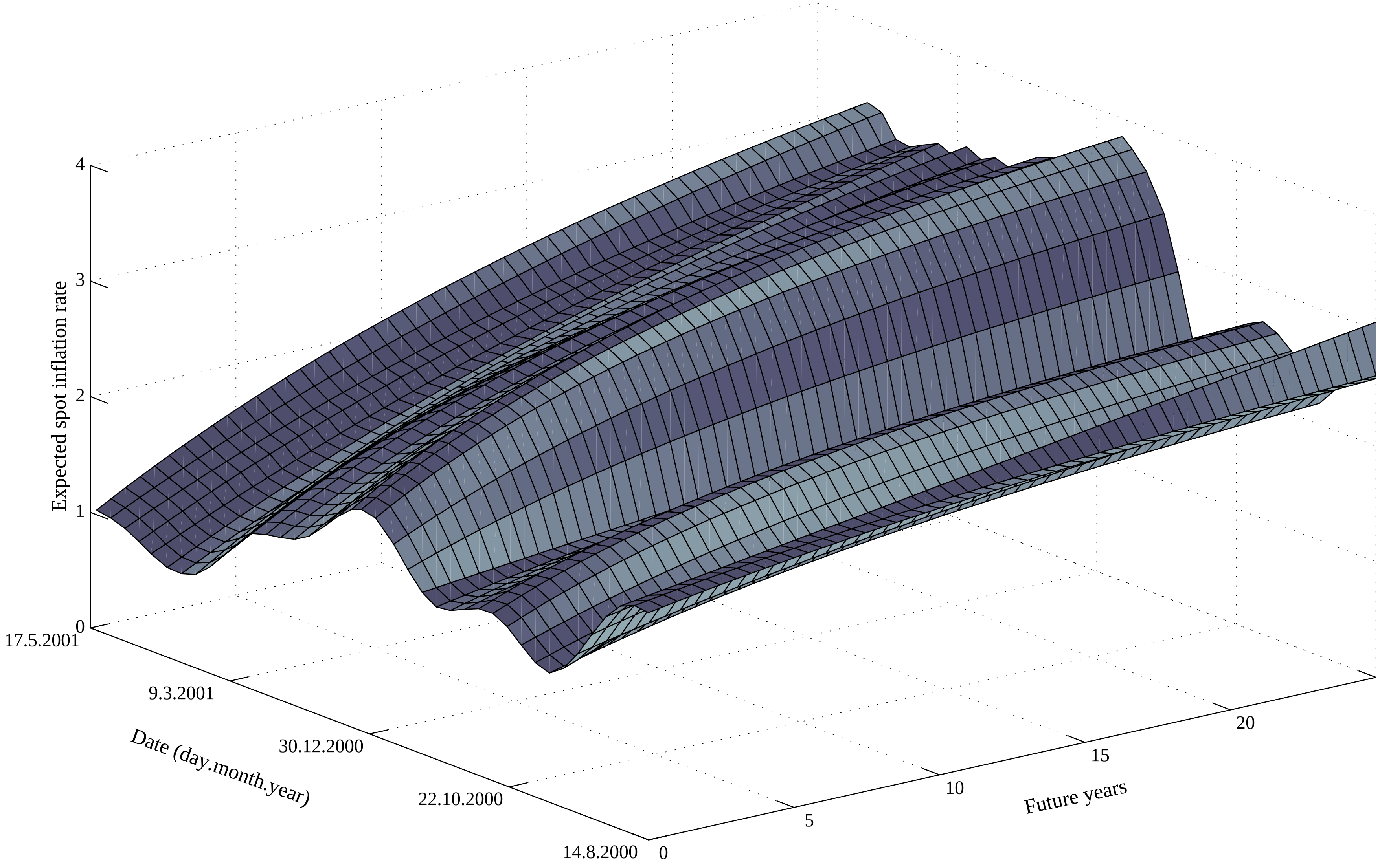


Figure 4a

Expected three-month spot interest rates in percentages per annum

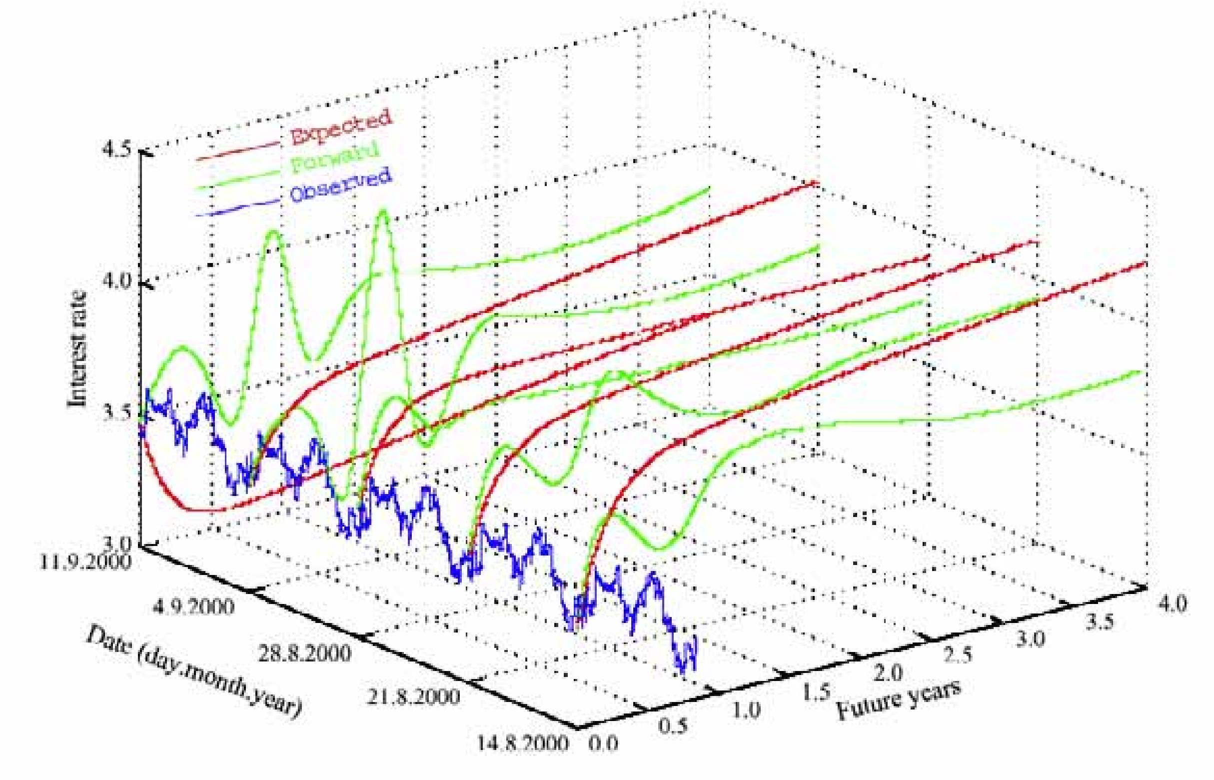


Figure 4b

Expected three-month spot interest rates in percentages per annum

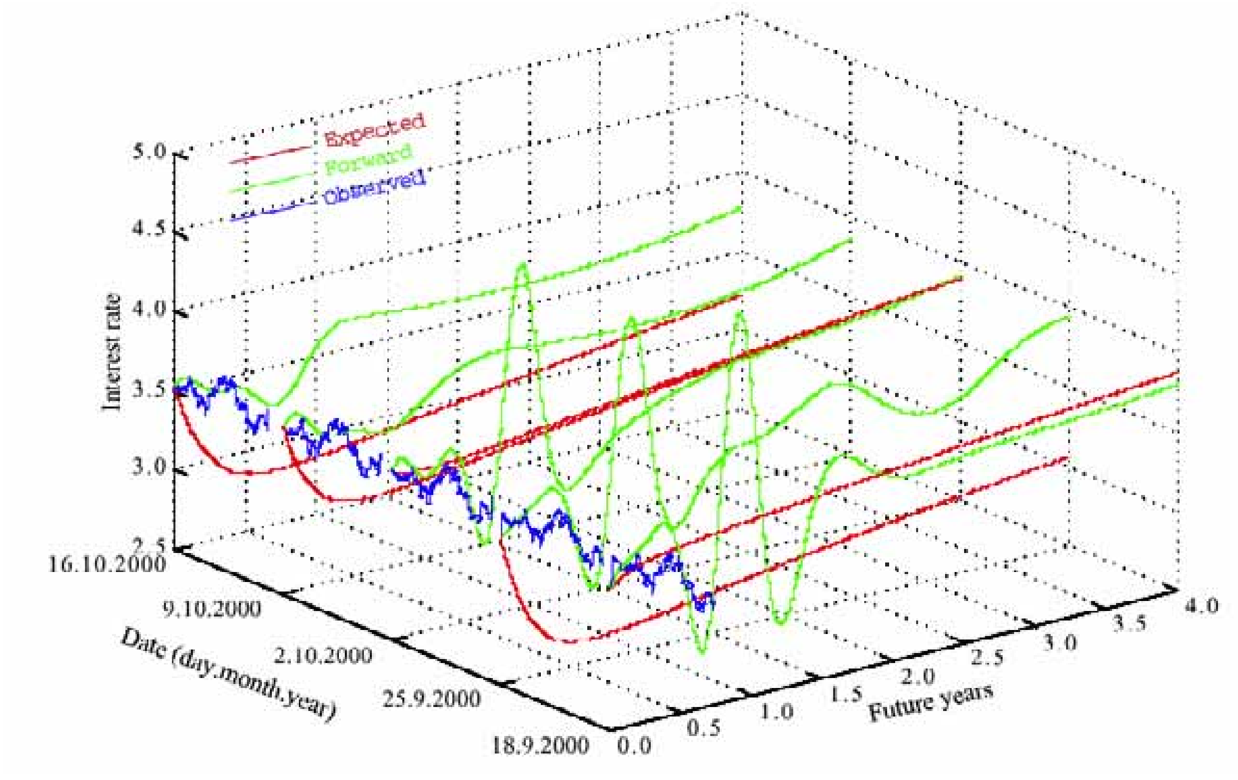


Figure 4c

Expected three-month spot interest rates in percentages per annum

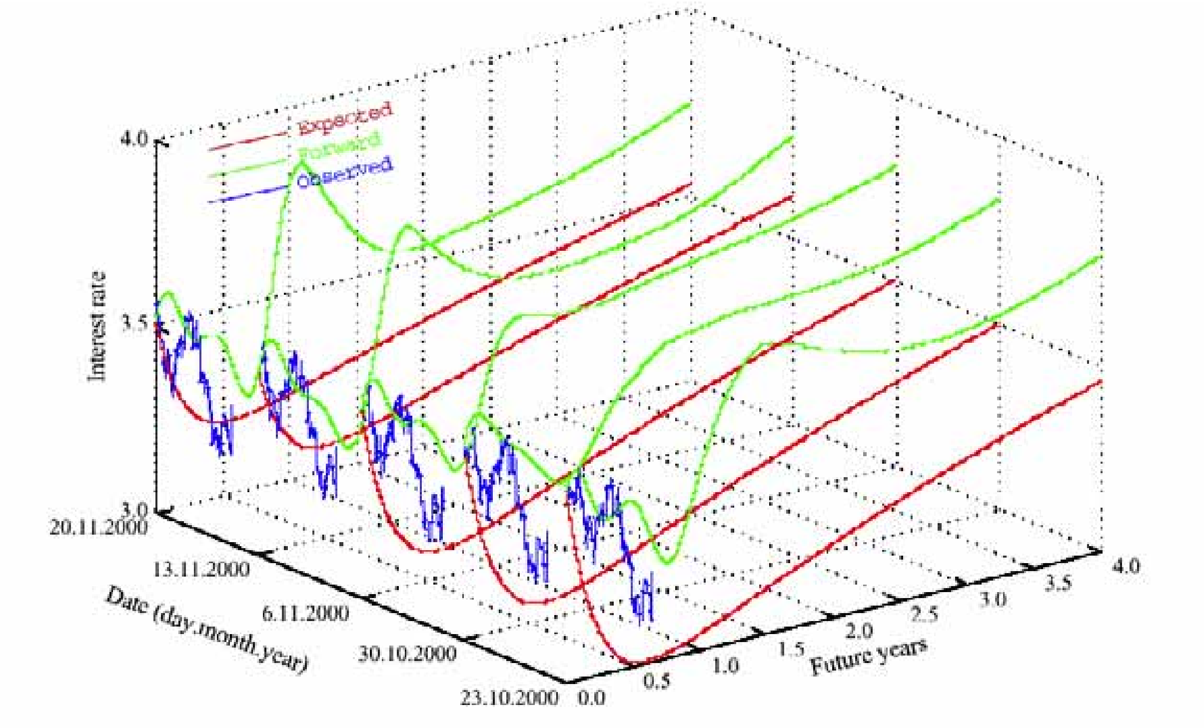


Figure 4d

Expected three-month spot interest rates in percentages per annum

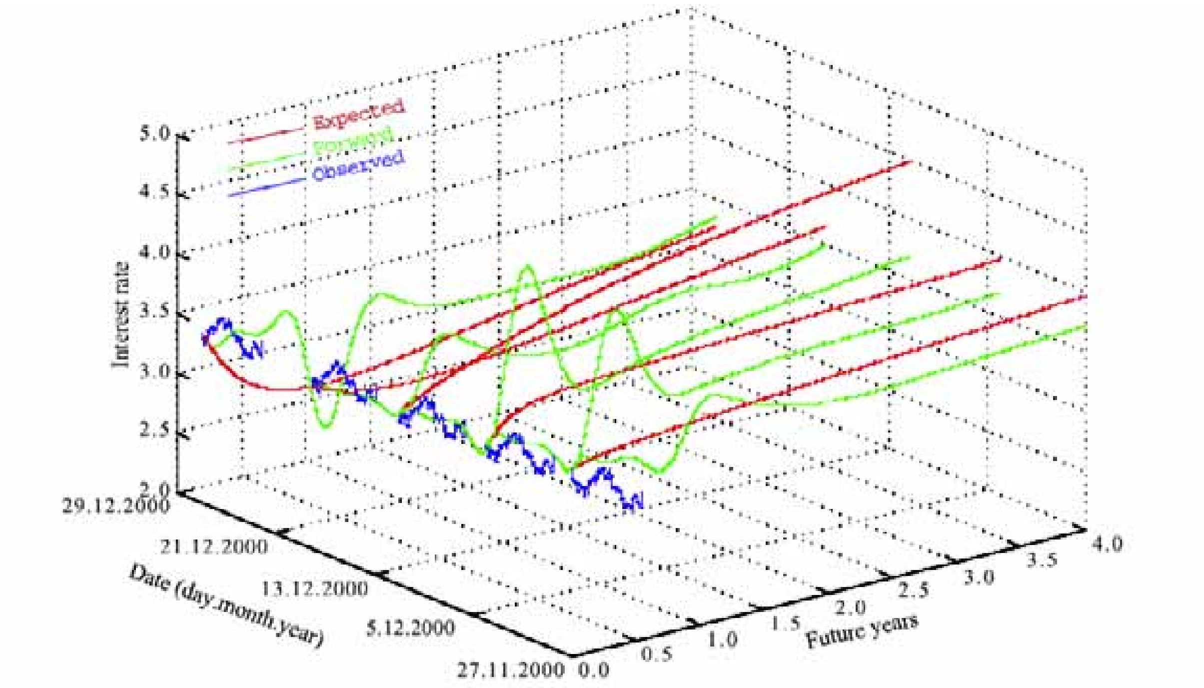


Figure 4e

Expected three-month spot interest rates in percentages per annum

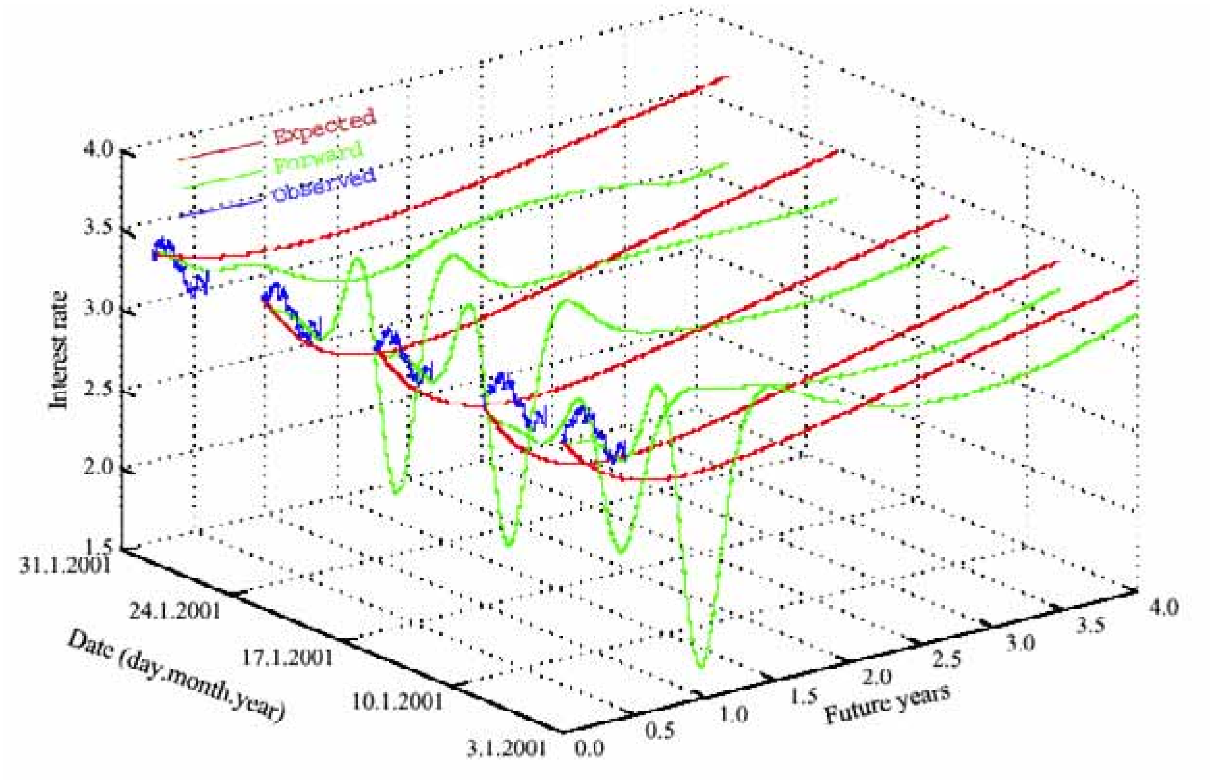


Figure 4f

Expected three-month spot interest rates in percentages per annum

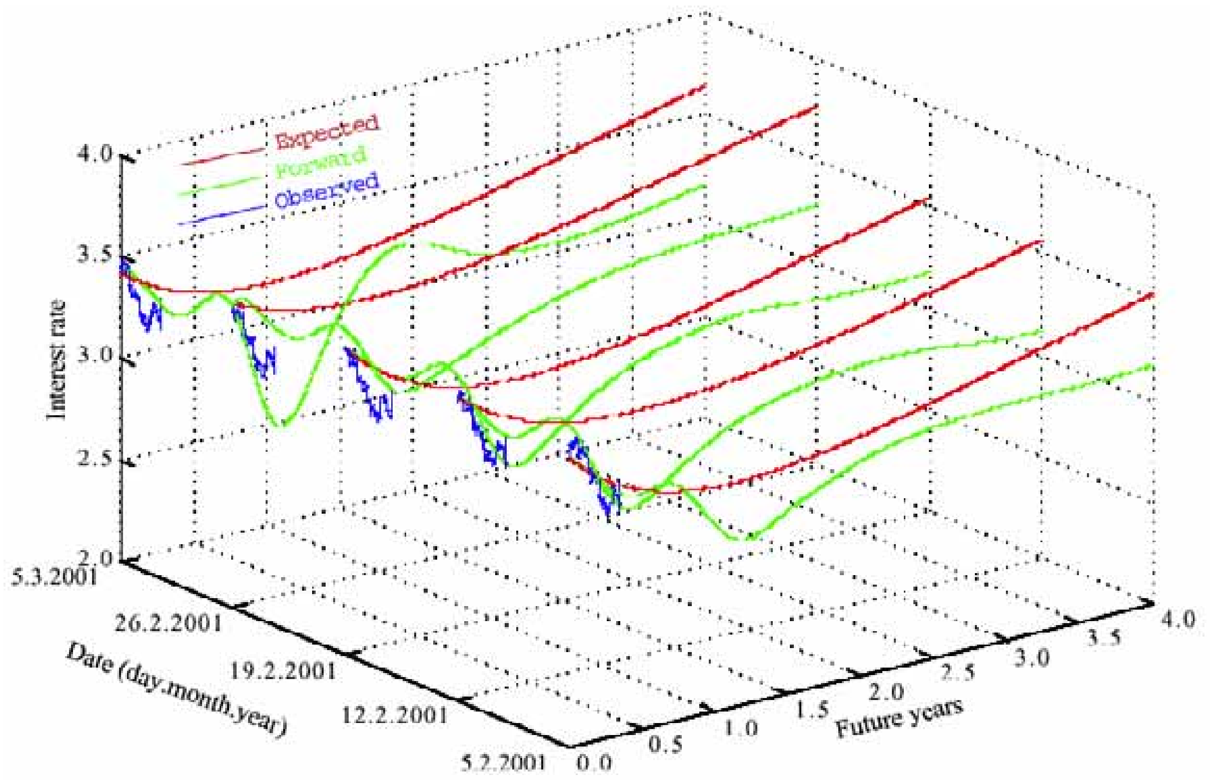


Figure 4g

Expected three-month spot interest rates in percentages per annum

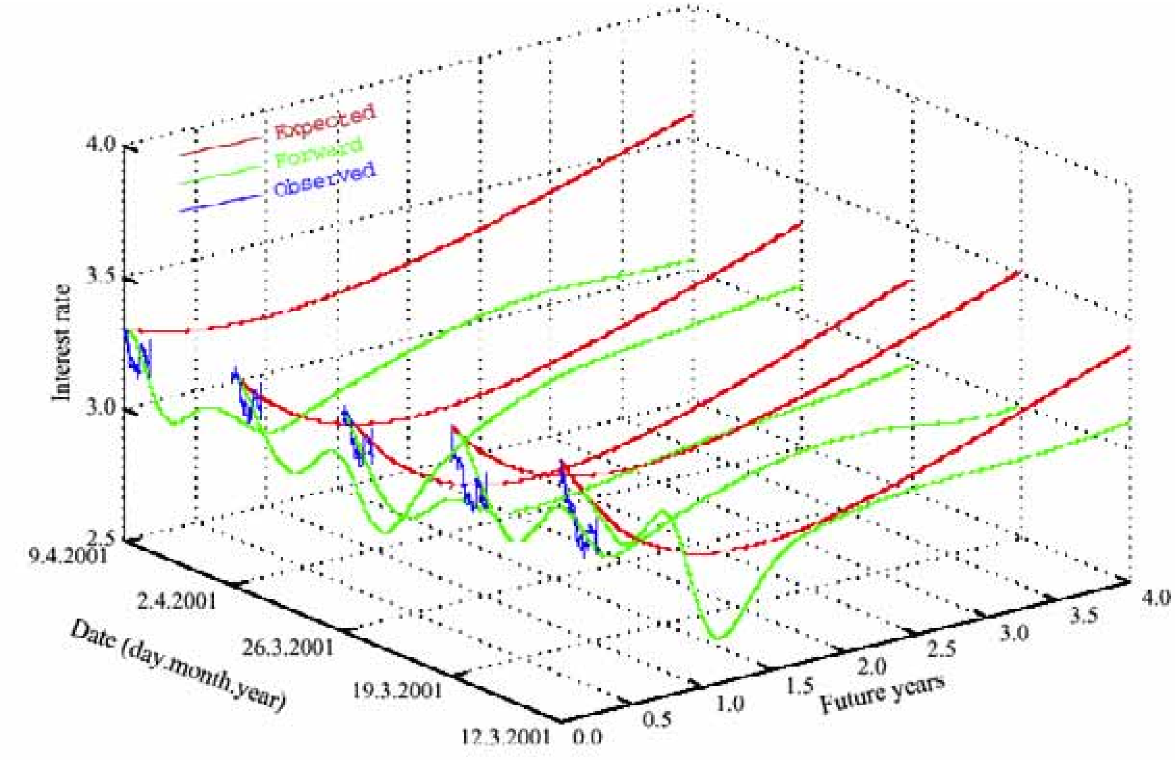


Figure 4h

Expected three-month spot interest rates in percentages per annum

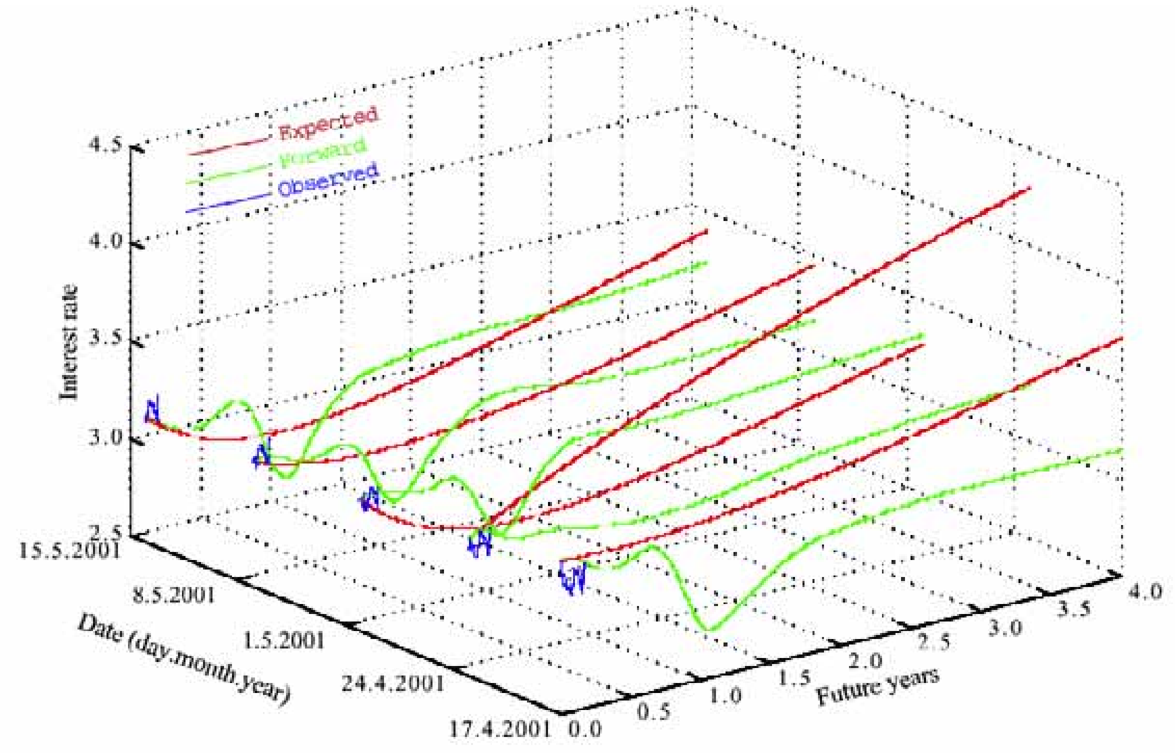


Table 1

Ordinary least-squares regressions

Independent variables	Future time horizon in days						
	1	**7**	**14**	**21**	**28**	**35**	**42**
Constant term	0.0496 (0.1151)	0.4750 (0.3438)	1.0890 (0.4315)	1.8123 (0.4846)	2.0643 (0.4853)	2.5239 (0.4723)	2.5909 (0.4406)
Expected 3M Libor	0.9862 (0.0337)	0.8636 (0.1011)	0.6843 (0.1273)	0.4697 (0.1435)	0.3943 (0.1442)	0.2570 (0.1407	0.2364 (0.1317)
Coeff. of determ.	0.9575	0.6577	0.4319	0.2199	0.1644	0.0807	0.0782
F-ratio	0.2847	1.4230	4.0122	7.6567	9.8006	15.2113	18.4928
Accept hypothesis	yes	yes	no	no	no	no	no
Independent variables	**Future time horizon in days**						
	49	**56**	**63**	**70**	**77**	**84**	**91**
Constant term	2.6048 (0.4097)	2.7086 (0.3728)	2.7893 (0.3464)	2.6624 (0.3171)	2.6536 (0.2982)	2.5929 (0.2782)	2.6242 (0.2684)
Expected 3M Libor	0.2309 (0.1227)	0.1975 (0.1120)	0.1715 (0.1042)	0.2080 (0.0956)	0.2084 (0.0901)	0.2255 (0.0842)	0.2138 (0.0814)
Coeff. of determ.	0.0852	0.0757	0.0665	0.1108	0.1234	0.1588	0.1536
F-ratio	21.5131	27.6284	33.6554	36.5186	40.6396	44.5484	48.6205
Accept hypothesis	no	no	no	no	no	no	no

Comments: The dependent variable is observed three-month Libor. Values in parentheses are standard deviations. The size of the sample of settlement days is 40. We test the joint hypothesis that the coefficient of the constant term is equal to zero and that the coefficient of expected three-month Libor is equal to one. The hypothesis is "accepted" if the *F*-ratio is less than the corresponding critical *F*-value. The critical one-tailed *F*-value is equal to 3.2448 for a probability of 95%.

Table 2

Restricted least-squares regressions

Independent variables	Future time horizon in days						
	1	**7**	**14**	**21**	**28**	**35**	**42**
Constant term	0.0000 (0.0000)	0.0000 (0.0000)	0.0000 (0.0000)	0.0000 (0.0000)	0.0000 (0.0000)	0.0000 (0.0000)	0.0000 (0.0000)
Expected 3M Libor	1.0007 (0.0011)	1.0031 (0.0032)	1.0055 (0.0042)	1.0060 (0.0052)	1.0070 (0.0057)	1.0084 (0.0061)	1.0097 (0.0063)
Partial coeff. of det.	0.9575	0.6577	0.4319	0.2199	0.1644	0.0807	0.0782
t-ratio	0.6197	0.9685	1.2863	1.1529	1.2285	1.3680	1.5519
Accept hypothesis	yes	yes	yes	yes	yes	yes	yes
Independent variables	**Future time horizon in days**						
	49	**56**	**63**	**70**	**77**	**84**	**91**
Constant term	0.0000 (0.0000)	0.0000 (0.0000)	0.0000 (0.0000)	0.0000 (0.0000)	0.0000 (0.0000)	0.0000 (0.0000)	0.0000 (0.0000)
Expected 3M Libor	1.0102 (0.0063)	1.0097 (0.0062)	1.0096 (0.0061)	1.0095 (0.0060)	1.0086 (0.0059)	1.0086 (0.0058)	1.0075 (0.0058)
Partial coeff. of det.	0.0852	0.0757	0.0665	0.1108	0.1234	0.1588	0.1536
t-ratio	1.6137	1.5694	1.5668	1.5892	1.4522	1.4916	1.2812
Accept hypothesis	yes	yes	yes	yes	yes	yes	yes

Comments: The dependent variable is observed three-month Libor. Values in parentheses are standard deviations. The size of the sample of settlement days is 40. We test the hypothesis that the coefficient of expected three-month Libor is equal to one, given the restriction that the coefficient of the constant term is equal to zero. The hypothesis is "accepted" if the *t*-ratio is less than the corresponding critical *t*-value. The critical two-tailed *t*-value is equal to 2.0244 for a probability of 95%.

Figure 5a: 1-day ahead forecast

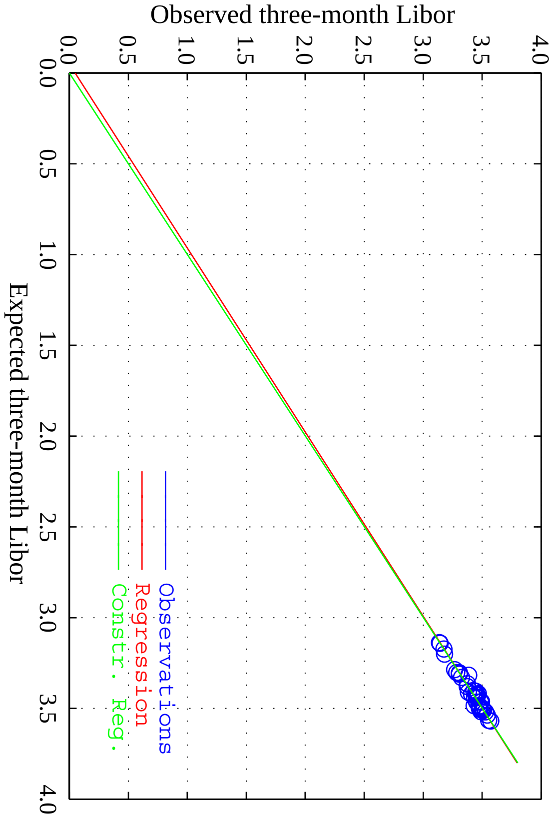


Figure 5b: 7-day ahead forecast

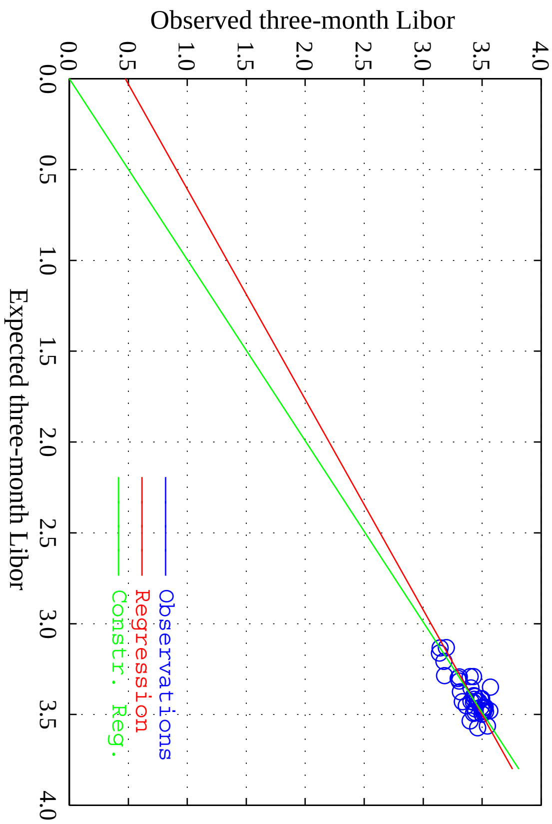


Figure 5c: 84-day ahead forecast

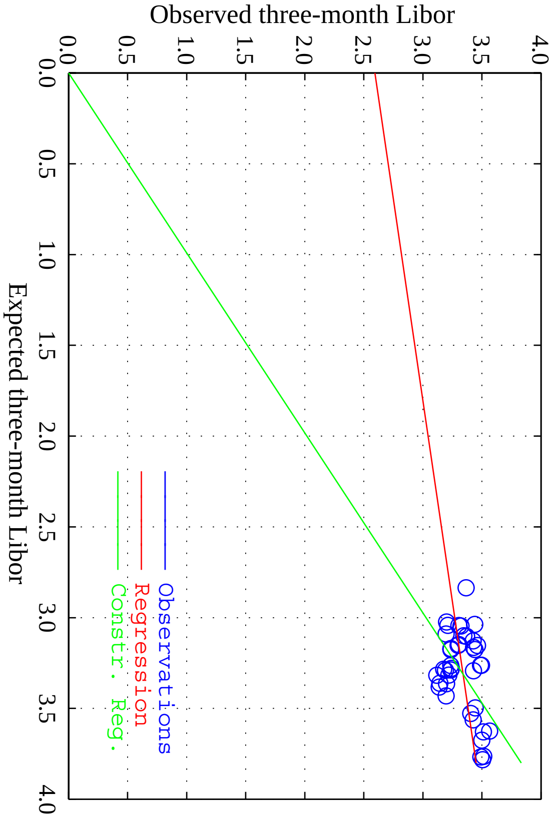


Figure 5d: 91-day ahead forecast

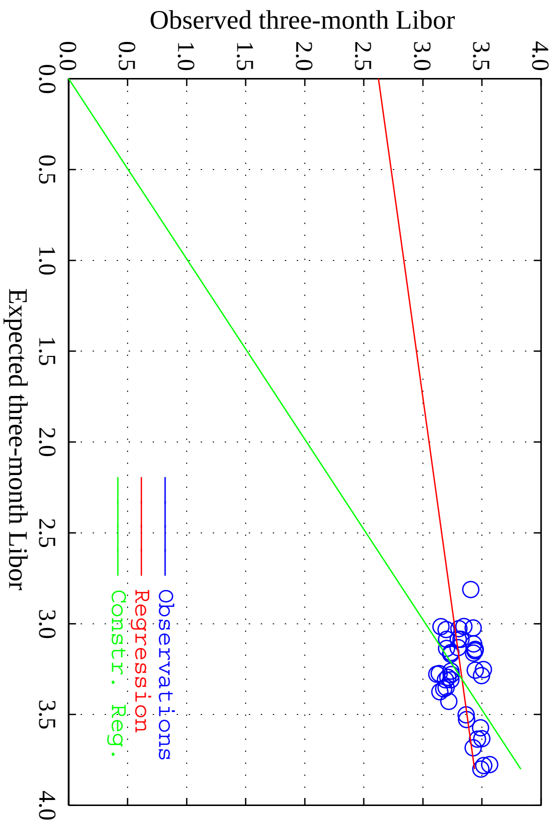


Figure 6: Premium difference between FIML and MOGA methods in percentage points

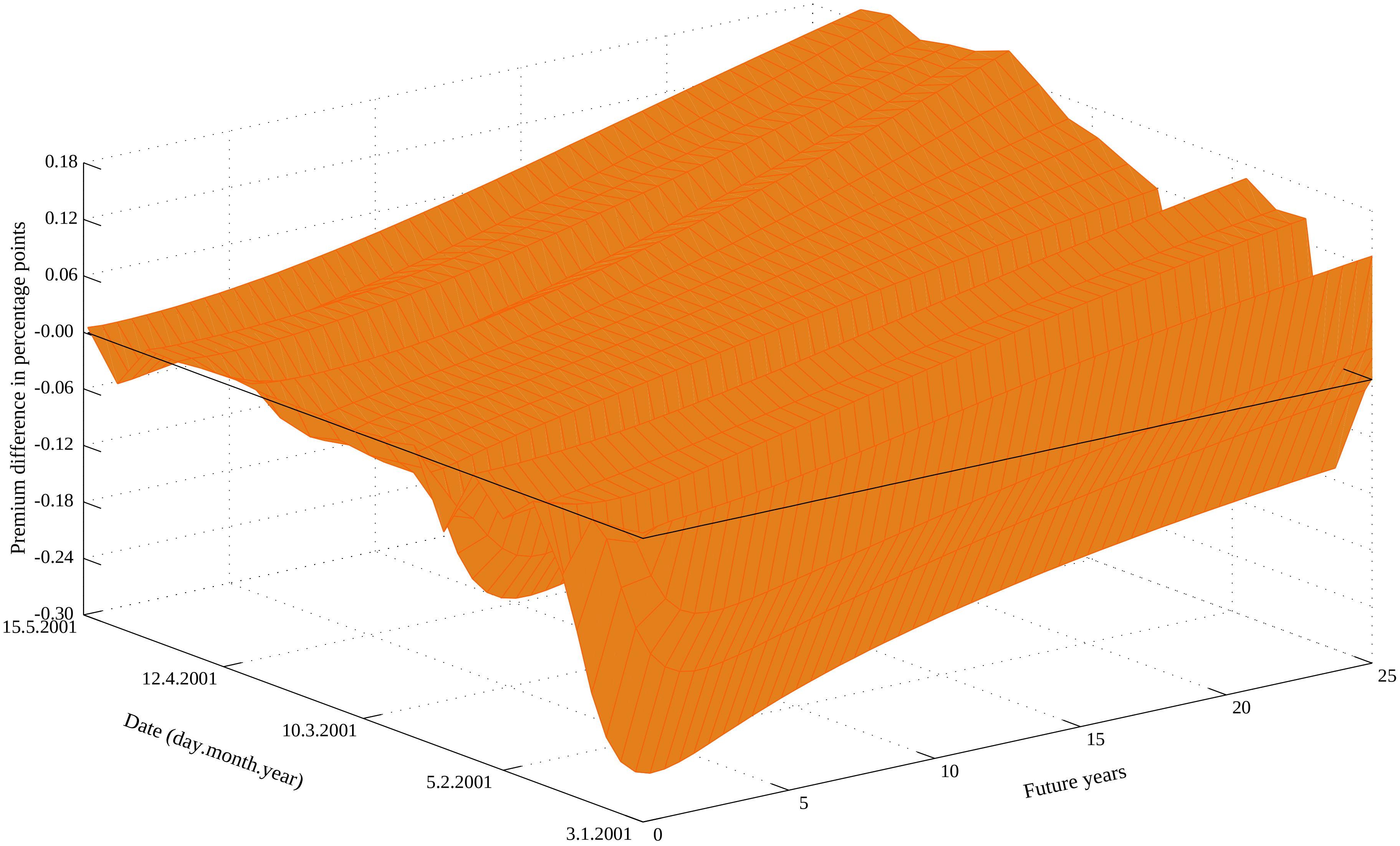
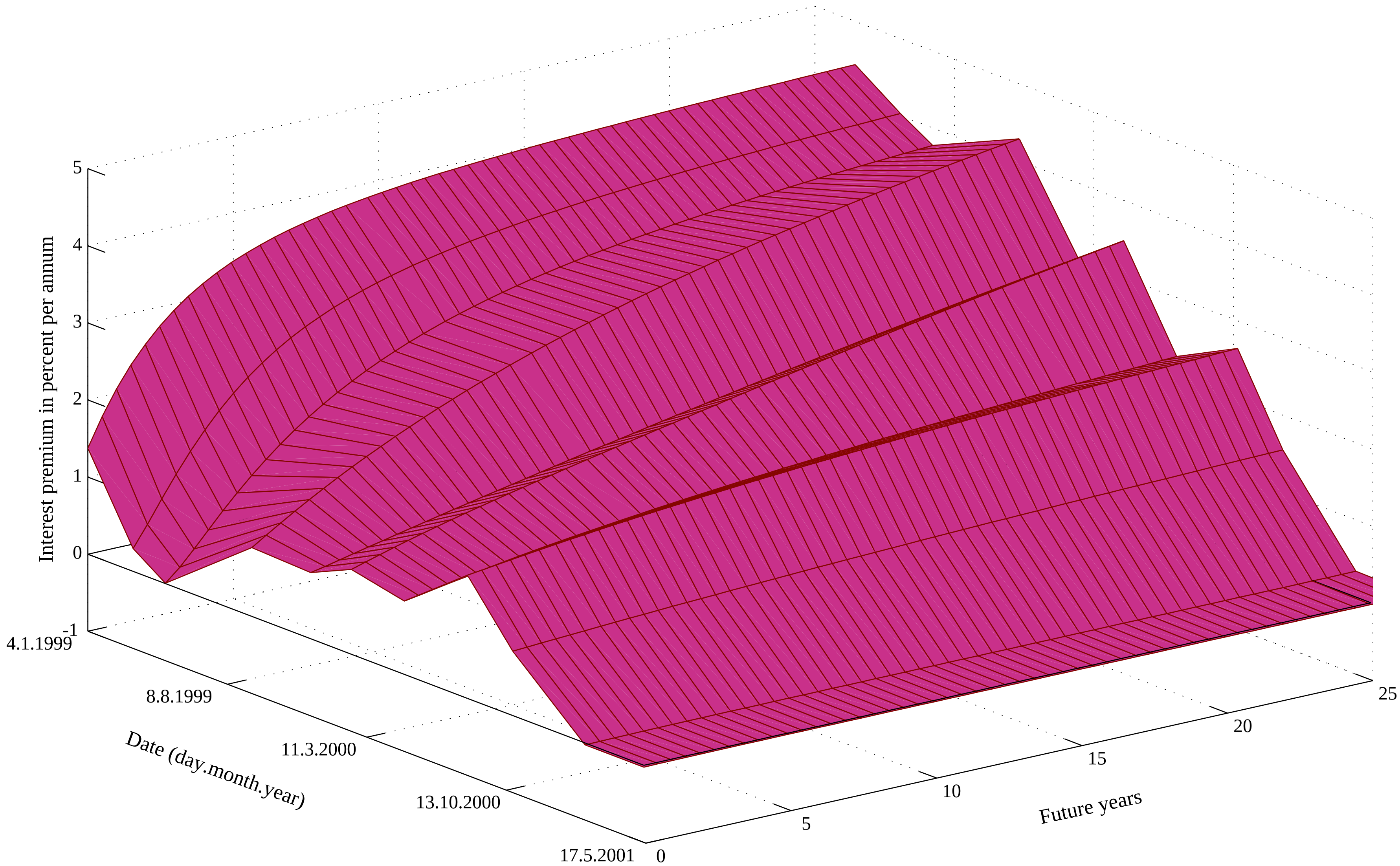


Figure 7: Interest premium in percent per annum



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What central banks can learn about default risk from credit markets

Ian W Marsh,[1] Bank of England

1. Introduction

The benchmark source of information from the credit markets is the credit spread, usually expressed as the difference between the yield offered on defaultable bonds and the yield on default-free bonds. Versions of this spread, and simple transformations of it, are used within central banks in at least three ways:

The assessment of default probabilities. The raw credit spread is used in the assessment of the financial stability conjuncture and outlook as an indicator of credit risk. Absent taxation asymmetries between corporate and default-free bonds, the textbook treatment of corporate bonds assumes that some corporate bonds will default and that investors require a higher yield to compensate for expected default losses (see, for example, Bodie et al (1993)). We demonstrate below how expected default probabilities can be extracted from credit spreads.

The assessment of market functioning. The dispersion of credit spreads on equally rated individual names or sectors is used as one of several indicators of the efficient functioning of credit markets. For example, a widening of spreads of A-rated bonds of a particular group of issuers relative to other A-rated corporates might be indicative of credit rationing were it also observed that issuance of new bonds by those issuers was low. The dispersion of the spreads reveals information about the influence of sectoral versus macroeconomic shocks. The dispersion can also indicate the ability of the market to differentiate creditworthiness. This is of interest if "unwarranted" contagion is suspected.

As a leading indicator of macroeconomic developments. Gertler and Lown (2000) suggest that the high-yield credit spread has been a superior leading indicator of the US business cycle. They argue that competing spreads (term spread and paper-bill spread) have lost explanatory power due to changes in monetary policy while the credit spread is a good and stable proxy for the premium for external funds which is central to financial accelerator models. Cooper et al (2001) is a recent application from a central bank perspective.

The remainder of this paper will focus on the first of these uses. In particular, we compare the information content of credit spreads with that of the relatively new credit default swap (CDS) market. We show that, theoretically, both corporate bond and default swap prices are formed from the same raw information. Indeed, the market practice is to base default swap prices on the credit spread although it is recognised that prices in the two markets are in two-way dynamic equilibrium. We demonstrate that analysis of the two markets should yield the same information. However, we also consider the imperfections of the credit markets and show why these may drive a wedge between CDS prices and credit spreads.

The paper proceeds as follows. In Section 2 we outline the credit default swap market. Section 3 demonstrates that theoretically this market should contain no additional information to that contained in credit spreads. However, it also highlights and attempts to explain the divergence between information on default probabilities extracted from default swap and bond markets. Section 4 draws some conclusions.

[1] Anne-Marie Rieu very generously gave me permission to use her work on this topic, and I draw on this widely. I am also grateful to Alex Bowen, Jean-Sebastien Bret, Simon Hayes and David Rule for valuable comments. Unfortunately I must remain responsible for any errors. The views expressed are those of the author.

2. Introduction to credit derivatives

The simplest instrument traded under the title of credit derivatives is the single name credit default swap. In a credit default swap, one counterparty (the "protection seller") agrees to compensate another counterparty (the "protection buyer") if a particular company or sovereign (the "reference entity") experiences one or more defined credit events. The protection seller is paid a premium, usually expressed as an annualised percentage of the notional value of the transaction, over the life of the transaction.

A CDS is often compared to a guarantee or insurance policy. The key difference is that a guarantee would compensate a protection buyer for its losses following a credit event and so is state-dependent (there has been a credit event) and outcome-dependent (the buyer has suffered losses), whereas a CDS is only state-dependent (compensation is paid by the protection seller irrespective of whether the buyer has experienced losses).

Despite moves to standardise the market, several features need to be defined before the CDS trade is executed:

- The *reference entity* must be specified.
- The *credit event(s)* that would trigger a payment to the protection buyer may include some or all of the following non-exhaustive list:
  - bankruptcy;
  - failure to pay;
  - obligation acceleration or default;
  - repudiation/moratorium (for a sovereign reference entity);
  - restructuring of the reference entity's debt.
- A *reference asset* is sometimes specified. This allows the precise specification of the capital structure seniority of the debt covered, and can give a better indication of the recovery rate after default.
- The *settlement convention* following the credit event. The contract is either physical or cash-settled. Physical settlement would entail the delivery of the defaulted security to the protection seller in exchange for par value in cash. Cash settlement would entail the protection buyer receiving par minus the default price of the reference asset in cash (usually gathered via a poll of dealers). The default price is market-determined (although a fallback arrangement ought to also be included in the documentation should it not be possible to market-price the asset).

3. Information from credit derivatives

3.1 A theoretical treatment of risky bond prices and credit default swap rates

In this section we briefly outline a method for the extraction of information from credit default swap rates. In parallel we do the same for defaultable bonds to highlight the theoretical linkages between the information contained in the two sets of market prices. This section draws heavily on Rieu (2001), which contains much greater detail of some steps made in this paper.

We start with a cash flow analysis. Assume we have a risky bond of maturity T_n, of nominal value 100, paying fixed annual coupons C. Should it default, the bond would pay a recovery rate of π. Assume also that we have a credit default swap with annual premium s. On default, the protection buyer receives π of the par value of the reference asset. The cash flows are summarised in the following table. Should default occur, of course, only one of the payments in the column headed default is received.

Time	Bond cash flows to holder		CDS cash flows to protection buyer	
	Survival	Default	Survival	Default
1	C	π.(100+C)	–s	100.(1-π)
2	C	π.(100+C)	–s	100.(1-π)
3	C	π.(100+C)	–s	100.(1-π)
	…	…	…	…
T_n	100+C	π.(100+C)	–s	100.(1-π)

We assume that the default can only occur on the coupon payment dates or maturity. This simplifies the analysis since we do not then have to worry about claims on accrued interest payments for mid-coupon date defaults. While somewhat unrealistic, Hull and White (2000) show that this assumption has little impact on extracted default probabilities.

The probability of default is time-varying. Define $q(0, k, k+1)$ to be the risk neutral conditional probability of default between period k and k+1, and $Q(0,T_k)$ to be the cumulative risk neutral probability of default between 0 and T_k. Similarly, define $P(0,T_k)$ to be the cumulative risk neutral probability of survival over the same period.

By Bayes' Rule we know that the conditional probability of survival between k and k+1 is

$$p(0,k,k+1) = \frac{\Pr[(\text{Survival until } k+1) \text{ AND } (\text{Survival until } k)]}{\Pr[\text{Survival until } k]} = \frac{P(0,k+1)}{P(0,k)}$$

and so $P(0,T) = \prod_{k=1}^{T} p(0,k-1,k) = \prod_{k=1}^{T} [1-q(0,k-1,k)]$.

Define $B(0, t)$ to be the spot price of a risk-free zero coupon bond paying one at time t. The present value of the risky coupon bond is then

$$PV_{bond} = C\sum_{i=1}^{T_n} B(0,i)P(0,i) + 100B(0,T_n)P(0,T_n) + \pi(100+C)\sum_{i=1}^{T_n} B(0,i)q(0,i-1,i)P(0,i-1) \tag{1}$$

and the credit default swap is priced such that

$$0 = -s\sum_{i=1}^{T_n} B(0,i)P(0,i) + 100(1-\pi)\sum_{i=1}^{T_n} B(0,i)q(0,i-1,i)P(0,i-1). \tag{2}$$

These equations express the present values of both risky bonds and credit default swaps in terms of zero coupon risk-free bond prices, conditional probabilities of default and the recovery rate. The important issue then is that since the prices of the risky coupon bond and the credit default swap are functions of the same recovery rate and default probabilities, the information extracted from both should theoretically be equivalent. This result is important. CDS prices are easy to observe directly whereas computing credit spreads involves the preliminary step of determining risk-free rates, which can be problematic where government bond yields are distorted by regulation or supply shortages (see Anderson and Sleath (1999) for a discussion of the Bank of England's methodology of deriving yield curves). Further, while indicative CDS prices are relatively easily available for maturities of three, five, seven and 10 years, credit spreads can only be observed at the maturities of outstanding bonds, which are sometimes not so widely or evenly dispersed. However, CDS prices are only quoted for a subset of reference entities that have issued bonds, and firm CDS prices are hard to find away from the most liquid points (typically five years). Being able to use information interchangeably from both markets would allow a more comprehensive picture of default risk.

We now show how to extract the risk neutral conditional probabilities of default from risky bond prices. The period t price of a risk-free zero coupon bond is

$$B(t,T_k) = \exp\left(-\int_t^{T_K} f(t,u)du\right) = \exp(-R(t,T_k)(T_K - t))$$

where $f(t, T_k)$ is the continuous-time instantaneous forward rate at T_k seen from t, and $R(t, T_k)$ is the risk-free rate over (t, T_k).

Similarly, the price of a risky zero coupon bond is

$$V(t,T_k) = B(t,T_k)\exp(-S(t,T_k)(T_k - t)) \tag{3}$$

where $S(t, T_k)$ is the credit spread at t for a claim of maturity T_k.

If we make the usual but critical simplifying assumption of independence between risk-free rates and default, then following the model of Jarrow and Turnbull (1995) we can define the price of a one-period risky zero coupon bond as

$$V(0,1) = B(0,1)\{[1 - q(0,0,1)] + \pi . q(0,0,1)\}. \tag{4}$$

Similarly, the expected value of a two-period risky zero coupon bond in the Jarrow-Turnbull model is

$$V(0,2) = B(0,2)\{[1 - q(0,0,1)][1 - q(0,1,2)] + [1 - q(0,0,1)]q(0,1,2)\pi + q(0,0,1)\pi\} \tag{5}$$

This assumption of independence is widespread in the literature and Moody's Investor's Service (2000) provides evidence that the correlations are small enough for this assumption to be warranted.

Rearranging (3) gives

$$\frac{V(t,T_k)}{B(t,T_k)} = \exp(-S(t,T_k)(T_k - t)) \tag{6}$$

which when combined with (4) gives the conditional default probability between [0, 1]

$$q(0,0,1) = \frac{1 - V(0,1)/B(0,1)}{1-\pi} = \frac{1 - \exp(-S(0,1))}{1-\pi}. \tag{7}$$

Substitution into (5) yields

$$q(0,1,2) = \frac{\exp(-S(0,1)) - \exp(-S(0,2)\times 2)}{\exp(-S(0,1)) - \pi}. \tag{8}$$

This process can be rolled forwards n periods revealing the generalised conditional risk neutral probability of default to be

$$q(0,k,k+1) = \frac{\exp(-S(0,k).k) - \exp(-S(0,k+1).(k+1))}{\exp(-S(0,k).k) - \pi} \tag{9}$$

and the cumulative probability of default to be

$$Q(0,T) = 1 - \frac{\exp(-S(0,T).T) - \pi}{1-\pi}. \tag{10}$$

That is, we can express the conditional and cumulative risk neutral probabilities of default in terms of the observable credit spread and the (ex ante unobservable) recovery rate. The standard financial pricing model says:

$$P = E(mx) \tag{11}$$

where P is the price of the asset, m is the stochastic discount factor, x is the payoff of the asset, and E denotes conditional expectations. In a state-price density framework we can rewrite this as

$$P = \sum_s \pi(s)m(s)x(s) \tag{12}$$

where $\pi(s)$ denotes the true probability of state s. However, if we denote the risk-free rate of interest by R^f, the risk neutral probabilities we have extracted (π^*) are such that

$$P = \frac{1}{R^f}\sum_s \pi^*(s)x(s). \tag{13}$$

The transformation between risk neutral and true probabilities is

$$\pi^*(s) = \frac{m(s)}{E(m)}\pi(s). \tag{14}$$

That is, the risk neutral probabilities give greater weight to states with higher than average marginal utility. Since default is likely to coincide with periods of economic downturn, when the marginal utility of an extra dollar is higher than average, the extracted probabilities are at best an upper bound on the true probabilities of default. Nevertheless, even though they may not be true default probabilities, the risk neutral probabilities extracted from the bond market should still equal those from the CDS market.

Duffie (1999) shows that the credit default swap price should equal the spread over Libor on a par floating rate note by arbitrage. He also argues that spreads on par fixed rate bonds and par floating rate notes are essentially equal (to within 1 basis point per 100 basis points of credit spread). Hull and White (2000) confirm this result in the presence of a flat (Libor) term structure but show that a steeply sloping term structure can lead to an imprecise arbitrage argument (approximately 7 basis points per 100 basis points of credit spread). Hull and White also examine the effect of using non-par bond spreads. They demonstrate that for spreads characteristic of BBB-rated issuers, the error is rather small in the presence of a flat term structure (5 basis points per 100 basis points of credit spread).

We read this literature as suggesting that the credit spread over Libor on fixed rate bonds and the CDS price should be (approximately) equal, and hence that either par bond credit spreads or credit default swap prices can be used in equations (9) and (10). To obtain true (risk neutral) default probabilities, the spread between Libor and the risk-free rate needs to be added to the CDS price and credit spread over Libor. Note that this reintroduces the problem of observing the risk-free rate given government bond market supply effects referred to above. The implication is that using CDS prices does not make this problem go away if the object of the exercise is to compute default probabilities.

This theoretical equivalence between CDS prices and credit spreads is violated in reality. The following section demonstrates the divergence between credit spread curves derived from bond prices and CDS rates, and the divergences between inference regarding default probabilities that result. The subsequent section considers reasons for the divergence over and above the imprecise arbitrage arguments already noted.

3.2 An empirical example

As an empirical example, we will consider implied default probabilities for a single company (Citigroup) on a given day (2 October 2001) derived from quoted bond and credit default swap prices.

Credit default swap prices. These were available for annual maturities between one and 10 years from the JP Morgan website. JP Morgan is a leading market-maker in credit default swaps. The prices are indicative middle-market rates. Firm bid and ask quotes are available from the same site for three-, five-, seven- and 10-year maturities. The additional information from the indicative prices makes them more attractive for our purposes. As noted above, CDS prices are a spread over Libor. Fair comparison against a (bond) credit spread over risk-free rates implies adding the Libor-risk-free spread to the CDS price at each maturity.

Risky bond prices. Middle-market prices on all Citigroup US dollar-denominated bonds were collected from Bloomberg. Only straight fixed coupon bonds with no embedded options were considered. Bonds with a maturity of less than one year were dropped since such short-dated bonds are infrequently traded and prices are likely to be either stale or misleading. If, for any given maturity, more than one bond was quoted, we took the price of the bond with the largest amount outstanding, all other things being equal. We did not exclude bonds priced far from par since this would have excluded too many bonds for subsequent optimisation (the furthest departure was a clean price of 109.5). Despite choosing a large player in the debt markets, we only found six suitable fixed coupon bond spreads. The implied zero coupon spread of the risky bonds over the risk-free zero coupon curve was then computed for each bond.

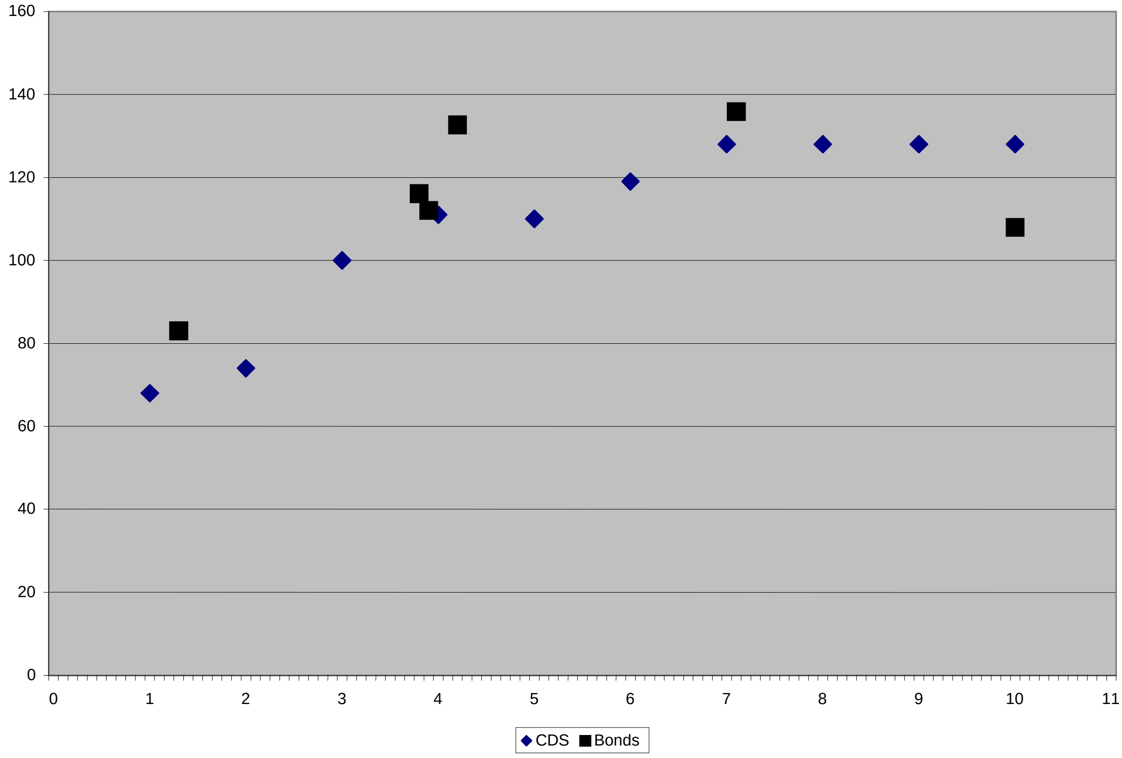
Default probabilities. A parametric curve of the form $s = a + b.t + c.t^2$ (where t denotes maturity and s is the spread over the risk-free rate) was fitted to both sets of spreads. Conditional and cumulative default probabilities were then calculated as in equations (9) and (10) with a recovery rate of 40% assumed.

Figure 1 reveals the raw spread data being analysed. The bond data are well dispersed by maturity, yet the tight grouping of three bonds around four years reveals a wide disparity of spreads.[2] The 10-year bond spread also appears out of alignment. The CDS spreads, while appearing smoother, also show some idiosyncracies. The lower cost of five-year protection relative to four-year reflects the concentration of CDS liquidity around the five-year horizon. The other "jumps" in CDS spreads are largely driven by jumps in the Libor-risk-free spread.

2 Duration effects can account for some but not all of this disparity. At least part of the remainder is due to relative liquidity.

Figure 1

Observed CDS and bond spreads over risk-free rates



Figures 2 and 3 reveal the different profiles of default probabilities extracted from the two markets. Cumulative and especially conditional probabilities are markedly different, even for a company such as Citicorp that is relatively creditworthy (Aa2/AA- rating at time of quotes), and has a reasonably active portfolio of bonds outstanding capable of providing yields over a wide spread of maturities. The differences in inference are robust to alternative functional forms for the spread curve and alternative, plausible, recovery rate assumptions. In the next subsection we discuss reasons why the two markets provide conflicting information.

3.3 Why bond spreads and credit default swap spreads may diverge

Define the swap basis to be the CDS price minus the par bond spread. Although the two components should be equal in theory, even in perfect markets there could be a non-zero swap basis. O'Kane and McAdie (2001) split the reasons into two groups. They term the first group "fundamental" factors and argue that these arise because of the simplifying assumptions made when describing the credit default swap and risky bond. The main elements in this group are:

- *Funding issues*. Trading in the bond is a funded transaction where the funding rate depends upon the credit rating of the market participant. Credit default swaps are unfunded and lock in an effective funding rate of Libor. Highly rated investors (or investors with natural funding such as pension funds and retail banks) may fund sub-Libor, which would lead them to prefer to buy the bond rather than sell protection. Conversely, lower-rated investors wishing to acquire credit risk would prefer the unfunded CDS transaction. Obviously, the exact circumstances of market participants will determine the effect this has on the swap basis. O'Kane and McAdie (2001) assert that most participants fund above Libor, which tends to narrow the basis since they will be willing to accept a lower CDS spread to obtain the funding advantage.

Figure 2
Cumulative risk neutral default probabilities

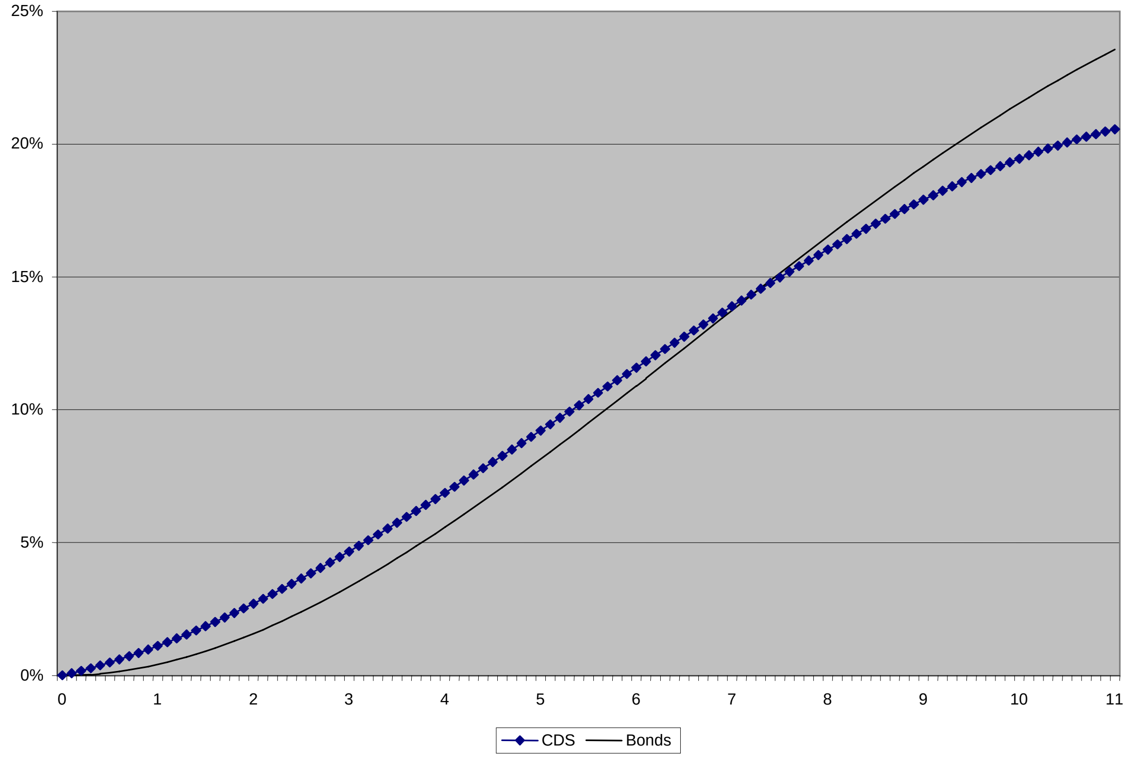
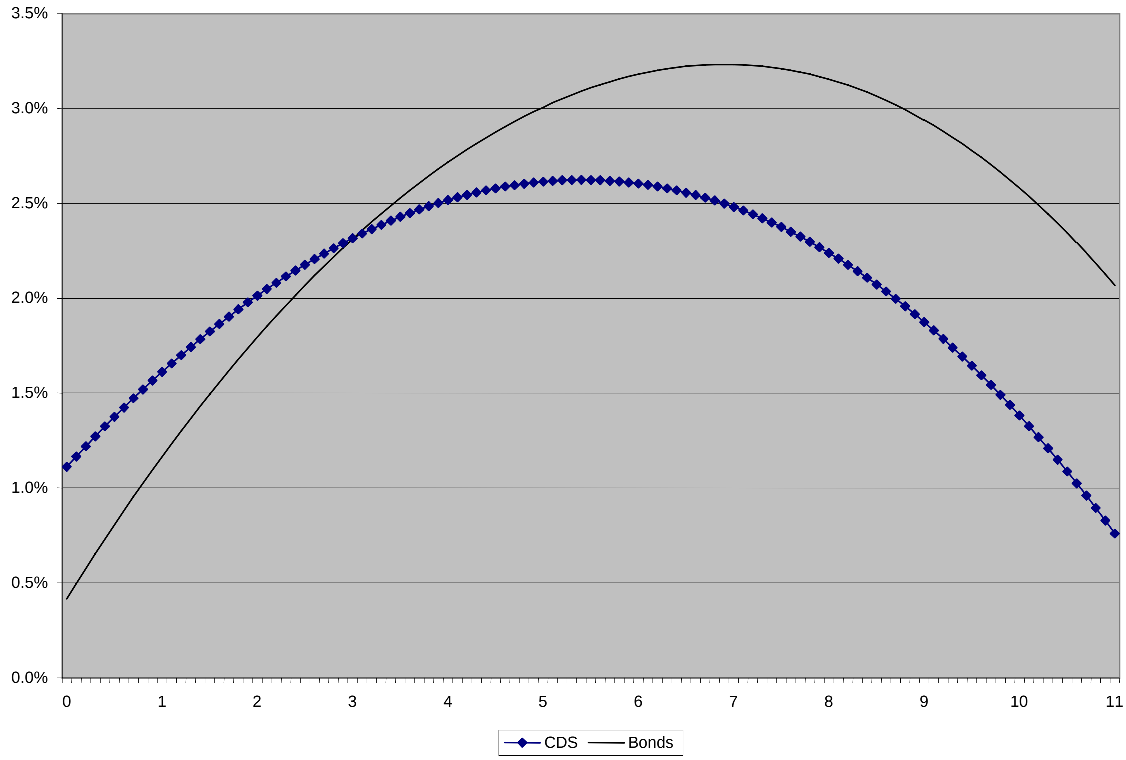


Figure 3
Conditional risk neutral default probabilities



- *Counterparty risk*. After settlement, the purchase of a bond is free from counterparty credit risk. A credit default swap is a bilateral transaction, which does entail counterparty risk. Protection buyers face by far the greater proportion of this risk and hence will pay a lower rate than in the absence of counterparty risk. This also tends to narrow the swap basis. Jarrow and Yu (2001) provide a method of pricing CDS subject to counterparty risk.

- *The delivery option in a physically settled CDS*. As mentioned above, it is possible that the protection buyer in a CDS contract has a choice of which exact asset to deliver to the seller. While in theory all equally senior assets issued by the reference entity should trade at the same price following a credit event (since bondholders of pari passu assets have equal claims to company assets), this does not always occur in practice if the event is less than "full default" (defined to be when all obligations become immediately due and payable). The delivery option may be potentially valuable in this situation and this should increase the swap basis. Recent changes to the ISDA documentation on credit swaps relating to restructuring have reduced the value of this option.

Other reasons for the swap basis not being equal to zero are grouped under the heading of "market" factors. These can be further separated into liquidity and demand and supply factors.

- *Liquidity factors*. The relative liquidity of the bond and CDS markets is very different. But the difference is not systematic across maturities. Typically, the CDS market is most liquid at the five-year maturity, followed by the three-year then 10- and one-year points. The bond market is usually liquid wherever on the yield curve the largest outstanding notional amounts lie. Not only is this likely to be at different maturities for different issuers, but it will shift over time for a given issuer as the bonds age.

- *Demand and supply factors*. It is sometimes claimed that the majority of participants in the single name CDS market are risk-takers that want to sell protection (O'Kane and McAdie (2001)). Financial institutions have a comparative advantage in assessing and managing credit risk, and this is most cleanly done by selling CDS contracts. This preponderance of "technical shorts" puts downward pressure on the swap basis.

  The other side of the coin is that shorting a credit can be difficult in bond markets since the supply of bonds on repo is often limited. Market-wide sentiment against a credit will raise the credit spread of that entity's bonds and its CDS rate. But the difficulty of shorting the bond may cause the latter to rise by more, and hence the swap basis increases.

  New issuance in the bond or loan markets leaves banks and underwriters long credit, leading them to buy protection via CDS either to reduce exposure or to free up regulatory capital. While the increased supply should make shorting the bond easier, market participants argue that the demand effect dominates and so the net effect is that the basis again widens.

It is of interest to examine whether the observed divergences between CDS prices and credit spreads demonstrated in Section 4.2 can be explained by fundamental factors, or whether there are serious discrepancies between the two markets. For example, after controlling for fundamental factors, a widening of the swap basis for financial institutions in liquid markets may be indicative of rising fears about general counterparty risk.

There are reasons why the two markets may be separated. Participation in the CDS market is limited to relatively highly rated entities due to the counterparty risk inherent in the swap. However, the bond market is a cash market. It is possible that the more constrained CDS market prices less information, or at least prices it more slowly, than the bond market. However, it is worth mentioning that CDS dealers view the basis as an indicator of credit pressure, given that commercial banks have better information about creditworthiness. They see a widening basis for an individual name, ceteris paribus, as a leading or, at least, current indicator of credit deterioration as informed banks take positions in the CDS market that are subsequently priced into bond spreads, reversing the supposed pricing efficiency.

Apportioning the differences between CDS prices and credit spreads econometrically is hampered by the fact that several of the factors mentioned are difficult to proxy. Essentially, all of the fundamental factors need contract-specific or transaction-specific information. Fortunately, the directions of the impacts of these factors are either indeterminate or partially offsetting. Rieu (2001) contains some initial work in explaining the swap basis for France Telecom in terms of liquidity and demand/supply factors which we now summarise, highlighting areas where further work is needed.

The market factors are more amenable to econometric investigation. Rieu (2001) uses three proxies for relative liquidity:

- *Maturities quoted*. Traded volume is not available for either the CDS or the bond markets. Instead the number of different CDS and bond prices actively quoted each day is used as a proxy. Typically, the higher the liquidity in the two markets, the more bonds/CDS maturities are quoted. The indicator used is simply the number of CDS prices minus the number of bonds quoted on any given day, a rising number indicating relatively more liquidity in the CDS market.
- *Bid-ask spreads*. A more liquid market is usually associated with a tight bid-ask spread. This is just one dimension of liquidity, but it has the clear advantage that it is the easiest to observe. The indicator used is relative spreads (CDS minus bonds), with rising numbers indicating lower relative liquidity in the CDS market. This indicator was maturity-specific since relative spreads could be computed for different maturities.
- *Deviation of observed prices from theoretical levels.* Following Monkkonen (2000), the difference between the largest and smallest absolute deviation of observed bond yields from the fitted yield curve is computed. Similarly, the difference between the largest and smallest absolute deviation of CDS prices from the CDS curve is calculated. The indicator used is the CDS difference minus the bond difference. Again, a higher number would be indicative of lower relative CDS market liquidity.

Finally, a credit protection demand indicator is included. An obvious factor likely to lead to an increased demand for protection is industry downgrading by credit rating agencies. The sample period considered runs from October 2000 to February 2001. The first wave of telecoms downgrades is in the middle of this sample. Rieu (2001) computed a simple indicator that increased (decreased) by unity every time a European telecoms company was downgraded (upgraded), but which decayed towards zero as demand pressures were satisfied in the credit markets. An increase in the demand indicator would suggest an increase in the swap basis as credit protection is more easily acquired by buying protection in the CDS market than by shorting the bonds.

Rieu (2001) applies a fixed-effects panel estimation procedure to the daily swap basis between curves fitted to France Telecom CDS prices and credit spreads over several maturities, using the above four independent variables. The model has to explain large time series changes (the swap basis moves between zero and 100 basis points during the sample) and cross-sectional variation (the term structure of the swap basis altered significantly during the sample, with the basis for longer maturities becoming much more positive than for the short end).

Key findings from the regressions include:

- All four explanatory variables are highly significant with the expected signs. The third liquidity factor (relative divergence from the theoretical spread curves) is statistically and economically the most important of the liquidity factors.
- Over 77% of the variance of the swap bases at various maturities is explained by the four variables.
- The fixed-effects terms indicate relative bond market liquidity at horizons between two and three years and in excess of five years. The CDS market is relatively more liquid below two years and around the five-year mark. This accords with the perceived liquidity rankings across maturities in the CDS market noted above.

These initial results highlight the importance of considering the impact of market conditions on the default probabilities extracted from either credit spreads or CDS prices. The swap basis for the single name considered by Rieu (2001) reached one percentage point during an admittedly volatile period for credit markets. However, a large proportion of the basis can apparently be explained in terms of liquidity and supply/demand imbalances.

Further work is needed to examine whether a similar picture emerges for other reference entities (we are applying similar tests to rates on leading banks), and whether some of the other factors detailed above are important in explaining the swap basis. In particular, we will address the supply side of the credit market. We noted above that new bond issuance by the reference entity (or a similar entity if cross-hedges are employed) increases the supply of shortable bonds but also increases the demand for protection. Incorporating new bond and debt issuance will allow us to test the dominance of one over the other.

4. Summary

The academic literature suggests that the credit default swap price should almost exactly equal the credit spread on par floating rate notes. Since par floating rate notes are rare, par fixed rate bonds provide a reasonably accurate alternative. Since par fixed rate bonds are not common, non-par fixed rate credit spreads are often used as an alternative. This paper has shown how expected default probabilities can be extracted from either credit spreads or CDS prices. We have also shown that the two probability profiles can be substantially different.

There are fundamental reasons why the relationship between CDS prices and non-par fixed rate credit spreads are not exactly equivalent. These are recognised by academics and market participants. For example, focusing on one key reason for a deviation, Scott (1998) notes:

"The market convention for pricing new default swaps is to take the credit spreads in the bonds of the reference entity and adjust up or down depending on the expected financing rates for the bonds."

We have also described market conditions that will drive a wedge between the credit spread and CDS price. Further, we have presented preliminary research that suggests that, for one prominent reference entity, the majority of the, sometimes large, observed deviations could be explained by relative liquidity and demand factors.

Some potentially important factors remain unmodelled. The ongoing research project will attempt to incorporate these factors and more fully account for the difference between CDS prices and credit spreads for a wider selection of names. Accounting fully for the swap basis could allow CDS and credit spread data to be pooled, giving a fuller picture of default expectations across a wider range of horizons.

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The changing information content of market interest rates

Vincent Reinhart and Brian Sack,[1]
Board of Governors of the Federal Reserve System

Abstract

This paper investigates the various factors underlying the pricing of US fixed income assets. In particular, we decompose movements in 10-year Treasury, swap, agency and corporate yields into five unobserved factors: the risk-free interest rate, a credit risk factor, a liquidity preference factor, and idiosyncratic shocks affecting Treasury yields and swap rates, respectively. Our findings indicate that the relative importance of these factors has shifted in recent years, with significant implications for the information content of market interest rates. First, Treasury yields have become increasingly divorced from the risk-free rate due to an increase in the volatility of idiosyncratic Treasury shocks. Second, spreads between the yields on various fixed income securities have been increasingly influenced by a number of different factors, making them harder to interpret.

1. Introduction

Financial markets play a critical role in the process of setting monetary policy. First, the influence of monetary policy on the real economy and inflation is largely transmitted through asset prices. Indeed, most economic activity is not directly affected by the overnight interest rate - the lever directly controlled by most central banks - but instead by longer-term interest rates and the wealth of economic agents. Second, central banks rely on financial markets for information to help inform their policy decisions. To that end, market interest rates summarise vast amounts of information about the expected course of monetary policy and the economy. The problem in both regards, though, is that many factors potentially influence market rates that are not necessarily related to monetary policy. In order to predict the consequences of their actions and to read correctly the signals from financial markets, monetary policymakers must have a firm understanding of the factors underlying movements in market rates.

This paper offers a statistical interpretation of the movements of key US market interest rates since 1993. In particular, we decompose weekly changes in 10-year Treasury, swap, agency and corporate yields into five unobserved factors: the risk-free interest rate, factors representing credit risk and liquidity preference, and idiosyncratic shocks affecting Treasury yields and swap rates, respectively. By concentrating on the underlying factors rather than the market interest rates themselves, we bring the financial market developments over that period into sharper focus. Moreover, the results indicate that the importance of individual factors has shifted in recent years, with significant consequences for the information content of market interest rates and, presumably, the appropriate investment and hedging strategies of private investors.

One important finding is that the extent of idiosyncratic movements in US Treasury yields has increased in recent years. Simply put, Treasury yields have become increasingly divorced from the risk-free interest rate due to a larger and more volatile idiosyncratic premium on those securities. This premium has presumably been moved in part by actual and prospective cutbacks in the supply of

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Treasury securities as the outlook for the federal budget swung in early 2000 towards sizeable surpluses. As a result, yields on government securities no longer serve as effectively as they once did as proxies for risk-free interest rates. The decomposition offers an alternative measure of the risk-free interest rate based on the common movements in the yields of all the assets considered.

The behaviour of private interest rates has also shifted importantly in recent years, as yield spreads on corporate bonds have been larger and more variable. Our results indicate that this pattern can only be partly attributed to the credit risk factor. Private yield spreads have also been influenced by an increase in the volatility of shocks to investors' preferences for liquidity, since private securities with different credit quality often have different degrees of liquidity as well, and by idiosyncratic movements in both Treasury yields and swap rates, the benchmarks against which corporate yield spreads are typically measured.

The paper is organised as follows. Section 2 describes our decomposition of US fixed income yields, and Section 3 shows the overall results from that exercise. Section 4 focuses on recent shifts in the behaviour of US fixed income markets and the lessons to be drawn for central banks, and Section 5 concludes.

2. A decomposition of US market interest rates

Our attempt to identify several fundamental factors that explain the yields on key US fixed income assets will focus on the rates on five different assets with maturities of around 10 years: an on-the-run Treasury security, an off-the-run Treasury security, an interest rate swap, a federal agency debt security and a corporate debt security. These securities are first described in some detail.

The ***on-the-run Treasury yield*** is that on the most recently issued 10-year Treasury note.[2] The amount of trading activity in this security is extensive, and its liquidity is remarkable.[3] An average of more than USD 200 billion of that security is estimated to have traded every week over the first three months of 2001. Bid-ask spreads on that issue are almost always below 1/2 basis point (in terms of yield) and are typically closer to 1/4 basis point. The impressive liquidity of the security (and other on-the-run Treasury issues) is partly related to its widespread use as a hedging instrument. More generally, the perception that this security is a very liquid instrument attracts investors employing strategies that involve intensive trading, which in turn makes the security more liquid.

The ***off-the-run Treasury yield*** considered is the par yield on a 10-year security derived from a smoothed yield curve estimated from the prices of off-the-run notes and bonds and some coupon strips.[4] Off-the-run Treasury securities are still quite liquid relative to other fixed income assets, with bid-ask spreads typically around or slightly greater than 1/2 basis point, but the market is not as deep or active as that for on-the-run issues.

The ***agency yield*** considered is based on a security issued by the Resolution Funding Corporation (Refcorp). Refcorp was established in 1989 to provide funding to the Resolution Trust Corporation for the resolution of insolvent thrifts, and it issued USD 30 billion of debt between 1989 and 1991. This debt is essentially free of credit risk: the coupon payments are backed by the full faith and credit of the US government, and the principal payments are fully collateralised by a special series of non-marketable zero coupon Treasury securities. The fact that these securities have essentially the same credit risk standing as Treasuries makes them particularly useful in the decomposition below. The specific security used is the October 2020 Refcorp bond, of which USD 5 billion were issued. Because the security is estimated to be about 90% stripped, we consider the yield on the principal

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2 All Treasury data considered are from a proprietary database collected by the Federal Reserve Bank of New York. Similar data are reported daily in the *Wall Street Journal*.

3 For a more complete discussion of the Treasury market, see Dupont and Sack (1999).

4 The smoothed yield curve is estimated following the method of Fisher et al (1995). It abstracts from the idiosyncratic features that sometimes affect individual securities and controls for the maturity and coupon of each issue. More details are available in Bank for International Settlements (1999).

strip from this security. Overall, the Refcorp strip, with bid-ask spreads of about 1 basis point, is somewhat less liquid than comparable Treasuries but more liquid than most corporate securities.

Among the private interest rates considered, the ***swap rate*** is the fixed rate on a 10-year interest rate swap - that is, the fixed rate one would receive in return for making floating rate payments tied to Libor.[5] Notional amounts of outstanding interest rate swap contracts have grown tremendously in recent years, and market liquidity is generally superior to that of even the most frequently traded corporate bonds. Bid-ask spreads on 10-year swap contracts are typically around 1/2 basis point.

The ***corporate yield*** considered is based on the Merrill Lynch AA corporate bond index. This index is a weighted average of the yields on all outstanding corporate debt securities with AA credit ratings and maturities between seven and 10 years, where the individual securities are weighted by their market capitalisation.[6] In the results following the decomposition, we also consider a BBB corporate yield derived in the same manner. The securities included in these indices must meet minimum requirements on their liquidity. Nevertheless, the liquidity of the corporate bonds included is lower than that of Treasury securities. While information on trading is mostly anecdotal, bid-ask spreads appear to vary considerably across issues and typically range from 1 to 5 basis points. The market depth at those quoted prices is much lower than that for Treasuries, and the trading volume for individual issues is far lighter.

The analysis that follows assumes that the yields on these fixed income assets are influenced by five unobserved factors: the 10-year risk-free interest rate R, a liquidity preference factor L, a credit risk factor C, an idiosyncratic Treasury factor T, and an idiosyncratic swap factor S. In principle, all of these unobserved factors could influence the five observed market rates. Our identification scheme is designed to make enough assumptions about the manner in which these factors feed through to market rates to be able to capture the underlying factors and the magnitude of their influence. In particular, the factors are assumed to influence the observed market rates as follows:

$$\begin{bmatrix} y^{on} \\ y^{off} \\ y^{r} \\ y^{c} \\ y^{s} \end{bmatrix} = \begin{bmatrix} 1 & -1 & 0 & 1 & 0 \\ 1 & \alpha^{o} & 0 & 1 & 0 \\ 1 & \alpha^{r} & 0 & 0 & 0 \\ 1 & \alpha^{c} & 1 & 0 & 0 \\ 1 & \alpha^{s} & \beta^{s} & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} R \\ L \\ C \\ T \\ S \end{bmatrix} \tag{1}$$

where y^{on} is the yield for the on-the-run Treasury security, with y^{off} for the off-the-run Treasury, y^{r} for the Refcorp security, y^{c} for the corporate bond and y^{s} for the swap.

A number of restrictions have been placed on the matrix of factor loadings, which in fact define the unobserved factors. The interpretation of the factors in equations (1) is as follows.

(i) The risk-free rate R is assumed to affect all yields equally, ie each market rate has a loading of one on that factor. Note that the risk-free rate is not just measured by the Treasury rate, which is also affected by the liquidity factor and the idiosyncratic Treasury factor, but is instead defined by the common movements observed across all market yields.

(ii) The liquidity preference factor L is the only factor that affects the spread between on-the-run and off-the-run Treasury securities, as this spread represents a premium that investors are willing to pay for the greater liquidity of on-the-run issues. In interpreting the liquidity factor, we assume that the relative liquidity of on-the-run and off-the-run Treasury securities remained relatively constant over the sample, in which case L reflects investors' preferences for liquidity rather than shifts in the amount of liquidity.[7] The influence of the liquidity factor on

[5] The data on swap rates are from Bloomberg. More recent data on swap rates are available from the Federal Reserve's H.15 data release.

[6] Since February 2001, we have instead used the 10-year par yield from a smoothed yield curve estimated using the yields of the individual securities contained in the Merrill Lynch index, which allows us to precisely obtain a maturity of 10 years.

[7] Of course, the liquidity of these and other securities considered may have shifted over the sample. An analysis of this shift is beyond the scope of this paper.

other market yields is determined by the correlation of movements in those yields with the yield spread between on-the-run and off-the-run Treasury securities.

(iii) The credit risk factor *C* reflects changes in compensation for bearing credit risk, which could reflect shifts both in the perceived amount of credit risk and in investors' willingness to bear credit risk. Note that this factor does not influence the Treasury or Refcorp yields, which have no credit risk. This factor accounts for some of the movements in corporate and swap spreads measured relative to the risk-free rate, although movements in liquidity preferences and idiosyncratic shocks can also affect these spreads.

The final two factors are idiosyncratic shocks to Treasuries *T* and swaps *S*, which are identified because they impact only those particular securities.

(iv) A decrease in the idiosyncratic Treasury factor pushes down Treasury yields relative to all other assets, causing all spreads relative to Treasuries to widen.[8] Note that this shock is distinguished from a credit risk shock because it has an equal impact on all spreads to Treasuries, whereas a credit risk shock has a differential impact according to the credit quality of the asset. The idiosyncratic Treasury factor may reflect any benefits to holding Treasury securities that are not shared by other assets, such as their transparency for balance sheet reporting or their widespread use as collateral in derivatives and repo transactions.

(v) Idiosyncratic swap shocks are identified in a similar manner.

Three of the interest rates included in the exercise - on-the-run Treasury, off-the-run Treasury, and Refcorp security - are free of credit risk, yet they can differ from each other considerably. These differences highlight some important conceptual issues about defining the risk-free interest rate.

According to the decomposition, one reason why the yields of these securities differ is the differences in their levels of liquidity. In fact, because assets are described by both their risk exposures and their liquidity, the risk-free interest rate can only be defined for an assumed level of liquidity. In the results that follow, we define the risk-free rate (the factor *R*) as corresponding to the liquidity level of the off-the-run Treasury security, which is accomplished by imposing the restriction $\alpha^o = 0$.[9]

Even adjusting for liquidity, there is still some difference between the Treasury rates and the risk-free rate, which indicates that some other factor is influencing these yields. In our exercise, we have assumed that this other factor is an idiosyncratic component of Treasury yields.[10] One implication of this assumption is that the risk-free interest rate is not simply given by the return on Treasury securities. Under our decomposition, an investor holding Treasury securities has exposure not just to the risk-free rate, but also to the idiosyncratic Treasury factor. This seems to accord well with recent history: investors holding Treasuries in recent years have clearly been exposed to the risks associated with changes in their supply, as discussed below.

To implement this model, it will be easier to work in terms of deviations from the off-the-run Treasury yield. The system of equations (1), under the restriction that $\alpha^o = 0$, can be rewritten as

$$\begin{bmatrix} y^{on} - y^{off} \\ y^r - y^{off} \\ y^c - y^{off} \\ y^s - y^{off} \end{bmatrix} = \begin{bmatrix} -1 & 0 & 0 & 0 \\ \alpha^r & 0 & -1 & 0 \\ \alpha^c & 1 & -1 & 0 \\ \alpha^s & \beta^s & -1 & 1 \end{bmatrix} \cdot \begin{bmatrix} L \\ C \\ T \\ S \end{bmatrix} \tag{2}$$

8 Duffee (1996) applies a factor-type analysis to short-term market yields and finds that an idiosyncratic component for Treasury bill rates became more evident beginning in the early 1980s.

9 As a benchmark for pricing other assets, one might want to construct a risk-free rate with the same liquidity loading as the asset being priced. Decomposing market rates into these fundamental factors allows one to do so.

10 We could have alternatively assumed that an idiosyncratic factor influenced agency yields, but our readings of the market are that the Treasury securities have had a much larger idiosyncratic component, which has motivated the structure of our model.

With this form, the risk-free interest rate factor drops out of the model, which reduces the dimension of the problem. Once the parameters and factors of the system of equations (2) are identified, the risk-free rate can be recovered using any of the equations in (1).

Working with the model in terms of deviations from the off-the-run Treasury yield also allows us to make adjustments to account for the fact that none of the securities has a maturity of exactly 10 years. This problem is particularly acute for the Refcorp security, which has a fixed maturity date in 2020. With the model written in terms of spreads, we can alter the off-the-run security used for the various individual securities. In the case of the Refcorp security, we derive a zero coupon Treasury yield with the same maturity date as the Refcorp security using our estimated off-the-run Treasury yield curve, which is then used to calculate the yield spread.[11]

A similar maturity problem arises for the on-the-run Treasury security, albeit on a much smaller scale. The on-the-run security has a maturity of 10 years when it is issued, but that maturity then shrinks over time until the next 10-year security is issued, typically three to six months later. Thus, to obtain an appropriate measure of the spread between on-the-run and off-the-run issues, we use our estimated off-the-run Treasury yield curve to create a "synthetic" off-the-run Treasury security that has the same coupon rate and maturity date as the on-the-run 10-year Treasury note. Again, the yield spread is defined relative to the yield on this synthetic security.

The on-the-run yield spread is also strongly affected by the Treasury auction cycle, in that the liquidity of the on-the-run issue drops considerably once a new on-the-run security is issued. As a result, the on-the-run premium tends to jump at the time of a new auction, when the liquidity services will be enjoyed for the longest time period, and then to gradually decline as the next auction approaches.[12] This pattern became more exaggerated in 2000, when the Treasury moved to a schedule of issuing new 10-year notes every six months rather than quarterly. To control for this pattern, we regress the yield spread between the on-the-run security and the synthetic off-the-run security on the number of days until the next auction. The residual from this regression, once adjusted for the average level of the spread, is taken as our measure of the on-the-run yield spread.[13]

All data are weekly averages of daily rates and cover the period from 6 January 1993 to 5 September 2001. The next section describes the procedure for solving for the parameters and unobserved factors from the above decomposition.

3. Method and results

Our identifying assumptions reduced the number of unknown parameters in the matrix given in equations (2) to four. These remaining parameters can be determined by imposing several additional restrictions that still allow us to be quite flexible in our treatment of the covariances of the underlying factors. In particular, we assume that the idiosyncratic Treasury factor and the idiosyncratic swap factor are orthogonal to all other factors. These restrictions correspond to our general interpretation of the shocks as movements specific to just those particular interest rates. In addition, we assume that the liquidity loading of the agency security equals that of the corporate securities, ie $\alpha^r = \alpha^c$. Both are less liquid than off-the-run Treasury securities, although the Refcorp bond may be somewhat more liquid than most of the corporate bonds included in the Merrill Lynch index. Nevertheless, the assumption is probably not violated too strongly.

These assumptions allow us to solve the model quite easily - indeed, recursively. The restriction on the liquidity loadings provides a direct measure of the credit factor:

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11 Of course, maturity differences will still affect the results if the magnitudes of the factors vary across different maturities.

12 One can also think of this pattern in terms of the repo market. Investors are often willing to earn a below market interest rate when they obtain the on-the-run security as collateral (those issues trade "on special"). The premium on the on-the-run issue incorporates the present value of the specialness of the security, as described by Duffie (1996). As the next auction approaches, the horizon for this specialness shrinks, thus reducing its impact on the yield of the on-the-run issue.

13 Making this adjustment is equivalent to adding a deterministic variable to the system of equations (2).

$C = y^c - y^r$.

Moreover, the liquidity factor is determined by the spread between on-the-run and off-the-run Treasury yields:

$L = y^{off} - y^{on}$.

Plugging this factor into the equation for the Refcorp spread yields:

$(y^r - y^{off}) = \alpha^r \cdot (y^{off} - y^{on}) - T$.

Because we have assumed that the factor T is orthogonal to the other factors, this equation can be estimated by an OLS regression, where the estimated coefficient determines α^r. The sum of the constant and the residual from the regression defines the idiosyncratic Treasury factor T. Similarly, an equation for the swap spread can be derived as follows:

$(y^s - y^{off}) = \alpha^s \cdot (y^{off} - y^{on}) + \beta^s \cdot (y^c - y^r) - T + S$.

The variable $(y^s - y^{off}) + T$ can therefore be regressed on the variables $(y^{off} - y^{on})$ and $(y^c - y^r)$ to recover the coefficients α^s and β^s, and the sum of the constant and the residual defines the idiosyncratic swap factor S.

Applying this approach, we recover all of the factors and coefficients from the system of equations (2).[14] Given those variables, it is straightforward to recover the risk-free rate from any of the equations in (1). Using the equation for the off-the-run Treasury yield, the risk-free rate is

$R = y^{off} - T$,

which indicates that the Treasury yield deviates from the risk-free rate by the idiosyncratic Treasury factor.

The estimated parameters from the decomposition are summarised in Table 1. All of the estimated factor loadings are significant with the expected signs. The estimates indicate that the liquidity factor pushes up agency, corporate and swap yields relative to off-the-run Treasuries, ie αr and αs are positive. The loading on liquidity for swaps is greater than that for agency and corporate securities, which may reflect the fact that the Refcorp security is fairly liquid. The loading on credit risk for the swap is about 58% of that for AA corporate bonds. Thus, the results indicate that swaps do have exposure to credit risk, although much less so than AA corporate bonds.

Table 1

Estimated parameters of the decomposition

Parameter	Coefficient	t-statistic
α^r	0.249	3.08
α^s	0.762	9.42
β^s	0.577	14.74

t-statistics are corrected for heteroskedasticity and serial correlation in the errors.

Swaps may have less exposure to credit risk than AA corporate bonds in part because the investor in a swap is not lending the principal amount to a specific AA firm for the duration of the contract.[15] The

[14] The variance-covariance matrix of the yields in (1) includes 15 observations, and the model has 11 unknown parameters, which leaves four overidentifying restrictions. We do not focus on testing the model using those restrictions but simply note that the restrictions are not strongly violated.

[15] The determinants of swap spreads are discussed by Lang et al (1998).

credit risk component of the swap rate arises from its ties to the Libor rate, which is a short-term borrowing rate paid by firms primarily with AA credit ratings.[16] More specifically, the forward rate on the swap is linked to the rate at which an investor would commit today to lend to a firm that is in the Libor panel in, say, 10 years. But the panel of firms used in determining the Libor rate changes over time, so that firms that fall into financial difficulty could be dropped from the panel. Moreover, even among the banks included in the panel, the four highest and four lowest borrowing rates are excluded in computing Libor, thus removing those firms paying the highest credit spreads. In contrast, the forward rate on the AA corporate bond is the rate at which the investor is willing to commit today to lend to a specific firm in 10 years, which may be a riskier prospect.

With the model solved, one can describe financial market developments in terms of the underlying factors rather than in terms of market interest rates. Note that the matrix multiplying the unobserved factors in equations (1) is invertible, allowing one to express the unobserved factors as linear combinations of the observed market interest rates. The five factors derived from the decomposition are shown in Figure 1. We will describe their behaviour first by going through a chronology of events in US fixed income markets, allowing these factors to help interpret those events, and then by reporting on their statistical properties over the period in the next section.

Policy tightening in 1994. As the Federal Reserve tightened monetary policy beginning in February 1994, market participants continued to mark up the expected path of policy, causing long-term risk-free interest rates to rise considerably. In fact, the risk-free rate accounts for most of the movement in market rates during this period. The credit risk factor widened, perhaps reflecting some concern that the policy tightening might slow the economy too much. However, this widening was modest, suggesting that those concerns were not severe.

Narrowing spreads from 1995 through the first half of 1998. This period was characterised by the remarkable stability of the economy and of monetary policy. The federal funds rate was reduced in three steps by a cumulative 75 basis points over six months beginning in July 1995, but was then adjusted only once over the subsequent two and a half years. The economy grew at a steady and robust pace over this period, and inflation gradually declined. The impressive growth of the economy and the benign inflation environment appeared to depress various risk spreads in fixed income markets. Long-term risk-free interest rates declined steadily over this period, perhaps reflecting a decline in the interest rate risk premium. Credit spreads also narrowed somewhat, reaching a trough in late 1997. The liquidity factor remained relatively steady at a fairly narrow level, as did the idiosyncratic Treasury and swap factors.

Flight to quality in 1998. The relative stability of the economy and financial markets changed suddenly in autumn 1998. The events of that time are widely known and have been generally described as a flight to quality.[17] In terms of our model, the events involved a sharp increase in both the liquidity preference factor and the credit risk factor. The increased liquidity preference explains the large spreads between on-the-run and off-the-run Treasury securities observed at that time, while increased concern about credit risk generated the strong tiering of yield spreads across credit quality in corporate and agency bond markets. The model above imposes no restrictions on the covariance between the credit risk and liquidity factors, and in fact they are significantly positively correlated: When investors become more concerned about credit quality, they also generally prefer more liquid assets. The developments in autumn 1998 were an outsized example of this behaviour.

Policy tightening in 1999 and early 2000. The US economy navigated through the financial market disruptions of autumn 1998 without major problems, and by early 1999 economic growth was clearly outstripping the economy's potential to produce. In response, the Federal Reserve began to tighten monetary policy in May 1999 and continued to do so in a string of six policy moves through May 2000. The policy tightenings implemented and the expectations of more to come pushed up the risk-free interest rate substantially - by nearly as much as in the 1994 tightening episode, even though the cumulative rise in the funds rate was much smaller. The credit risk factor and the liquidity preference

[16] The Libor rate is computed by the British Bankers' Association as the trimmed average of the eurodollar deposit rate offered by a panel of 16 banks. See www.bba.org.uk for more details.

[17] The events of autumn 1998 are reviewed in detail in a report by the Committee on the Global Financial System (1999) published by the Bank for International Settlements.

factor both remained at levels well above those observed over the previous few years, and the credit risk factor began to widen more in early 2000.

Widening spreads in 2000. By mid-2000, US economic growth began to moderate from its rapid earlier pace. The long-term risk-free rate declined from its peak in the spring of 2000, as market participants gradually altered their expectations that policy would continue to tighten. The slowing economy and falling stock prices contributed to a considerable rise in the credit risk factor over this period, while the liquidity preference factor narrowed. The idiosyncratic Treasury factor, which had barely budged since 1993, fell sharply in early 2000, moving about 30 basis points lower by April of that year. This movement probably reflects the concerns about the potential scarcity of Treasury securities that emerged at that time, which may have resulted in a sizeable premium on Treasury securities, as discussed in much more detail in the next section.

Sizeable policy easing in 2001. Towards the end of 2000, it became increasingly apparent that the economy was slowing more abruptly than had been expected. Long-term risk-free rates began to decline sharply in November 2000 in anticipation of monetary policy easing. In the event, the Federal Reserve eased policy quickly and by sizeable amounts beginning in January 2001, lowering the federal funds rate by 3 percentage points by early September. Having fallen ahead of the policy actions, the risk-free rate fluctuated in a narrower range after the easings began as market participants assessed the extent of the slowdown and the prospects for a pickup in economic growth. The credit risk factor narrowed somewhat once the easings began, while the Treasury and liquidity factors held relatively steady. Interestingly, the idiosyncratic swap factor became much larger in 2001.

4. The shifting behaviour of market interest rates

The decomposition offered in the previous section allows policymakers and market participants to focus on the fundamental factors that determine movements in market interest rates. But this narrative also suggests that the relative importance of the factors shifts over time. Indeed, our results indicate that a number of factors have become larger and more volatile in recent years. Table 2 shows the average levels and weekly changes of all the factors, dividing the sample into three subperiods to highlight the behaviour of the factors in recent years. Shifts in the size or volatility of various factors are indicated by the bold entries in the table.

Table 2

Recent behaviour of the factors

(basis points)

	1993:1 to 1998:2	**1998:3 to 1999:4**	**2000:1 to 2001:3**
Average levels			
Risk-free rate	660	577	613
Credit risk	31	**51**	**90**
Liquidity	11	**28**	**16**
Idiosyncratic Treasury	– 10	– 9	**– 28**
Idiosyncratic swap	– 10	– 7	– 9
Average weekly changes			
Risk-free rate	8.0	8.6	7.5
Credit risk	1.6	**2.5**	**3.1**
Liquidity	1.0	**1.9**	**1.3**
Idiosyncratic Treasury	0.9	0.7	**1.3**
Idiosyncratic swap	1.3	**3.3**	**2.9**

The shifts in the behaviour of the underlying factors have numerous implications for the information content of market interest rates. Here we focus on two broad conclusions that might be particularly relevant to monetary policymakers.

(i) Treasury yields have become increasingly divorced from the risk-free rate

Over much of the sample, the yield on the off-the-run Treasury security provided an effective measure of the 10-year risk-free interest rate. According to equation (1), the Treasury yield deviates from the risk-free rate by the idiosyncratic Treasury factor. This factor was remarkably flat from 1993 through 1999, leaving the Treasury rate below the risk-free rate by a nearly constant amount, as is apparent from Figure 2.[18] However, as pointed out above and shown in Table 2, the idiosyncratic Treasury premium has become much larger since 2000, pushing the Treasury rate down relative to other market interest rates and increasing the wedge between the Treasury yield and the risk-free interest rate.[19]

The decline in Treasury yields relative to all other market yields in early 2000 may have resulted from a "scarcity premium" on Treasury securities. Indeed, the publication in early 2000 of the CBO's forecasts for sizeable surpluses over the coming decade and the Treasury's implementation of a debt buyback programme and other debt management decisions seemed to focus the market's attention on the possibility that the Treasury would pay down a considerable amount of its outstanding debt over the coming decade. Concerns that Treasury securities would become increasingly scarce appeared to have a considerable impact on the yields of those securities, particularly at longer maturities where fewer safe and liquid substitutes are available.

These developments can be characterised using a simple diagram depicting overall supply and demand conditions for longer-term Treasuries as in Figure 3, which is repeated from Reinhart and Sack (2000). Traditional finance models, such as the capital asset pricing model (CAPM), suggest that premiums for holding Treasury securities relative to other fixed income assets should be quite small and that the demand for Treasuries should be very sensitive to interest rates. In that case, even large changes in the supply of Treasury securities would have only small consequences for Treasury yields, and thus concerns about supply could not account for the sizeable movement in the idiosyncratic Treasury factor.

The recent movements in relative yields instead suggest that the demand schedule for Treasury securities is everywhere well below the CAPM curve and becomes very inelastic at lower levels of supply, as shown in the figure. The relatively low level of the demand curve reflects the value that investors place on the liquidity of Treasuries, a characteristic not captured in the CAPM model. And the demand schedule probably contains an inelastic portion at lower quantities because of the heterogeneity of investors. In particular, there are some types of investors who place very high value on the safety and liquidity of Treasury securities.[20]

Under this demand schedule, large shifts in the supply of Treasury securities could have important consequences for the pricing of those securities, as the shrinking supply of Treasuries would increasingly be held by those investors willing to sacrifice the most yield to hold them. Of course, actual supply did not suddenly drop to the inelastic portion in early 2000. But the prospect that supply might reach that region within a couple of years, along with the forward-looking behaviour of markets, may have had a substantial impact on current longer-maturity Treasury yields. Investors also faced considerable uncertainty about the speed and magnitude of the paydown in Treasuries and about the

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18 Because there is no idiosyncratic factor affecting the Refcorp yield, any portion of the spread between the Refcorp and the off-the-run Treasury yields not explained by liquidity must be attributed to the Treasury factor, which pushes it away from the risk-free interest rate by this constant amount. However, the more interesting focus of the model is on the movements in the factors, not on the constant terms.

19 A research report by Lehman Brothers (see Kocic et al (2000)) reaches a similar conclusion using a different methodology. They assume that the risk-free rate is a random walk and apply a Kalman filter approach, controlling for liquidity and credit risk in a manner similar to ours.

20 Included in that set are probably foreign official institutions, which might be very concerned about avoiding losses on their portfolio and about being able to liquidate positions quickly.

shape of the demand schedule in that region, which may have made the idiosyncratic Treasury factor more volatile as well.

The larger idiosyncratic premium on Treasury securities raises the question of whether some other asset could serve as a better proxy for the risk-free interest rate. Indeed, there has been considerable discussion about a possible transition to interest rate swaps as a "benchmark" for the pricing and hedging of other fixed income assets. Our results indicate that swaps do not represent a benchmark for the risk-free rate, but instead one that has less credit risk than most corporate bonds.[21] Indeed, as shown in Figure 2, the swap rate has deviated from the risk-free rate by more than the Treasury rate in recent years, reflecting the impact of the credit risk and liquidity factors.

Of course, the fact that swaps have some credit risk may be an important advantage to becoming a benchmark for the pricing and hedging of private instruments. Much of the discontent with Treasuries as a hedging instrument began in autumn 1998, when the flight to quality discussed above pushed down Treasury yields and pushed up lower-rated corporate yields. Unlike Treasuries, swaps have exposure to both the credit risk and liquidity preference factors, the two factors influenced by the flight to quality, which makes them more comparable to corporate bonds. Thus, swaps would have provided a better hedge for corporate bonds during that period.

Nevertheless, swaps appear to also have a significant idiosyncratic factor that reduces their effectiveness as a hedging instrument, and that component became larger in 2001 (see Figure 1). It is not clear at this point why the swap rate became more idiosyncratic in 2001. One conjecture is that this pattern reflects the increased use of swaps as hedging instruments, which may cause their rates to be influenced by the amount of corporate bond issuance or prepayment risk on mortgage-backed securities. In addition, the government-sponsored enterprises (GSEs) have reportedly been very active in the swaps market in recent years. Changes in their behaviour or strategies could introduce variation in swap rates that would be viewed as idiosyncratic in this model.[22]

(ii) Spreads between various yields have been increasingly influenced by a number of different factors

Spreads between various yields have become harder to interpret in recent years because they have been increasingly influenced by a number of different factors. Of course, the impact of those factors on any given spread will depend on the factor loadings of the securities involved. Above, we identified the loadings for five different assets. But if the factors identified truly represent fundamental influences on asset prices such as liquidity preference, credit risk and risk tolerance, then one would expect them to have some influence on the prices of a wider range of financial assets. In particular, it may be interesting to look at the behaviour of corporate bonds with lower credit ratings, such as the Merrill Lynch BBB corporate bond index.

We can measure the factor loadings of BBB corporate bonds simply by regressing the BBB yield on our factor measures. In doing so, we impose that its loading on the risk-free rate is one and its loadings on the idiosyncratic Treasury and swap factors are zero. Under those assumptions, the regression indicates that the BBB yield responds significantly to the liquidity and credit risk factors, with loadings of 1.82 and 1.48 respectively. Note that the lower-rated corporate yield has a significantly higher loading on both the liquidity factor and the credit factor in comparison to the AA yield (which has loadings of 0.25 and 1.00 respectively) and the swap rate (0.76 and 0.58 respectively). The higher loading on the liquidity factor is consistent with the fact that lower-rated bonds are generally less liquid than many higher-rated issues.

Figure 4 shows the resulting factor decompositions for the AA and BBB corporate yield spreads measured relative to on-the-run Treasury securities, which is still the most common quoting convention. The average levels of these yield spreads and the various components are detailed in Table 3. For both the AA and BBB corporate bonds, the credit risk factor accounted for a sizeable

21 Conversely, Kocic et al (2000) argue that swaps have become a better proxy for the risk-free rate than Treasuries.

22 If we regress the yield on the 10-year Fannie Mae benchmark security since 1998 (the beginning of that programme) on the five factors, we find that the swap factor enters with a strongly significant coefficient. This supports the notion that there is some linkage between the swap factor and the behaviour of the GSEs.

portion of the average yield spreads from 1993 through the first half of 1998, although the liquidity factor and the Treasury factor also importantly contributed to the spreads.

Both corporate yield spreads jumped higher over the period from the second half of 1998 through 1999, but that widening cannot be attributed entirely to credit risk. In each case the heightened preference for liquidity contributed at least as much to the widening of the spread as did the increase in credit risk. Over the period beginning in 2000, both yield spreads again increased sharply. According to the results, the credit risk factor accounted for most of the increase in spreads. But the increase in the idiosyncratic Treasury factor at that time contributed about 20 basis points to the average spread widening. Overall, these results emphasise the importance of considering factors other than credit risk for interpreting corporate yield spreads, as both liquidity and Treasury-specific factors have strongly influenced yield spread movements in recent years.

Table 3

Average level of corporate yield spreads

(basis points)

	1993:1 to 1998:2	1998:3 to 1999:4	2000:1 to 2001:3
AAA yield spread			
Total spread	54.7	94.5	138.2
Due to:			
Credit risk	31.2	51.3	90.1
Liquidity	13.7	34.5	20.3
Idiosyncratic Treasury	9.8	8.7	27.7
BBB yield spread			
Total spread	103.5	186.3	222.6
Due to:			
Credit risk	46.3	76.0	133.6
Liquidity	31.0	78.0	45.9
Idiosyncratic Treasury	9.8	8.7	27.7

Spreads are measured relative to on-the-run Treasury securities. For the BBB yield spread, the components do not add up to the total spread because of the constant and the residuals from the regression.

Another interesting development in US fixed income markets in recent years has been a striking increase in the volatility of the yield spreads between various US fixed income securities, as shown in Figure 5. Table 4 provides some details on this behaviour for both corporate and swap yield spreads. The volatilities of these yield spreads jumped in the more recent subperiods to several times their earlier levels, even though the volatilities of the rates themselves changed only modestly. The factor decomposition offers some explanation of these patterns. The volatility of the risk-free rate - the common component of all yields - did not change much (see Table 2), thus keeping the volatilities of all of the market interest rates relatively steady. However, the volatilities of other factors became elevated in the more recent periods, resulting in the greater variation in yield spreads. The liquidity factor was particularly volatile in the 1998-99 subperiod, while the idiosyncratic Treasury factor was more volatile over the period beginning in 2000. In addition, both the credit risk factor and the idiosyncratic swap factor were very volatile during both of the more recent periods.

The fact that numerous factors were at work can explain the breadth of the increase in volatility across different instruments. Looking down the left-hand side of Figure 5, the volatilities of all spreads relative to the on-the-run Treasury yield (the ones included in Table 4) increased considerably, reflecting the greater variation in the idiosyncratic Treasury factor, the liquidity factor and the credit risk factor. The right-hand side of the figure more closely isolates the contributions of individual factors. Notable increases are observed in the volatility of the spread between the on-the-run and off-the-run Treasury yields, reflecting the liquidity factor, and in that of the spread between the Refcorp and off-the-run Treasury yields, largely reflecting the idiosyncratic Treasury factor. Lastly, even spreads between the yields of corporate bonds with different credit standings became more variable, reflecting greater variation in both liquidity preference and credit risk.

Table 4

Average absolute value of weekly changes

(basis points)

	1993:1 to 1998:2	1998:3 to 1999:4	2000:1 to 2001:3
Yields			
On-the-run Treasury	8.2	8.8	8.0
Swap	8.2	8.7	8.0
AA corp	7.8	8.8	7.0
BBB corp	7.8	8.7	7.8
Spreads			
AA - Treasury	1.2	2.9	3.0
BBB - Treasury	1.4	3.4	3.8
Swap - Treasury	0.9	2.9	3.4

Spreads are measured relative to on-the-run Treasury securities.

5. Conclusions

Overall, this paper suggests that it is more informative to focus on movements in the fundamental factors influencing market interest rates than on the market rates themselves. This paper offers a decomposition of market interest rates into five fundamental factors based on the co-movements of the yields on different types of US fixed income assets. Those factors offer a sharper interpretation of market events since 1993, thus providing policymakers with useful information for formulating appropriate policy decisions. Similarly, market participants would also benefit from understanding the fundamental factors driving movements in fixed income prices, which would allow them to more accurately assess the risks and potential rewards associated with their investment and hedging strategies.

In addition, the analysis suggests that significant shifts in the importance of the underlying factors have taken place in recent years, with important consequences for interpreting market interest rates. The increased variation of a number of different types of shocks in recent years has made it more difficult to derive information from individual market rates or spreads. Two examples were highlighted in the paper: Treasury yields have become increasingly separated from the risk-free interest rate, and corporate yield spreads have been increasingly influenced by shocks other than credit risk. As a consequence, policymakers should rely more heavily on using the co-movements in yields across a number of different securities to effectively identify movements in the fundamental factors that drive the markets.

Figure 1

Unobserved factors

Risk-free interest rate factor

Other factors

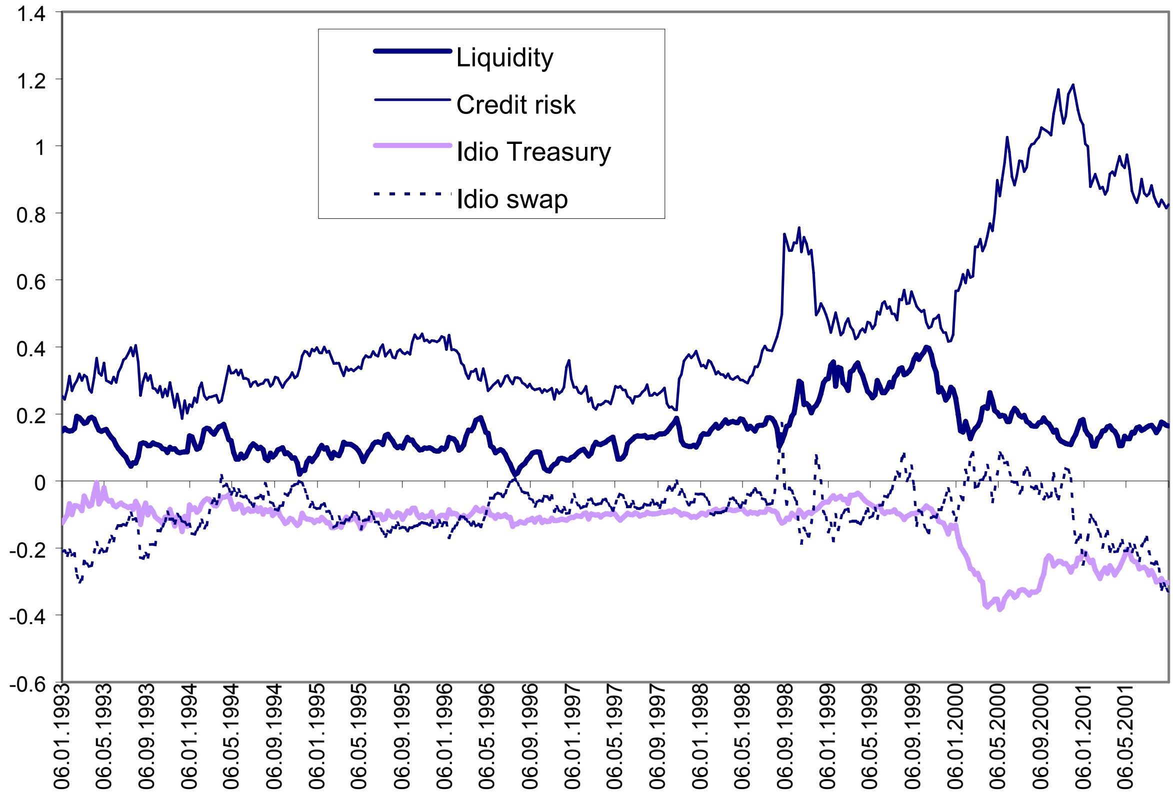
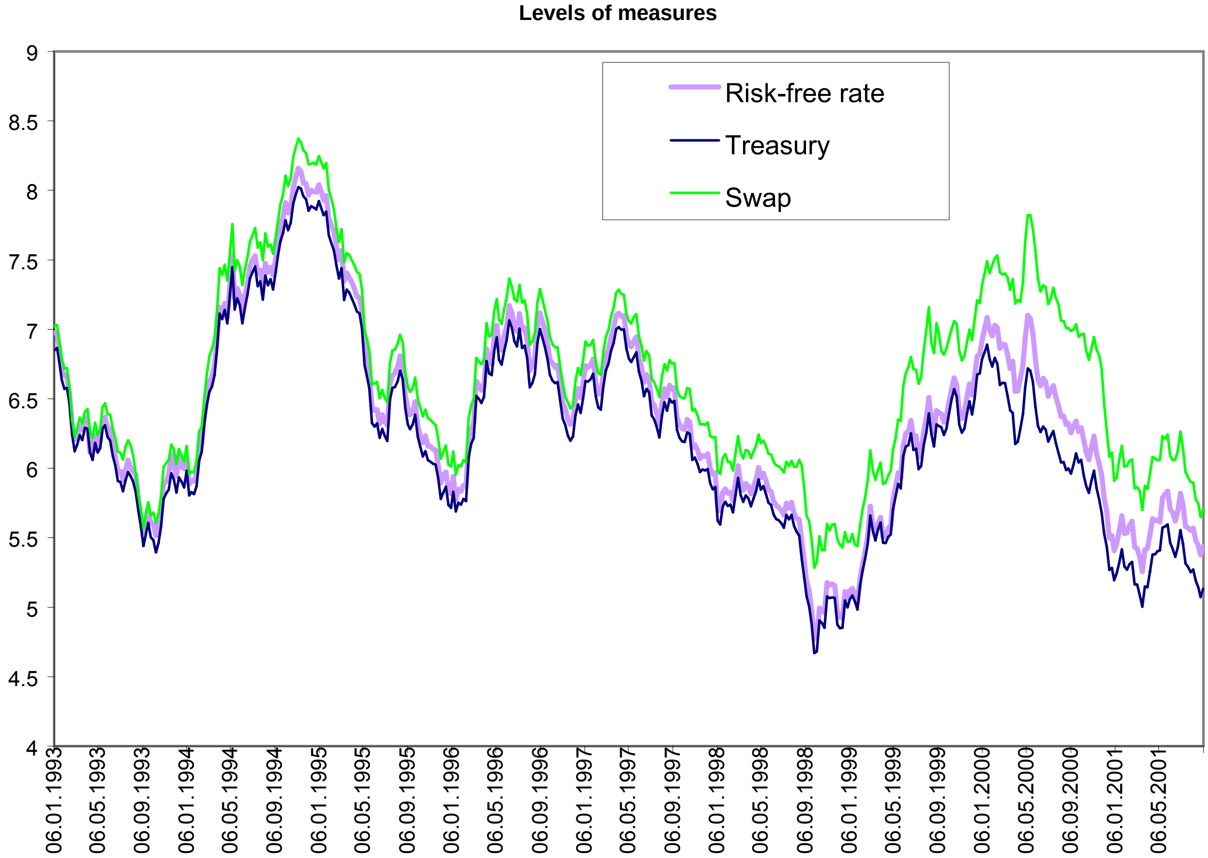


Figure 2

Measures of the risk-free interest rate



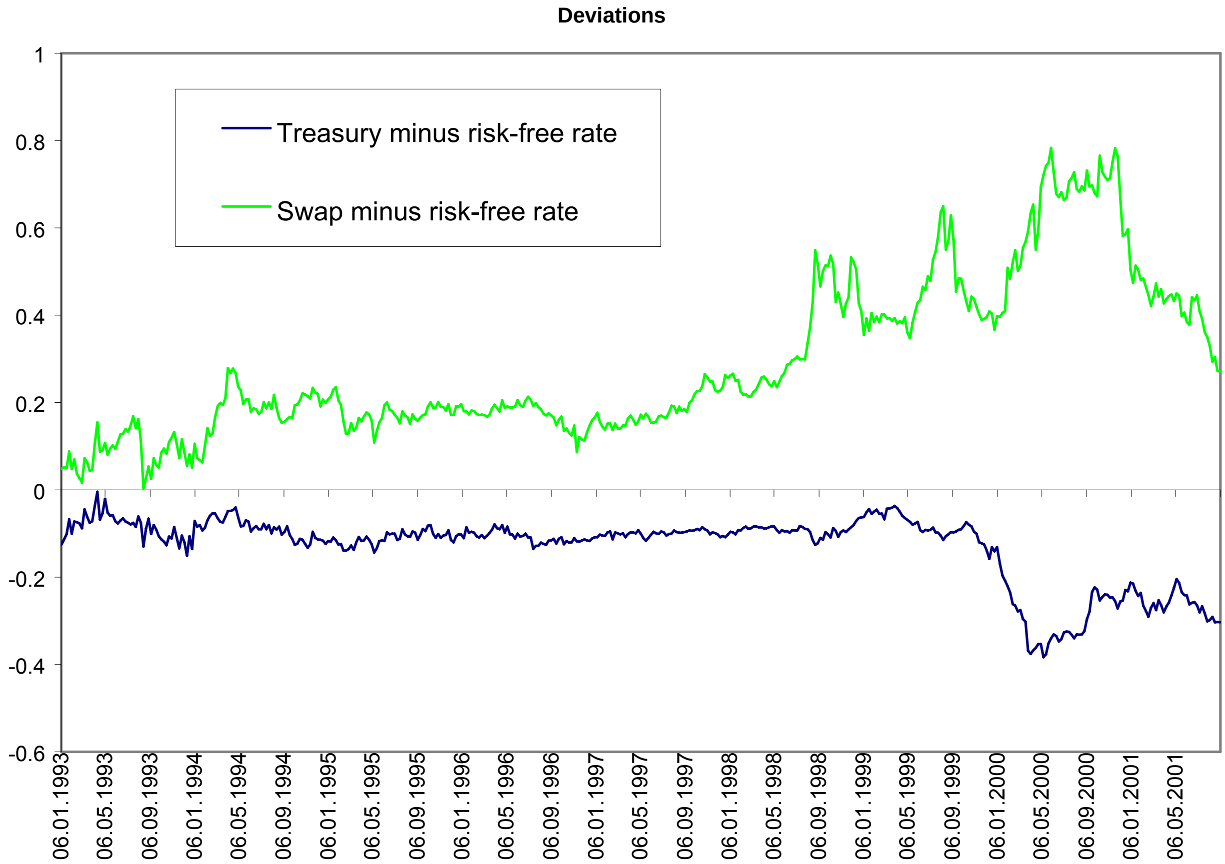


Figure 3
Demand and supply for Treasury securities

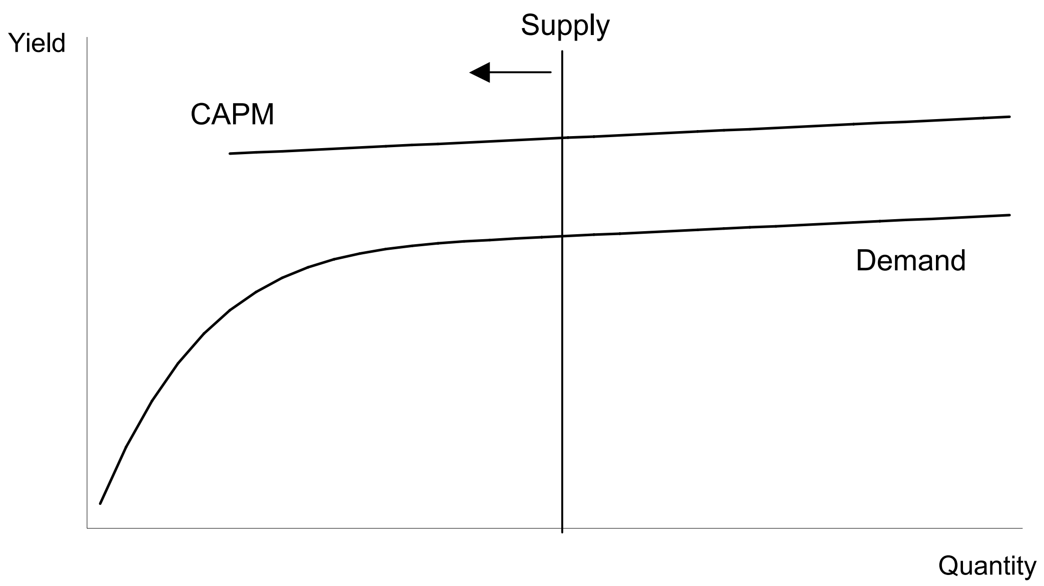
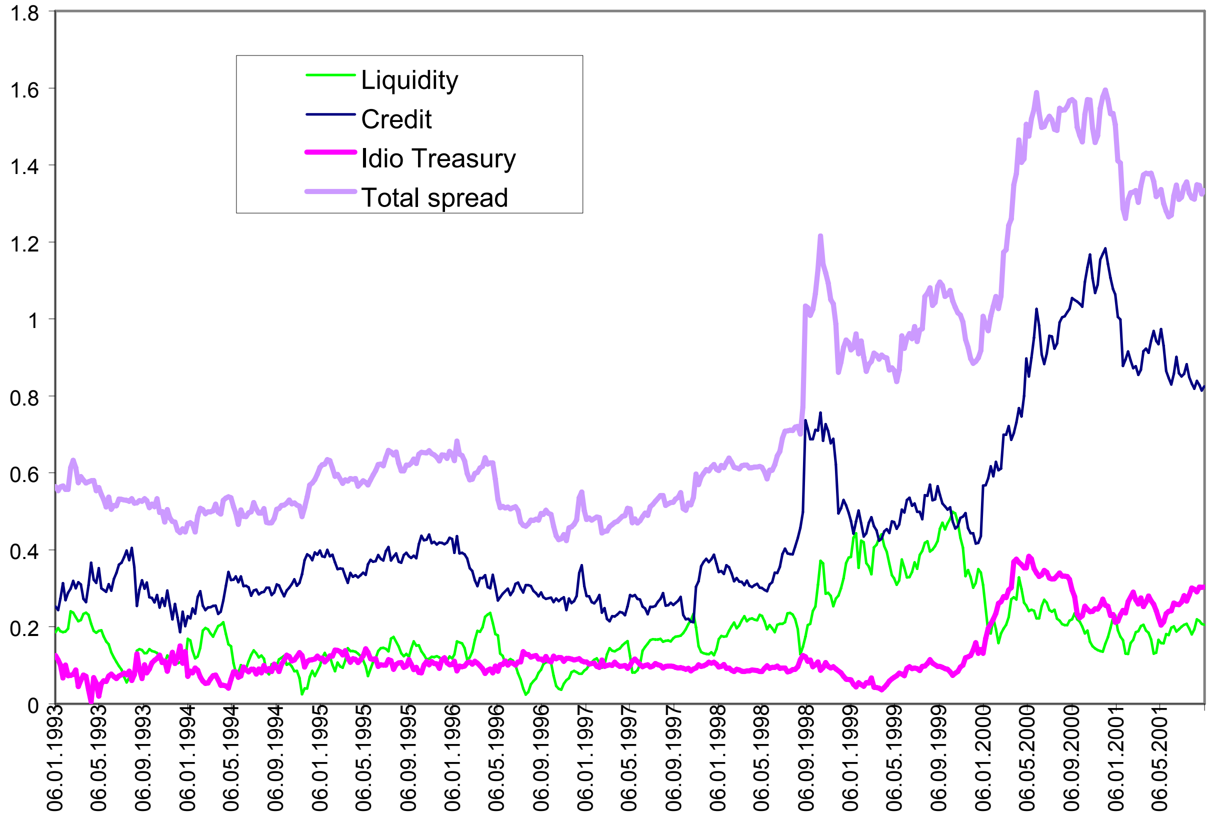


Figure 4

Corporate yield spreads and components

AA spread over on-the-run Treasury



BBB spread over on-the-run Treasury

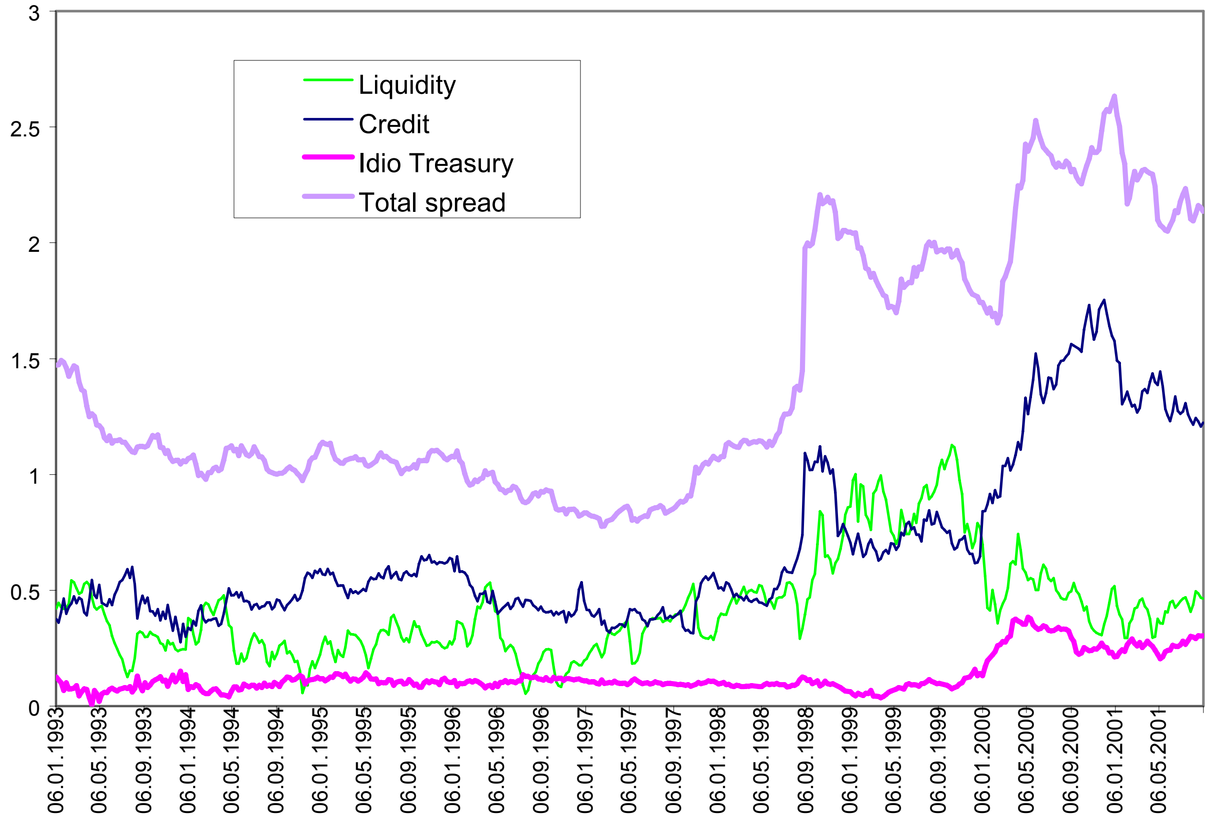
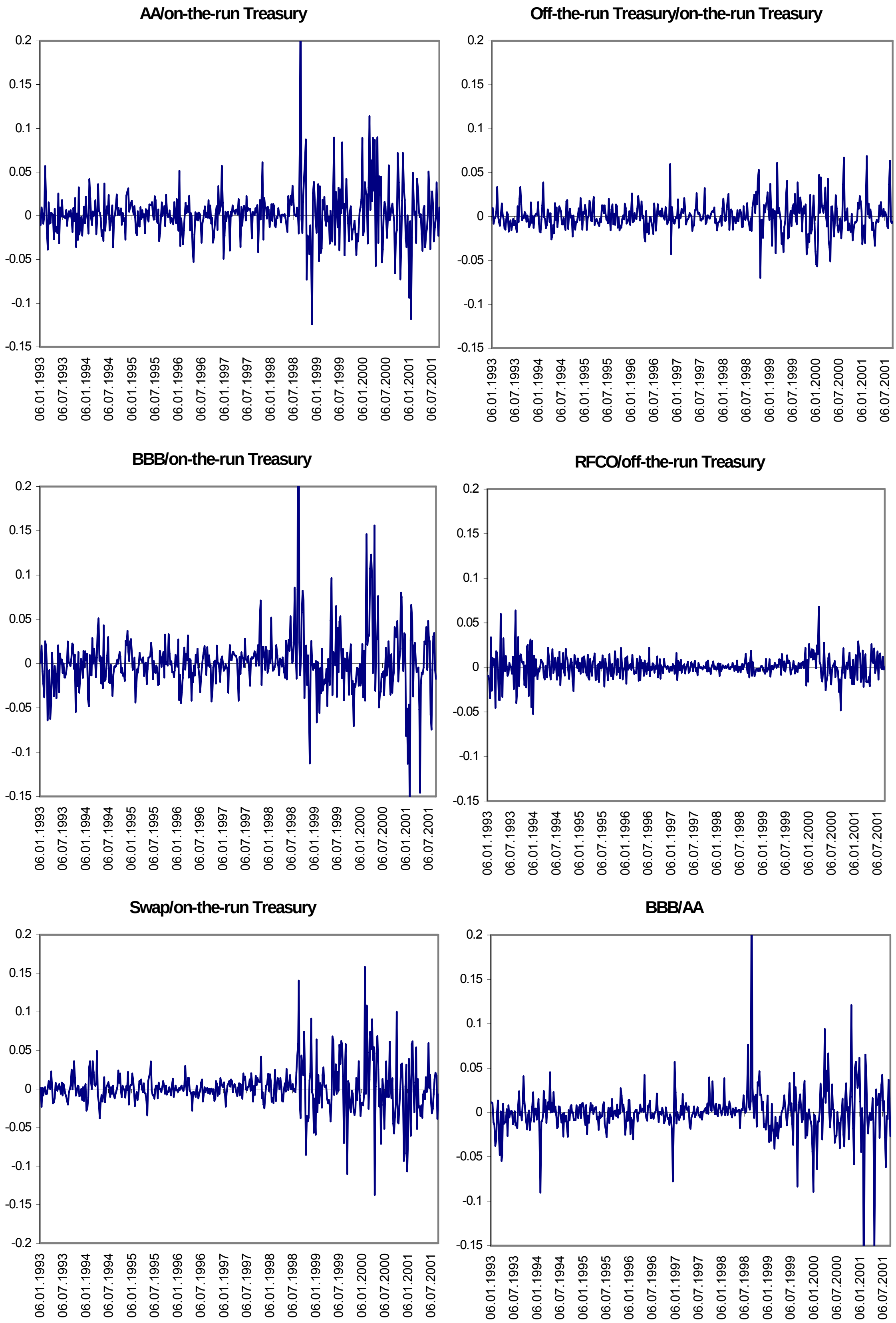


Figure 5
Weekly changes in yield spreads



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Inflation targeting in Brazil: shocks, backward-looking prices and IMF conditionality

Joel Bogdanski, Paulo Springer de Freitas,
Ilan Goldfajn and Alexandre Antonio Tombini,[1]
Central Bank of Brazil

Abstract

This paper examines the recent evolution of monetary policy since the adoption of formal inflation targeting in Brazil. We argue that the new policy framework has been subject to a severe test in its first years of existence, represented by external shocks, eg oil prices, and increased international financial volatility. Moreover, we examine some selected issues that deserve due consideration given their importance to the conduct of monetary policy. The first issue is the presence of a substantial portion of prices with backward-looking adjustment, a fact that affects monetary policy reaction since it reduces the efficiency of domestic interest rates in controlling inflation. The second addresses the question of how inflation targets should be monitored in a country that has an ongoing economic programme with the International Monetary Fund. This last issue is particularly important when considering the effects of shortening monitoring horizons on the variability of inflation and output.

1. Introduction

In mid-January 1999, Brazil abandoned its crawling exchange rate band regime. Surprisingly enough, the country's economic performance in the aftermath of this episode was much better than expected, given the performance of other emerging market economies after a move towards floating. In fact, despite the large devaluation of the domestic currency that followed the regime shift, GDP grew 0.8% in 1999 and 4.6% in 2000, while consumer price inflation behaved much in line with the declining targets established in mid-1999, of 8% and 6%, respectively.

This paper examines the main factors that helped Brazil withstand the negative effects of a change in the exchange rate regime and enabled the economy to recover rapidly, namely, the combination of fiscal restraint with a well defined purpose for monetary policy. The following section describes the macroeconomic background that culminated in the currency devaluation, the volatile expectations environment that followed, and the evolution of monetary policy in the transition to inflation targeting.

Section 3 presents a stylised model that we use in our discussion of the transmission mechanism. Section 4 discusses the transmission mechanism, highlighting the main channels, the lag structure and the exchange rate pass-through. These issues are presented with a prospective view of their evolution as the economy converges to its new steady state.

The model outlined in Section 3 serves as the basis for the simulations performed in Sections 5 and 6. Section 5 describes how monetary policy has reacted to shocks since the implementation of the inflation targeting regime based on inflation forecasting. We examine the Central Bank's track record in responding to all sorts of shocks, including international oil prices, food prices and volatility in international financial markets. Given the relative weight of institutionally backward-looking prices in the consumer basket, we decompose the model into inertial prices and market prices to show how the institutional framework in Brazil affects the transmission mechanism of monetary policy and therefore its instrument's efficiency when reacting to shocks.

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[1] The opinions in this paper reflect the authors' view, and not necessarily the official position of the Central Bank of Brazil. Needless to say, any errors are our own responsibility.

Section 6 focuses on alternative ways to monitor the performance of monetary policy under inflation targeting. This issue is especially relevant when a country has an ongoing programme with the IMF, since the traditional quarterly reviews demand a monitoring horizon much shorter than that of the targeting economy. We show that if the higher frequency targets are not set in accordance with the lower frequency ones, and if policymakers try to meet all the targets, there will be suboptimal outcomes in terms of inflation and output variability. Section 7 concludes.

2. Macroeconomic background[2]

The Brazilian economy has undergone significant structural changes in the last decade. In the early 1990s the country's real income remained stagnant, with low investment and saving rates, and very limited access to international capital markets. Inflation was high and rising, helping to conceal the serious structural imbalances of the public sector and making it extremely difficult to carry out even the simplest planning activities. Brazil started to make real progress in economic and financial stability only from 1994, with good results in terms of inflation, growth, trade liberalisation and international insertion. Despite this relative success, critical problems remained to be addressed, mainly the rising deficits in the current account and the deterioration of fiscal position. It is important to discuss this macroeconomic evolution in order to understand the current economic environment, characterised by a consistent combination of inflation targeting, floating exchange rate and fiscal discipline.

2.1 From exchange rate based stabilisation to floating

The stabilisation programme known as the Real Plan was successful in putting an end to Brazil's history of chronic high inflation. It was preceded by a minimal fiscal adjustment and followed by tight monetary control. The key issue was to coordinate a deindexing process to break the inflationary inertia, since the automatic price adjustments to past inflation were not synchronised. The solution was the introduction in March 1994 of a new unit of account, the unified reference value (URV), whose value the Central Bank fine-tuned on a daily basis in line with the loss of the currency's purchasing power. All prices and wages, as well as the exchange rate, were denominated in URV. Prices were converted directly, while wages were converted by their average past purchasing power. Then, on 1 July 1994, the indexation mechanism was extinguished and the URV became the new currency, called the real. Demand pressures naturally arose with the sharp inflation decline - for example, the reduction of inflation tax alone accounted for an additional disposable income of R$ 15 billion in the subsequent 12 months - and a very tight monetary policy was needed to counter these pressures, mainly with high real interest rates and stringent credit restrictions.

Even though the stabilisation programme was correctly conceived with due attention to fiscal austerity, the implementation of the comprehensive agenda of structural reforms was much slower and more difficult than had been expected, especially when legislative support was needed. On the other hand, the international financial environment seemed favourable, and the Brazilian economy re-entered the route of foreign investment after the rescheduling of its external debt within the Brady Plan. With these perspectives, it was natural for policymakers to concentrate first on the fight against inflation and indexation, since the immediate results on this front would determine the future of stabilisation, and there seemed to be enough time to address the remaining fundamentals.

Another key issue in the first phases of stabilisation was the choice of a suitable exchange rate policy. The monetary authorities decided to start with a float, which immediately led to a continuous nominal appreciation, given that the high real interest rates were effectively attracting capital inflows. The Mexican crisis in late 1994 prompted a shift to a crawling band regime, which was formally adopted in March 1995. From July 1995 to mid-January 1999, exchange rate policy was conducted on the basis of an annual devaluation target of around 7.5%. The price stabilisation plan was successful, since the

2 In outlining this section we greatly benefited from internal documents of the Central Bank Research Department, in particular the unpublished manuscript by Fachada (2000).

economy eliminated short-run indexation practices, and annual inflation dropped from 929% in 1994 to less than 2% in 1998.

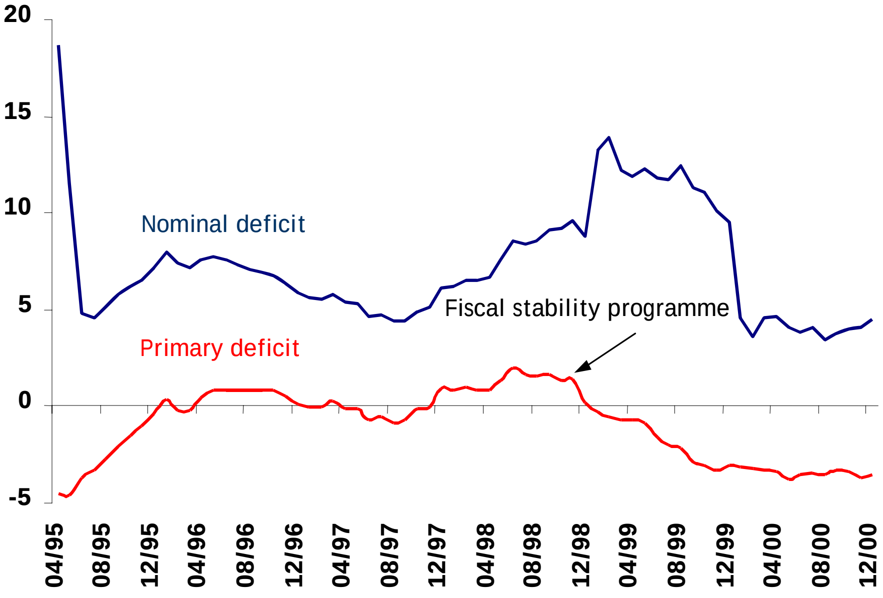
The stabilisation process included a wide programme of economic reforms. The size of the public sector was substantially reduced through privatisation of state companies operating in sectors like telecommunications, chemistry, steel, railroads, banking and mining. Likewise, trade liberalisation was deepened through the reduction of import tariffs and elimination of non-tariff barriers. The financial system was submitted to a full-fledged restructuring: unsound institutions were liquidated, merged or restructured; prudential regulation was updated; and supervision was reorganised to take a more preventive approach. This strengthening of the financial system was a crucial element in the country's reaction to the external crises that were to come.

The fiscal position gradually worsened, however, as the success in reducing inflation brought to light the masked structural imbalances of the public accounts. The initial fiscal adjustment was recognised as insufficient, but efforts to bring about a sounder fiscal environment were frustrated as several constitutional reforms of high priority to the government remained stuck in the congressional agenda. The absence of a further fiscal adjustment, combined with continued high interest rates and sterilised intervention - which were required to support the exchange rate policy - produced adverse fiscal results, with nominal deficits often tied in with primary deficits (Figure 1). Currency appreciation, growth of domestic demand and incentives to short-term capital inflows resulted in a rapid growth of the current account deficit. At the time, the good overall performance of the world economy seemed to guarantee a sufficient amount of private capital flows to finance the Brazilian balance of payments, but confidence shocks were soon to come.

Figure 1

Public sector borrowing requirement

(as a percentage of GDP in 12 months)



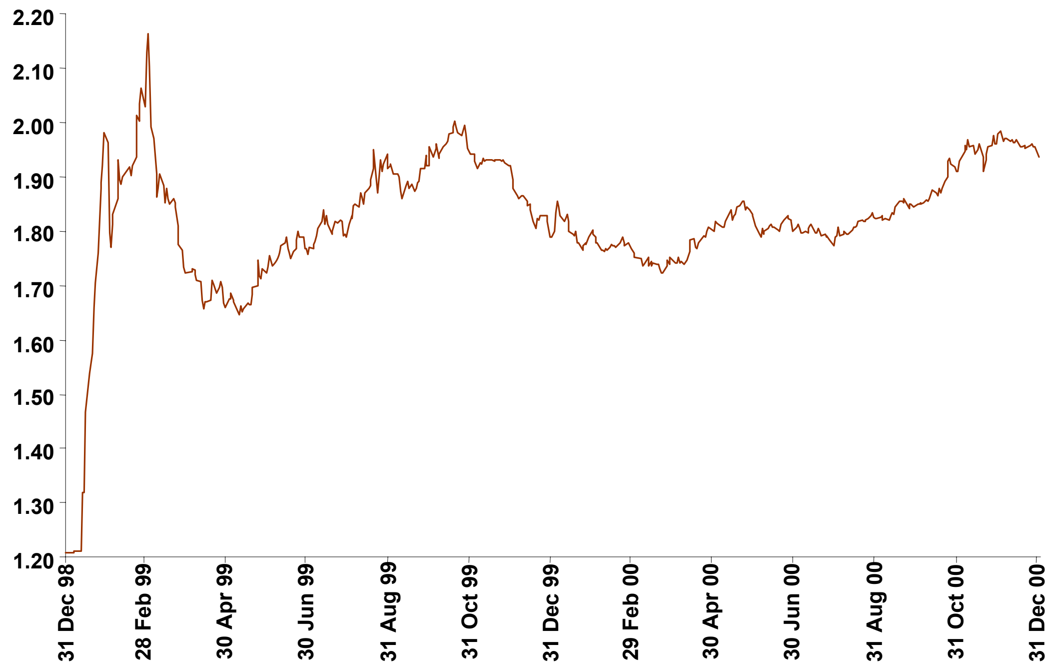
The first shock was prompted by the Asian crisis in the second half of 1997. In the face of falling international reserves, the Central Bank reacted by doubling the basic interest rate to 43.4% pa in November. The government pressed for a strong fiscal response to complement the monetary tightening. In a matter of weeks, Congress approved a fiscal programme called "Package 51", which featured 51 measures to cut expenditures and increase taxes, totalling R$ 20 billion or about 2% of GDP*.* The fast recovery of international reserves that followed allowed the Central Bank to reduce interest rates, but the fiscal programme was only partially executed. In particular, the spending cuts were postponed, as the political will to undertake them diminished in line with the perceived contagion effects.

The second shock followed the Russian moratorium in August 1998. The country was much more affected by international turbulence than in the previous episode as a result of a worldwide reassessment of risk exposure to emerging markets. Capital outflows were substantial in the ensuing months. The authorities responded with the same policy mix used to counter the Asian crisis effects. In September, the basic interest rate doubled to 40%, calling for a new fiscal tightening. This time, however, the government could not count on market support, a price it paid for not delivering the previously promised fiscal results. To address the issue of enforceability of fiscal discipline, the government sought a preventive programme with the IMF. The financial support package amounted to US$ 41.5 billion, with about two thirds of the total becoming available in the first year. However, it was not enough to prevent expectations from deteriorating, especially because some of the newly proposed fiscal measures faced strong resistance in Congress.

This time, the fiscal tightening measures were mostly implemented. Market confidence, however, continued to erode up to January 1999, partly reflecting concerns over the newly elected governors' commitment to adjust their states' finances. Any new sign of potential deviation from the fiscal target induced extreme market nervousness. Given its limited ability to sustain the crawling exchange rate band regime, the Central Bank allowed the exchange rate to float by mid-January, and the dollar value quickly jumped from R$ 1.21 to nearly R$ 2.00 at the end of January (Figure 2).

Figure 2

Exchange rate evolution (R$/US$)



The currency devaluation set in motion a sharp realignment of relative prices. The wholesale price index increased 7% in February, while consumer price inflation rose slightly more than 1%. Given the change in the exchange rate regime, the agreement with the IMF had to be reformulated. The estimates set in the revised Memorandum of Economic Policy were -3.5% for GDP growth and 17% for inflation, measured by the general price index.[3] The great uncertainties surrounding the country's future and the lack of a nominal anchor prompted a volatile expectations environment, with inflation and recession forecasts much larger than those above.

A new Board of Governors took office at the Central Bank on 4 March and immediately worked on two main fronts. The first was to calm the nervous financial markets by raising real interest rates and

3 The general price index in Brazil is a weighted average of wholesale prices (60%), consumer prices (30%) and civil construction prices (10%).

pinning down inflation expectations in the short run. The second was to propose inflation targeting as the new monetary policy regime, thereby anchoring expectations also in the medium run.

2.2 Transition to inflation targeting (March to June 1999)[4]

The shift to a floating exchange rate regime occurred in a moment of crisis. Even so, the regime seemed reasonable for Brazil. The country does not present the classical features required for an optimal currency area with the dollar or any other currency, and it is hard to find arguments to justify the adoption of a fixed exchange rate regime, even in the more recent literature about monetary integration as a credibility instrument. Therefore, the main task of the Central Bank's new Board was to find a monetary policy strategy compatible with the floating exchange rate regime.

A fully discretionary monetary policy without an explicit anchor would not tackle the inevitable uncertainties, especially during the transition period. It was natural to opt for a more rigid system, one that would represent a definite, strong commitment but that could also offer some indication of the future path of the economy; one that would allow enough flexibility for policymaking but that could also effectively anchor the public's expectations. The authorities therefore decided to set up an inflation-targeting framework. However, the immediate announcement of a numerical inflation target was out of the question. The exchange rate was still overshooting, making any realistic assessment of pass-through effects all but impossible. Thus, setting a specific target value would not enhance credibility; on the contrary, it could even bring the new policy regime into disrepute. The Central Bank took a gradualist approach: it made clear that monetary policy would aim at keeping inflation under control, but a formal inflation targeting framework would be in place only by the end of June.

At the time, a remarkable turnaround in fiscal policy was materialising. The targets for the cumulative primary surplus of the consolidated public sector were met with margins, in a clear demonstration of the government's commitment to fiscal adjustment. Policymakers seized the opportunity created by the crisis to enforce a major shift in the fiscal regime, thus erecting a fundamental pillar to support inflation targeting. Although the reforms that were needed to ensure long-run fiscal equilibrium were far from complete, the government had the necessary instruments to achieve a reasonable fiscal performance for at least a decade. Even the most sceptical analysts had to acknowledge the feasibility of the announced fiscal targets. Whereas confidence in the new fiscal stance would require a much longer sequence of positive results to consolidate, the primary surplus served to mitigate concerns about a rising trend in the debt-to-GDP ratio.

The new Board took office at the Central Bank on 4 March, and the team immediately worked to calm financial markets. The expectation that an inflation hike could cause the real rates of return on public debt instruments to drop into the negative range was the first to be attacked. The Monetary Policy Committee (Copom), whose voting members are the Governor and Deputy Governors, raised the basic short-term interest rate (the Selic) from 39% pa to 45% pa, taking into account that the future contracts for the next maturity were already trading at 43.5%. The idea was to accommodate the devaluation shock, but to counter its further propagation. It was acceptable that the relative price movements set in motion with the devaluation would shift the price level upwards, but the interest rate had to be set high enough to prevent the second-round inflationary process that could follow. The question was how to translate these ideas into practice, given the then chaotic state of expectations.

Expectations had to be anchored one way or another, and for that purpose clear communication was crucial. The Committee released a brief explanation of the policy decision right after the meeting - the minutes used to be released only after three months - asserting that "maintaining price stability is the primary objective of the Central Bank".[5] Other official declarations indicated that price stability meant a monthly rate of inflation in the range of 0.5-0.7% by the end of the year. Moreover, "in a floating exchange rate regime, sustained fiscal austerity, together with a compatible monetary austerity, supports price stability; as fiscal policy is given in the short run, the control over inflationary pressures should be exerted by the interest rate; observed inflation is due to the currency depreciation, and

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4 Fraga (2000) provides a comprehensive discussion of the problems faced by the Central Bank in this period and the steps taken to deal with them. This subsection draws a lot on this article.

5 Explanatory Note to Copom's Decision - 4 March 1999.

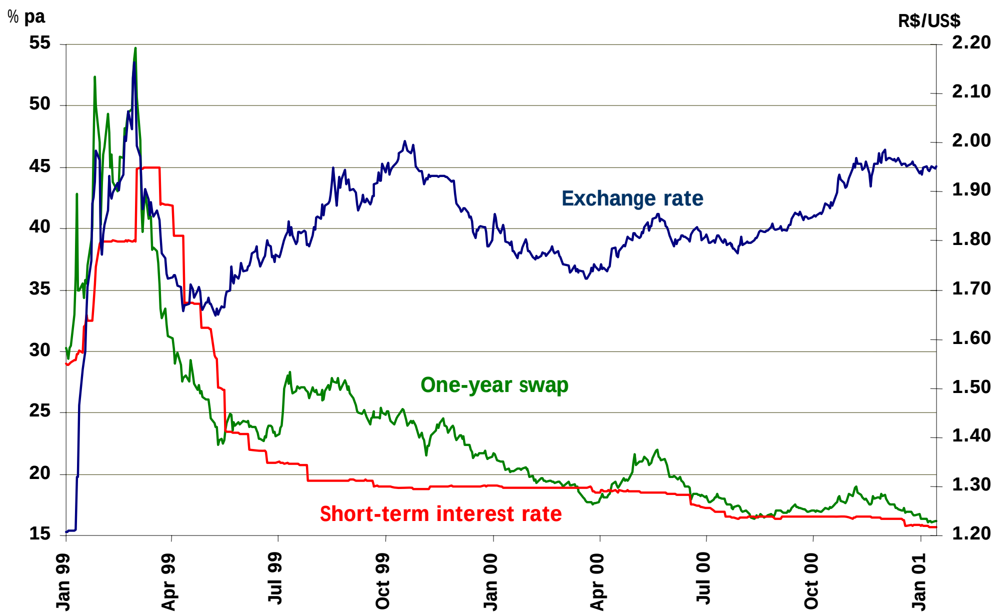
markets expect a further rise in the price level this month; the basic interest rate should be sufficiently high to offset exchange-based inflationary pressures; and so, we decided to raise the basic interest rate to 45% pa, but with a downward bias,[6] for if the exchange rate returns to more realistic levels, keeping the nominal interest rate that high would be unjustified."[7]

The complementary issue to address was the external financing of the balance of payments, since the doubts about its availability were thought to be one of the main reasons behind the exchange rate overshooting. The financial support package coordinated by the IMF already covered part of the needs; the remainder was sought through the voluntary commitment of foreign banks to roll over trade-related and interbank lines. Here again transparency played an important role: detailed information on overall bank exposure to Brazil was provided, a practice that was to continue through regular updates. In addition, temporary incentives for capital inflows were granted in the form of tax reductions that would last until June. In the foreign exchange market, the rule was free floating, with the Central Bank only keeping the prerogative to make a limited amount of unsterilised intervention to counter disorderly market conditions.[8]

The general outlook started to improve soon after. The reversal of the exchange rate overshooting occurred very fast, in tandem with the change in the slope of the term structure of interest rates. The exchange rate fell from a peak of R$ 2.16 per dollar in early March to R$ 1.72 at the month-end, while the one-year forward interest rate plunged from 55% to 31% (Figure 3), prompting a reduction in both observed and expected inflation rates.

Figure 3

Interest rates and exchange rate



Confidence was strengthening for a number of reasons. Domestically, consumers put up resistance to price increases, giving rise to a profit margin squeeze along the supply chains and helping dampen latent inflationary pressures. The indicators then released failed to confirm a deep economic slowdown; on the contrary, agricultural output was growing rapidly and the open unemployment rate

6 The bias on the interest rate was also an important novelty: it delegated to the Central Bank's Governor the power to alter interest rates during the period between two ordinary Committee meetings (usually five weeks). A downward bias allows the Governor to reduce the interest rate. However, if an increase in the interest rate is needed instead, while a downward bias is valid, an extraordinary meeting is required.

7 Explanatory Note to Copom's Decision - 4 March 1999.

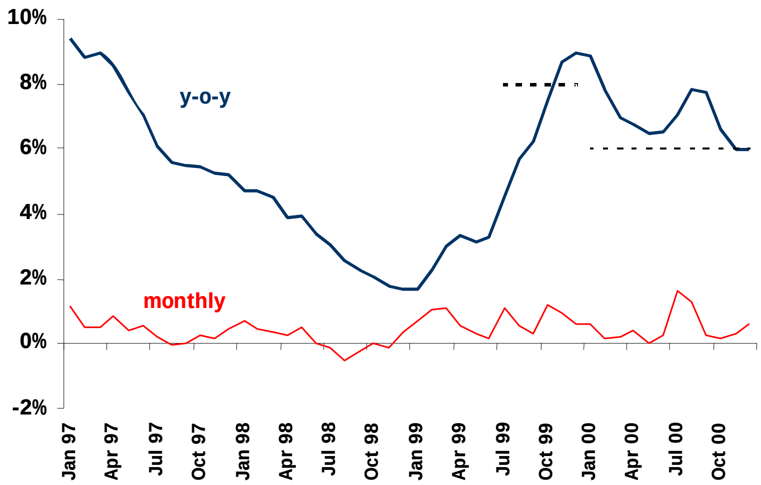
8 Brazil Memorandum of Economic Policies, released on 8 March 1999.

was stable. The fiscal stance delivered a primary surplus of 4.1% of GDP in the first quarter, in excess of the government's target. The improvement in the trade balance came primarily through a decline in imports, but on the financial side capital inflows were recovering, and in particular foreign direct investment (FDI) was pouring in at a strong pace. Therefore, the downward bias was applied twice before the Copom's next meeting: the interest rate was reduced first to 42% in late March and then to 39.5% in early April. At the mid-April meeting, a further reduction to 34% was decided on.

The behaviour of observed inflation and the pace of convergence of inflation expectations served as a rough guide to determine the appropriate rhythm of nominal interest rate reductions. This was the case in April and May, when the confirmation that inflation was decelerating allowed the basic interest rate to be lowered by more than 10 percentage points, from 34% to 23.5%. The reversal of the exchange rate overshooting and a positive supply shock - the downward pressure the new harvest exerted on food prices - were held responsible for the immediate decline in inflation. The wholesale price index even showed a slight deflation in these two months. Consumer inflation measured by the broad consumer price index (IPCA) fell to 0.3% in May from more than 1% in February and March (Figure 4), and inflation expectations followed suit.

Figure 4

Inflation evolution



In June, however, the level of uncertainty rose again as a result of external developments. The US Federal Reserve Board set an upward bias for the federal funds rate, suggesting that the combination of rising energy prices, robust aggregate demand and record low unemployment could require a tighter monetary policy in the second half of the year. The perspective of a deterioration in international liquidity conditions, the concentration of amortisation payments of private sector external debt due in June, and the near termination of the incentives on capital inflows introduced in March, all led to an increase in Brazil's risk. The immediate repercussions were on market-determined interest rates and the exchange rate. The slope of the term structure curve turned from negative to positive and the exchange rate weakened (Figure 3). Therefore, monetary policy became somewhat more conservative, reducing the interest rate at a slower pace.

In sum, the policy response to the crisis entailed a combination of tighter fiscal policy, tighter monetary policy with a price stability objective, and external financial support. The exchange rate stabilised quickly and inflation expectations also came down, allowing a 50% cut in the basic interest rate between March and June. With the strengthening of confidence and the fact that the private sector was adequately hedged against foreign exchange risk at the outset of the crisis, GDP was already able to recover in the second quarter. The average maturity of the government's securitised debt underwent a gradual extension, while the fiscal stance was consolidating. FDI inflows were more than enough to cover the declining current account deficit, thus averting the need of other than trade-related short-term capital to finance the balance of payments. In this improved after-crisis environment, a full-fledged inflation targeting framework could be implemented with a fair chance of success.

3. The stylised structural model[9]

According to Mishkin and Savastano (2000), inflation targeting comprises five main features: (i) the public announcement of medium-term numerical targets for inflation; (ii) an institutional commitment to price stability as the primary goal of economic policy, to which other objectives are subordinated; (iii) an information-inclusive strategy, encompassing the use of several variables and models, to enable the monetary authority to set policy instruments; (iv) a transparent monetary policy strategy that ascribes a central role to communicating to the public the plans, objectives and rationale of the central bank's decisions; and (v) mechanisms for making monetary authorities accountable for achieving the inflation targets. The first feature, a numerical target value, must be low, feasible and compatible with the macroeconomic outlook.

With this in mind, the Brazilian authorities placed a high priority on understanding the transmission mechanism of monetary policy to prices, with emphasis on developing a set of forecasting tools, including structural models for the transmission mechanism, non-structural time-series vector autoregression (VAR) and autoregression moving average (ARMA) models for short-term forecasting, measures of core inflation, leading inflation indicators, and surveys of market expectations. The most important of these tools is the family of structural models, which is estimated and/or calibrated with the dual objective of identifying the mechanism of monetary policy and assessing the transmission lags involved. A representative structural model of this family contains four basic equations. The first is a standard IS equation that captures the aggregate demand response to the real interest rate and real exchange rate. The second is a typical open economy Phillips curve, representing the supply side trade-offs. The third is an equation for the exchange rate and the fourth is an interest rate rule that is essential for simulations.

The standard specification of an IS curve with quarterly frequency could be as follows:

$$h_t = \beta_0 + \beta_1 h_{t-1} + \beta_2 r_{t-1} + \beta_3 \theta_t + \varepsilon_t^h \tag{1}$$

where h is the log of the output gap; r is the log of the real interest rate (log(1+R)); θ is the log of the real exchange rate; and ε^h represents a demand shock. Other specifications might include different lag structures or additional explanatory variables. Bogdanski et al (2000), for example, present a "fiscal" IS specification, which explicitly considers the effects of the shift in fiscal regime on aggregate demand.

The first problem for the Central Bank was how to measure the variables that are not directly observable, like the output gap. The usual starting point is the calculation of potential output, either by extracting a linear time trend from historical GDP data, by filtering out the GDP series, or by estimating production functions. In the Brazilian case, the linear trend and HP filter were preferred since both produced similar results. The output gap was then obtained by the difference between actual and potential GDP, allowing direct estimates of the different IS curves. However, research efforts on this crucial topic are far from over.

The estimation results posed a second problem, since they were heavily influenced by post-Real Plan data (third quarter 1994 to fourth quarter 1998). As mentioned in the previous section, the managed exchange rate regime in the Real Plan was very instrumental in reducing inflation and keeping it low, at the cost of setting the domestic interest rates high enough to attain a balance of payments position compatible with the desired parity. The equilibrium real interest rate under the current floating exchange rate regime should therefore be substantially lower than under the previous regime. The transition effects stemming from the new equilibrium level of real interest rates called for a long-term calibration of the demand side reduced-form model. In the long-run steady state, the output gap should remain constant at zero. As a first approximation, it is assumed that the long-term equilibrium real interest rate must equal the potential GDP growth rate. A thorough analysis of this question should also include fiscal policy considerations, like the long-run fiscal balance and debt administration issues, which may add or subtract a few percentage points to the first approximation for the neutral rate. In the IS curve specification above, this is equivalent to setting $\bar{r} = -\beta_0 / \beta_2$, since β_3, the real exchange rate coefficient, is very close to zero. So, a straightforward calibration would consist of

[9] This section is based on Bogdanski et al (2000).

estimating the IS curve with the additional restriction on the pair (β_0,β_2), whose ratio must equal the long-term equilibrium real interest rate.

The supply side of the economy is modelled with a Phillips curve specification, directly relating price inflation to some measure of real disequilibrium (typically the output gap), inflation expectations and exchange rate changes. For example,

$$\pi_t = \alpha_1\pi_{t-1} + \alpha_2 E_t(\pi_{t+1}) + \alpha_3 h_{t-1} + \alpha_4 \Delta\left(p_t^F + e_t\right) + \varepsilon_t^n \tag{2}$$

where π is the log of consumer price inflation, h is the log of the output gap, p^F is the log of the foreign producer price index, e is the log of the nominal exchange rate, Δ represents the first-difference operator, $E_t(\cdot)$ is the expectations operator, conditional on information available at time t, and ε^n stands for a supply shock. The coefficients on the right-hand side of the equation, except for the output gap one, are constrained to sum to unity; this ensures the long-run verticality of the Phillips curve, that is, that inflation is neutral with respect to real output in the long run.

This specification combines backward- and forward-looking elements. A purely backward-looking specification would be simpler to estimate and would fit past data. However, it would also be vulnerable to the Lucas critique. Its predictive power would be weak because of the recent changes in monetary policy and exchange rate regimes, which almost certainly have altered the formation of inflation expectations and the short-run trade-off between inflation and output. Using a purely forward-looking specification would be an attempt to overcome the parameter instability commonly found after structural breaks. It might also stem from the natural assumption that as the inflation targeting regime gains credibility, expectations tend to converge to the targeted value. Such a specification raises difficult estimation issues, however, about the appropriate measures of expectations, especially when reliable survey data are not available.

The Central Bank tested different assumptions about the expectations mechanism, but the estimations generally led to a weighted average of past and future inflation, with at least 60% on the forward-looking component. The preferred Phillips curve specification, together with the other equations in the complete model, exhibited the desired dynamic properties of the economy, with inflation persistence arising from sluggish adjustment forced by the backward-looking terms, while the rational expectations environment was preserved by the forward-looking component, thought to be increasingly important in the transition period after the changes in monetary policy and exchange rate regimes.

For the purpose of running simulations to investigate the implications for inflation and output of different monetary policy rules, it is easy to experiment with alternative assumptions about the expectations formation mechanism. For example, expectations can be taken exogenously from a market survey and augmented by a hypothesis about how they react to new information, or they can be calculated recursively to ensure consistency with the model.

The pass-through of exchange rate changes to domestic inflation is another key issue in the Phillips curve setup. Several linear and non-linear specifications for the pass-through coefficients were tested, and the alternatives implemented in the preferred simulation tool were narrowed down to four. The first is a standard constant coefficient α_4 = constant, simply estimated from a suitable sample of past data. The second is a quadratic transfer from exchange rate variations to inflation, $\alpha_4 = \alpha_{41} + \alpha_{42}\Delta\left(p_{t-1}^F + e_{t-1}\right)$. The third is a level-dependent coefficient, $\alpha_4 = \alpha_{41} + \alpha_{42} e_{t-1}$, which is estimated under the assumption that the pass-through depends on the level of the log of the nominal exchange rate. Finally, the fourth is a quadratic function of the nominal exchange rate level, $\alpha_4 = \alpha_{41}\dfrac{E_{t-1}^2 - \alpha_{42}}{E_{t-1}^2 + \alpha_{42}}$, motivated by a simple partial equilibrium model in which exchange rate devaluations shift the supply curve of competitive producers of tradable goods.[10] All non-linear variants aim to capture more precisely the effects of a temporary exchange rate overshooting. Given the small number of observations available in a quarterly frequency, however, their results were very close to the linear variant and consistent with international evidence that the pass-through coefficient

[10] See the appendix in Goldfajn and Werlang (2000).

is inversely proportional to the degree of real exchange rate appreciation at the moment prior to the devaluation.

The determination of the nominal exchange rate is as important as it is difficult. The Central Bank's first approach was to use an uncovered interest parity (UIP) condition to model the link between the exchange rate and the interest rate through capital markets. The UIP condition relates expected changes in the exchange rate between two countries to their interest rate differential and a risk premium:

$$E_t e_{t+1} - e_t = i_t - i_t^F - x_t \tag{3}$$

where e is the log of the exchange rate, i is the log of the domestic interest rate, i^F is the log of the foreign interest rate, and x is the log of the risk premium. Taking the first difference $E_t e_{t+1} - E_{t-1} e_t - \Delta e_t = \Delta i_t - \Delta i_t^F - \Delta x_t$ and assuming for simplicity that the expectation change follows a white noise process[11] $E_t e_{t+1} - E_{t-1} e_t = \eta_t$, it is possible to specify the exchange rate dynamics as:

$$\Delta e_t = \Delta i_t^F + \Delta x_t - \Delta i_t + \eta_t \tag{4}$$

This equation contains two exogenous variables: the foreign interest rate and the risk premium. Given the relative stability of foreign interest rates, reasonably accurate projections can be obtained from contracts traded in international futures markets. However, the risk premium, which can be measured by the spread between US Treasury bonds and Brazilian sovereign debt, has presented high volatility in recent years. The risk premium is usually associated with macroeconomic fundamentals and a number of other subjective factors that are not easily anticipated. Two alternative approaches were therefore considered. The first was to gather the opinions of Copom members about the future evolution of the country's risk premium, conditional on the overall scenario and based on anecdotal evidence; these opinions were then translated into an exogenous expected path to be used in simulations. The second approach was to make assumptions linking the risk premium behaviour to the main objective factors thought to influence it, thereby allowing the model to endogenously determine the premium. A list of these factors would typically include the fiscal stance, perspectives on the current account balance, international liquidity conditions and interest rates, the performance of foreign capital markets, commodity prices and country rating.

Finally, the fourth equation is left unspecified in the general model. Since the primary instrument of monetary policy is the short-term interest rate set by the Central Bank, it is necessary to choose a policy rule in order to run simulations in any of the different reduced-form model specifications. The rules can be divided into three basic families: fully exogenous interest rate paths, linear combination of system variables and optimal response functions.

An exogenous interest rate path is useful for analysing the consequences of a particular interest rate trajectory, such as that implied by financial market instruments or the implicit path considered in the government budget. A particular rule of this family is helpful for institutional communication. The inflation forecasts published in the quarterly inflation report are traditionally constructed under the assumption that the short-term interest rate will remain constant at the current level along the projection period. This projection is illustrated by means of an inflation fan chart, which shows the probability distribution around the central forecast for each quarter. On visual inspection, one can infer whether monetary policy should be altered and in which direction.[12]

The interest rate rule can be written as a linear function of some system variables. For example, monetary policy can react contemporaneously to the output gap and deviations of inflation from target: $i_t = (1-\lambda) i_{t-1} + \lambda\left(\omega_1 (\pi_t - \pi^*) + \omega_2 h_t + \varpi_3\right)$. When λ=1, this is equivalent to a standard Taylor rule, whereas it is a Taylor rule with interest rate smoothing when $\lambda \in (0,1)$. The values of ω_i can be set

11 This is equivalent to a random walk with monetary surprise, where a surprise is characterised by changes in interest rate differentials or in risk perception.

12 Britton et al (1998) explain how to interpret inflation forecasts presented as fan charts. Haldane (1997) discusses how the introduction of a partially subjective probability distribution may help clarify the policymakers' assessment of the current economic stance. The Brazilian *Inflation Reports* make use of both resources to convey information about monetary policy decisions.

arbitrarily or using specific optimisation procedures available in the simulation tool. Finally, an optimal interest rate rule can be found by minimising an appropriate loss function, subject to the model in use.

4. The transmission mechanism

The initial modelling efforts succeeded in reaching an early mature stage - that is, a reasonable degree of reliability and sensible dynamics. Two qualifications must be stressed, however. First, the general limitations stemming from model and parameter uncertainty apply. Second, the statistical time series for the Brazilian economy after the floating is too short to yield sufficiently robust results. Moreover, a sequence of failed stabilisation plans from 1986 to 1994 produced important structural breaks in many economic series, thus making it extremely difficult to treat them with the usual econometric techniques. The various non-structural tools are therefore fundamental for complementing and checking the consistency of structural modelling results. Policymakers are well aware of the limitations of the available tools and have no illusions about their effectiveness. Nonetheless, the models have been very useful and have helped discipline the discussion on monetary policy within the Central Bank.

This modelling approach embodies the understanding that as in most other economies, the most important transmission channels are through aggregate demand, the exchange rate and expectations. Preliminary estimation results with quarterly data indicate that permanent changes in the basic interest rate take one to two quarters to impact aggregate demand. This aggregate demand response, in turn, takes an additional quarter to be fully perceived in consumer inflation. Changes in short-term interest rates are thus transmitted to inflation through the aggregate demand channel with an estimated lag of two to three quarters. The exchange rate channel is estimated to have a shorter transmission lag: the effect of permanent interest rate changes on consumer prices through this channel is contemporaneous (on a quarterly basis), but its magnitude is smaller than through the demand channel. These results are based on the strong assumptions that expectations remain consistent with the model after any policy change and that the policy change itself is a sufficiently small departure from the initial position so that the log-linear approximation remains valid.

Further qualifications come into play at this point. First, the lag structure in the aggregate demand channel is shorter than that found in the majority of either industrialised or developing economies. This may be the result of the large swings in real interest rates that characterise the post-Real Plan sampling period. These large swings generated prompt output and inflation responses, although the magnitude of the responses was relatively small in comparison with the interest rate variations. The lag is expected to increase gradually as the economy converges towards its long-run steady-state equilibrium.

Second, although the lag structure is short, the overall effect is modest, for several reasons. The financial system, for example, is overregulated, with a variety of credit restrictions, mandatory allocation of funds, and distorting taxes. The banking spread has therefore remained extraordinarily high, and the system as a whole presents a low leverage by international standards. This banking spread makes the transmission channel from the basic interest rate to market-determined final loan rates much weaker than desirable, and it explains part of the high volatility of interest rates observed in the last three to five years. This fact leaves the impression that a slight deviation from the expected path requires a significant change in the basic interest rate to bring the economy back to the central path. In other words, the interest rate elasticity of the macroeconomic equilibrium is low. A series of parallel projects is under way to correct these distortions in the financial system and improve the efficiency of the transmission mechanism.

The third qualification has to do with the pass-through. Goldfajn and Werlang (2000), who analyse panel data, conclude that the pass-through coefficient generally depends on four main factors: the degree of overvaluation of the exchange rate prior to the devaluation, the previous level of inflation, the degree of openness and the economic activity level. On this ground, Brazil shifted to a floating exchange rate regime with good prospects for a low degree of pass-through, since inflation was low and the exchange rate showed clear signals of overvaluation after the deterioration of the terms of trade and the Russian crisis in 1998. Open and heated economies tend to present higher pass-through coefficients, other things equal. Although trade liberalisation progressed well and fast in the 1990s, the degree of openness of the Brazilian economy (around 14%) is quite low by international standards. Furthermore, the economy evolved below its potential after the Russian crisis. When the real floated, the output gap was undoubtedly negative, which provided a major force for countering pass-through pressures. Preliminary results thus confirm the tendency for a low pass-through.

5. Policy reaction to shocks

In this section we examine how monetary policy reacted to shocks after inflation targeting was implemented in Brazil. We begin by identifying the main shocks that occurred after July 1999 and the corresponding policy behaviour. The identification addresses the nature as well as the duration of shocks. This task is obviously easier with the benefit of hindsight, although in some cases even the ex post interpretation of shocks is not straightforward.

The problem of inflation persistence is another key factor for understanding the policy reaction. Given the Brazilian institutional setting, which features a high weight of backward-looking prices in the consumer basket, policy responses are different from those in an environment in which all prices are forward-looking. Other peculiarities of the Brazilian inflation targeting framework are also relevant for discussing policy reactions. These include the absence of escape clauses, the use of a headline price index, and the adoption of multi-year targets. All these peculiarities leave relatively little room for accommodation by monetary policy.

The term “backward-looking prices” deserves an explanation. These prices are also known as “government-managed prices”, given that they used to be arbitrarily set by the government before the privatisation of state companies. Government-managed prices are now those that, in one way or another, are defined or affected by a public sector agency, independently of current supply and demand conditions, but not arbitrarily. The major administered prices (and respective weights) in the reference consumer price index (IPCA) fall into two categories: those that are defined at the federal government level, including oil by-products (6%), electricity charges (3.3%), telephone and postal services charges (3%), and the minimum wage (3%); and those that are defined at the local government level, including water and sewage charges (1,5%), public transportation (6%), and property taxes (1%).[13] Taken together, these components account for around 25% of IPCA, reflecting their importance in daily expenditures of households in the income bracket from one to 40 times minimum wage. It is important to stress that “managed” does not mean “controlled”. Public utility charges constitute a substantial component of these prices. Their adjustment leaves no room for discretion: they follow the terms of their concession contracts; this links them to the past behaviour of general price indices and thus justifies the designation of “institutionally backward-looking prices”. The minimum wage, in turn, is set by Congress. The central government has effective direct control only over the wholesale prices of oil by-products, and it has been resetting them in accordance with international prices, in anticipation of the full liberalisation of the domestic oil market scheduled for 2002.

5.1 Description of main shocks and corresponding policy behaviour

We identified a total of eight shocks between July 1999 and November 2000, including a wide variety of supply and “financial” shocks. The supply shocks were primarily associated with food market conditions and backward-looking prices, which include the effects of international oil prices. The financial shocks mainly derived from increased international volatility and a deterioration of the market perception of Brazil’s risk premium, which immediately alters the exchange rate value. Seven out of eight are classified as adverse shocks to the extent that their preponderant effect was to press inflation upwards. The taxonomy is somewhat dubious, given the fact that the economy is generally hit by more than one shock at the same time. Disentangling the combined effects of simultaneous shocks is somewhat arbitrary, as it is to associate monetary policy decisions with individual shocks.

The Brazilian economy in this period was far from its long-run balance, particularly with regard to the level of nominal and real interest rates. This means that in the absence of shocks, the interest rate

[13] These figures are approximations, given that the actual weights vary over time.

would be expected to follow a declining path. Therefore, when policy reacted by keeping the interest rate constant, this actually represented a policy tightening, and not an accommodative stance.

Table 1 summarises the main shocks that hit the Brazilian economy in the first 18 months of inflation targeting.

Table 1
Main shocks and policy reaction

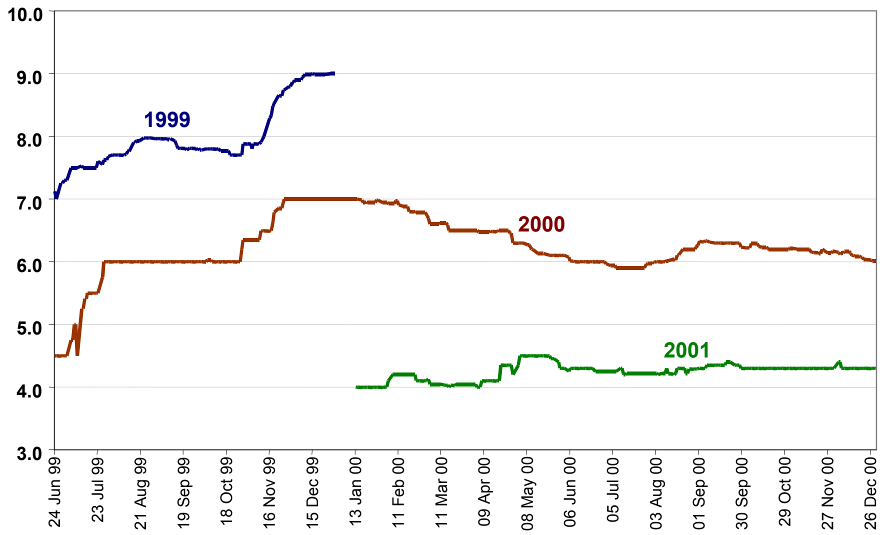
	Type of shock	Timing	Description	Reaction
1	Backward-looking prices (BLP)	Jul 1999	BLP higher than expected by the market; oil price	Interest rate reduced from 22% to 21%
2	BLP	Jul/Aug 2000	BLP accompanied by adverse oil and food prices	Interest rate held constant at 16.5%
3	Food prices	Jun 2000	Inflation much lower than expected in the first half	Interest rate reduced from 18.5% to 17.5%
4	Financial	Aug 1999	Disagreement with monetary policy, increased hedging demand	Interest rate held constant at 19.5%
5	Financial	Oct 1999	Inflation above expectations; trade deficit; concerns about pass-through and Y2K-related capital outflows	Interest rate held constant at 19%; NIR floor reviewed
6	Financial	Apr/May 2000	Int'l stock market volatility; oil price upsurge; robustness of fundamentals	Interest rate held constant at 19%
7	Financial	Nov 2000	Oil price; Argentina	Interest rate held constant at 16.5%
8	Oil prices	Dec 1999	Concerns about tightening abroad, oil price evolution and BLP for 2000; unexpected rise in food prices	Interest rate held constant at 19%; foreign exchange auctions

The shocks that we classify as "backward-looking prices" (BLP) stem from the annual resetting of public utility charges (including electricity, telecommunications, and water and sewage) that occurs at the beginning of the third quarter in most of the 11 cities covered by IPCA.[14] A great part of these services were privatised in the late 1990s, and their price adjustment follows contracts linked to the past variation of general price indices. The first shock (number 1 in Table 1) is considered so because market participants did not anticipate it correctly. After the inflation figures for July 1999 were released, inflation expectations rose by a full percentage point (Figure 5). However, Copom had been taking this temporary inflation rise into consideration since the first issue of the Central Bank's *Inflation Report* (June 1999). The Committee decided to reduce the basic interest rate, since forecast year-end inflation was very close to the targeted level.

[14] Other managed prices, such as the minimum wage, oil by-products and urban bus fares, are not necessarily readjusted at the beginning of the third quarter.

Figure 5

Inflation expectations[1]



[1] Median of market expectations for year-over-year IPCA inflation.

Source: Investor Relation Group - Central Bank.

When the second BLP shock (number 2) occurred, one year after the first, it was fully anticipated. Throughout the previous three quarters, monetary policy decisions had been explained to the public as aiming to counter possible second-round effects of this expected rise in backward-looking prices. However, this shock coincided with other two adverse developments. First, the domestic price of oil by-products was raised as a result of a new upsurge in international prices. Second, bad weather conditions throughout the country pushed food prices strongly upwards. Consequently, the inflation forecast for the year was revised upwards, and the interest rate was held constant. At the time, evidence from previous episodes (for example in the last quarter of 1999) indicated that the effects of supply shocks vanish quickly once they are recognised as temporary, and they seem to have little impact on inflation expectations. This low price inertia was confirmed with the substantial decline in inflation that was observed in September and October 2000 (Figure 3).

The food price shock (number 3) was the only positive supply shock in the period covered.[15] It consisted of a gradual reduction in food prices that began in February 2000, but became stronger only in May and June. Thus, although this shock was identified early, the presence of other shocks in April and May concealed its effect on inflation expectations. The external uncertainties were attenuated in late June and the inflation forecast was revised downwards with the positive influence of food prices, allowing a 1 percentage point reduction in the basic interest rate.

The shocks we denominate as "financial" comprise four episodes featuring considerable shifts in the financial market perception of risks, which led to an increased difference between medium- and short-term interest rates, as well as to changes in the value of the exchange rate. These financial shocks reflected both the market reaction to the monetary policy stance and changes in the risk premium motivated either by domestic fundamentals or by external developments.

The first of these shocks (number 4), which hit the economy in August 1999, stemmed from a combination of factors. First, as shock number 1 caused market inflation expectations to rise sharply in July, the pace at which the Central Bank was reducing the interest rates was seen as too rapid (Figure 5). Second, the level of external uncertainties was rising fast, mainly because monetary tightening in the United States generated concerns that financing for the Brazilian private sector would be inadequate, especially towards the end of the year. Also, for the first time since the Gulf war, oil prices became a serious concern, together with their potential inflationary impact on Brazil. This

[15] Positive here means that it contributed to bringing inflation down.

caused a continuous depreciation of the real, and the demand for hedging instruments against further devaluation rose. The monetary policy response was twofold. First, hedging demand was matched by increased placement of dollar-indexed liabilities, since private market instruments were not available in appropriate amounts.[16] Second, the interest rate was held constant, interrupting the sequence of reductions initiated in mid-March 1999 (Figure 4). The interest rate level was thought to be enough to take care of inflationary pressures through the aggregate demand channel. If expectations deteriorated further, however, then the pass-through could have endangered the achievement of the year target, making a tougher policy response advisable. The strategy was successful, as expectations improved: fiscal policy delivered better results than targeted, observed inflation fell until September, and sovereign risk perception started a continuous decline that ended only in April 2000.

In October the foreign exchange market experienced a liquidity squeeze that coincided with a concentration of amortisation payments of private sector debt (shock number 5). Moreover, the trade deficit was not recovering at the expected rate and there were mounting concerns that Y2K fears would trigger capital outflows by the end of the year. These factors brought about renewed pressure on the exchange rate. The policy reaction this time was of a different nature, aimed at coping with the temporary liquidity shortage expected for the upcoming weeks. The measures included lowering the floor on net international reserves (NIR) - a performance criterion in the IMF agreement - by around US$ 2 billion; issuing new sovereign bonds; and arranging a loan from the Inter-American Development Bank (IADB). In early December, the Central Bank structured two forward foreign exchange auctions, in which it would sell a certain amount of dollars at the end of December and repurchase the same amount at the beginning of January, thereby eliminating doubts about possible currency shortages arising from Y2K problems. The strategy was instrumental in improving confidence, and as a result, capital inflows expected only for the next year were brought forward.

Shock number 6 is a good example of how the robustness of domestic fundamentals is capable of avoiding the harmful effects of high external volatility. It started in April 2000 with the strong asset price correction in international markets, combined with a new upsurge in oil prices and an additional rise in the US federal funds rate. As in all other recent cases of increased external uncertainty, the risk premium was the first variable to adjust to the new conditions. Inflation expectations did not deteriorate, however. Expectations even improved somewhat, as the domestic macroeconomic outlook presented no fundamental misalignment and the food price shock kept current inflation low. The foreign exchange market adjusted itself smoothly, without any intervention. There was no perceptible increase in hedging demand, and the maximum exchange rate variation was less than 7% during the April-May period (Figure 4). Copom held the interest rate constant in this period, but it clearly signalled in the minutes from the April meeting that the real interest rate would decline as soon as the external uncertainties were mitigated.

This brief description of the Brazilian experience shows that there is no unique prescription for how monetary policy should react to shocks. Similar events may demand different responses because the overall economic conditions should be taken into account. Inflation targeting in Brazil was subject to serious tests right from start. For example, the oil price shock, which pervaded this entire period with an intensity unprecedented since the 1980s, led to a substantial rise in domestic fuel prices, which more than doubled in less than a year. Nonetheless, inflation was kept within target in 1999 and 2000.

5.2 Monetary policy response: theoretical and empirical evidence

This section presents impulse response functions to different shocks and compares them to the actual reaction of monetary policy to supply and financial shocks. The results are summarised in Figures 6 to 9.

We assume that the economy can be described by the three-equation system presented in Section 3: the IS curve specification is given in equation (1), the augmented Phillips curve in equation (2) and the exchange rate dynamics in equation (4). To complete the model, we assume that the interest rate is set by the Central Bank with the objective of minimising the following loss function:

[16] These dollar-indexed bonds are not foreign debt, as they are payable in domestic currency, even though their face value is adjusted according to the current exchange rate at maturity. The share of these bonds in total public domestic debt had been declining gradually since January 1999.

$$\min_{\{i\}} L_t = \sum_{j=1}^{T} \rho^j \left[\omega_\pi D_{t+j} \left(E_t \pi_{t+j} - \pi^*_{t+j} \right)^2 + \omega_h \left(E_t h_{t+j} \right)^2 + \omega_i \left(\Delta i_{t+j} \right)^2 \right]$$

This loss function is a weighted average of the squares of the deviation of expected inflation (π) from the target (π^*), of the expected output gap (h) and of the nominal interest rate variation. The weighted average is discounted by a factor ρ (0<ρ<1). D is a dummy variable that equals one in the last quarter of each year and 0 otherwise; it characterises the fact that the Central Bank is concerned only with year-end deviations of realised inflation from the established target.

We assume that the economy starts from a steady-state equilibrium and is hit by shocks of one standard deviation, whose magnitudes are 0.3 percentage points for supply (equation (2)), 0.45 percentage points for demand (eq (1)), and 5 percentage points for financial shocks (eq (4)).

As standard models would predict (see Clarida et al (1999)), demand shocks require the largest reaction. Figure 6 shows that demand shocks lead to the highest nominal interest rates during the first six quarters. Supply and financial shocks lead to very similar reactions, despite the fact that the financial shock is almost 10 times as large as the supply shock. This can be explained by the fact that the reaction of monetary policy to financial shocks is mainly through its effect on inflation, with a negligible influence on the output gap. Since the pass-through from exchange rate variations to inflation is about 10%, the final impact of a financial shock on inflation is approximately the same as the supply shock, which suggests that a similar reaction is appropriate for both cases.

The real interest rate presents a different response pattern. It increases in the first period after a demand shock, but it decreases in the first period after supply and financial shocks. In other words, right after the economy is hit by the latter two shocks, the optimal response of the Central Bank is to increase nominal interest rates by a lower amount than the increase in inflation, thus bringing about an initial reduction in real interest rates. In the following periods, however, real interest rates rise above equilibrium, putting inflation into a sine-wave convergence path to its steady-state value. Figure 7 shows that the deviations of real interest rates from equilibrium after supply and financial shocks are usually higher than those observed after demand shocks. The counterpart of this finding is a more stable path for the output gap following supply and financial shocks, as shown in Figure 9. The accumulated deviations of the output gap, measured by the area between the impulse response curve and the horizontal axis, can be interpreted as the sacrifice ratio. After one year, the accumulated deviation of the output gap is 0.83 for demand shocks, 0.14 for supply shocks and 0.12 for financial shocks; the long-run values are 0.73, 0.04 and 0.03, respectively.

One should not expect the real economy to replicate the behaviour of an impulse response function, since it is awkward to identify and isolate the effects of individual shocks. However, an analysis of Figure 10 reveals some similarities between the actual behaviour of the nominal interest rate and inflation and the prediction of the impulse response functions. Only supply and financial shocks occurred after the devaluation of the real in early 1999, as described in Section 5.1.

It is interesting to examine the shocks that hit the economy in the second half of 1999. The exchange rate depreciated by 10% from the second to the third quarter of that year; backward-looking prices increased 8% in the third quarter and 3% in the last quarter; and food inflation reached 5.6% in the last quarter. In the face of such supply shocks, the Central Bank kept the nominal interest rate constant for almost six months. Given the prevailing out-of-equilibrium environment, this procedure was equivalent to an increase in the nominal interest rate when the economy is in steady state. It took from two to three quarters for the nominal interest rate to resume its downward trajectory, as in the impulse response cases.[17] The behaviour of real interest rates was also consistent with the predictions of the impulse responses: despite the "increasing" nominal interest rate in the first period (fourth quarter 1999), there was a contemporaneous reduction in the real interest rate. In the following quarter, however, the real interest rate did rise. Finally, as predicted, inflation increased in tandem with the shocks, but it declined faster than expected: in the first quarter of 2000, IPCA inflation was already below the target value for the year, if expressed in annualised terms.

[17] The overnight rate was lowered from 21% to 19.5% in July 1999, and it remained constant until October, when it was reduced by 0.5 percentage points. The overnight rate was not lowered again until March 2000, this time to 18.5% (Figure 4).

Figure 6

Impulse response of nominal interest rate

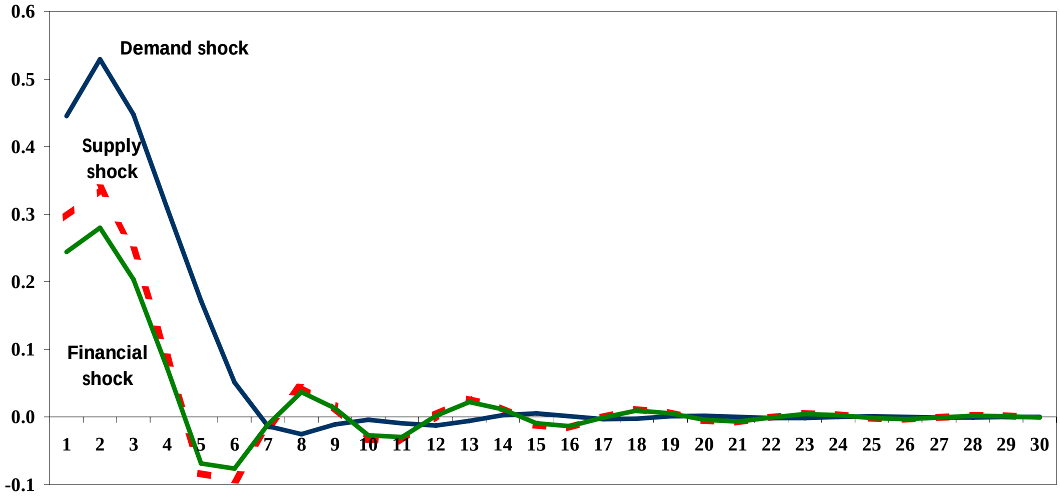


Figure 7

Impulse response of real interest rate

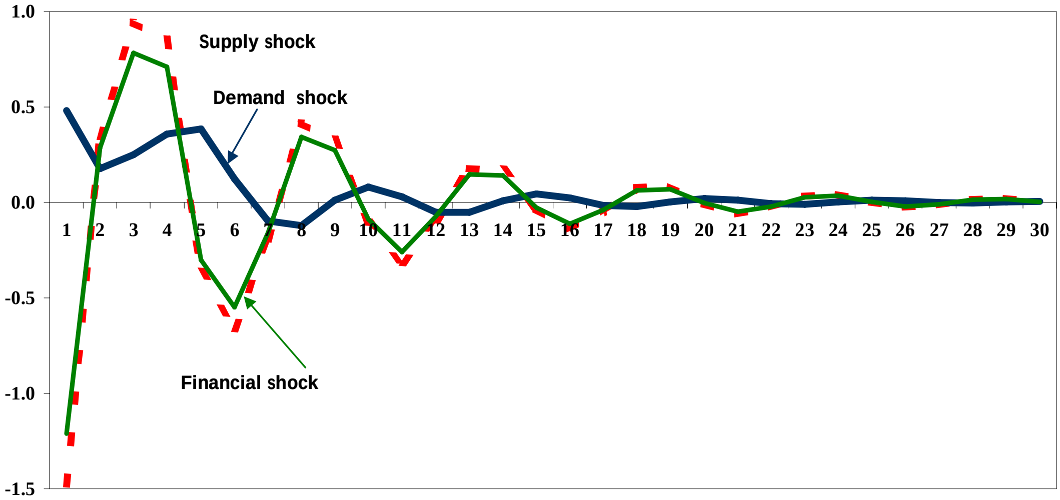


Figure 8

Impulse response of inflation

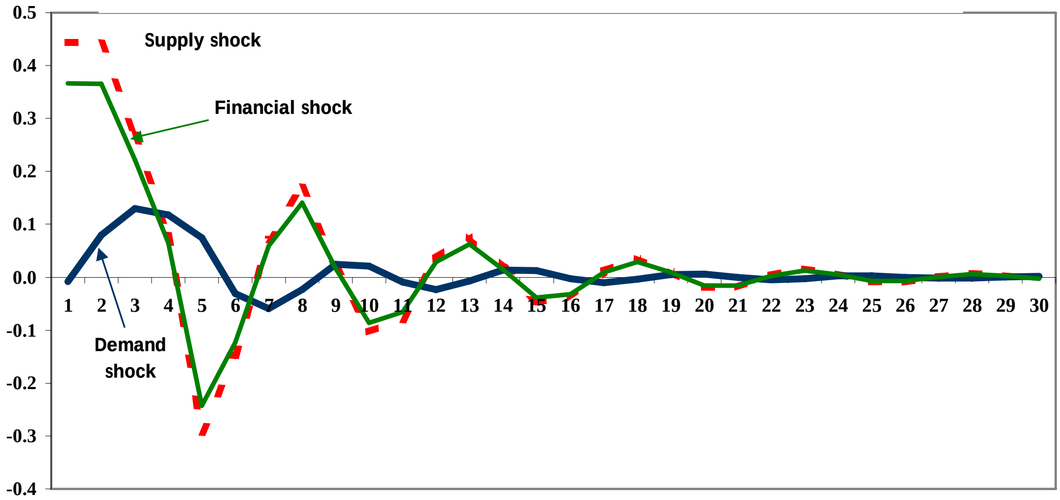


Figure 9

Impulse response of output gap

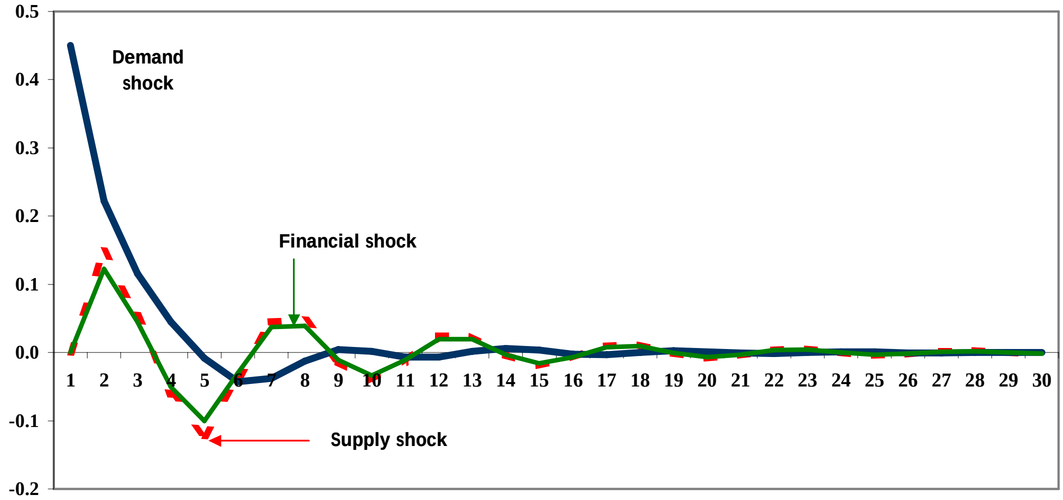
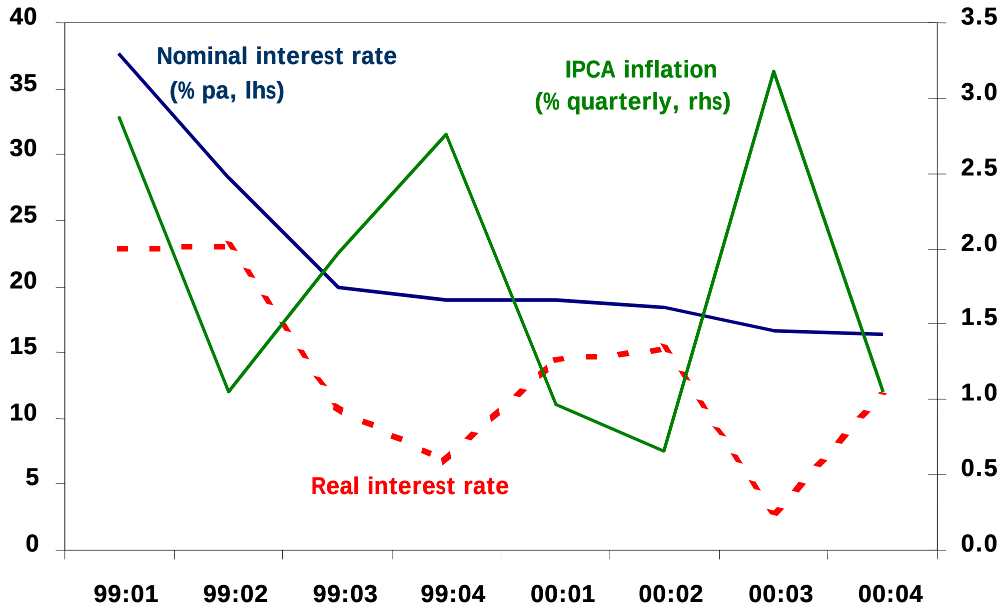


Figure 10

Quarterly inflation and interest rates



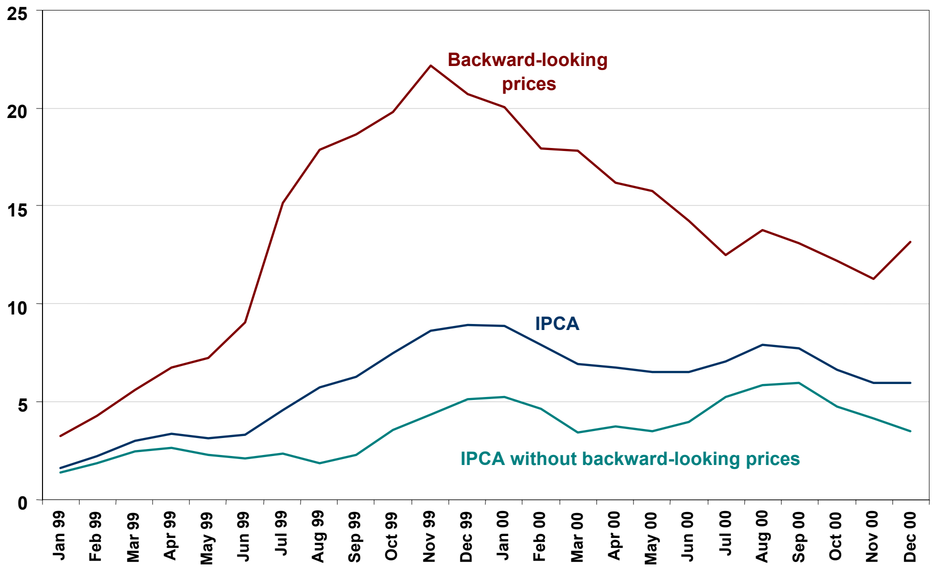
5.3. Inflation targeting and backward-looking prices

In the Brazilian framework, the inflation target is set for the annual variation of IPCA, a consumer price index in which the weight of backward-looking prices is approximately 25%. This particularity poses an additional challenge for monetary policymaking, since backward-looking prices are insensitive to interest rate decisions.

The most important items with backward-looking prices are public utilities, fuel, public transportation and the minimum wage.[18] The adjustment of these prices follows several rules. To respect contractual clauses, increases in utility charges are generally based on past inflation as measured by the general price indices. Prices of gasoline and oil by-products tend to increase in accordance with the exchange rate and international oil prices. Finally, the annual adjustment of the minimum wage is not defined by formal rules, but the political discussion in Congress usually starts from past consumer price inflation.

The group of backward-looking prices accumulated a 36.6% increase in 1999-2000, while other prices of the economy rose by only 8.8%. Figure 11 shows the evolution of headline IPCA inflation, along with a breakdown of the behaviour of backward-looking prices and the remaining prices. Because the targets are set for headline IPCA inflation, the behaviour of backward-looking prices clearly imposes an important restriction on monetary policy: real interest rates need to be high in order to keep the forward-looking prices at levels below the inflation target.

Figure 11
Year-over-year inflation



To quantify the influence of backward-looking prices on monetary policy decisions, we simulate the behaviour of monetary policy from 2000 to 2002, assuming that the economy starts from the initial conditions that prevailed at the end of 1999. We then compare this behaviour using different assumptions about the weight of backward-looking prices in the IPCA and about their adjustment rules. The results of the exercises are based on the four-equation model presented in Section 3. The only difference is that the Phillips curve is modified to take explicit account of backward-looking prices in explaining inflation.

The estimation of the Phillips curve is based on the following system:

$$p_t = \omega \cdot p_t^m + (1-\omega) \cdot p_b^{bl} \tag{5.1}$$

$$z_t \equiv e_t + p_t^* \tag{5.2}$$

$$p_t^m = \delta \cdot w_t + (1-\delta) \cdot z_t \tag{5.3}$$

$$w_t - w_{t-1} = \psi \cdot E_{t-1}\pi_t + (1-\psi)\pi_{t-1} + \kappa \cdot h_{t-1} \tag{5.4}$$

[18] In the IPCA, the minimum wage variation corresponds to the full variation of the "Domestic Employee" category, whose weight is around 3%.

All variables are expressed in logarithms; *p* stands for the price level, *w* for wages, *h* for the output gap, *e* for the nominal exchange rate, the superscript "*m*" for market goods (that is, goods and services whose prices are free to adjust to market conditions), and the superscript "*bl*" for backward-looking prices.

Equation (5.1) establishes that consumer prices are a weighted average of market and backward-looking prices. Equation (5.2) defines the variable *z* as international prices (p^*) expressed in terms of the domestic currency. Note that the exchange rate, *e*, is the number of units of domestic currency needed to buy one unit of foreign currency, such that an increase in *e* means a depreciation of the domestic currency. Equation (5.3) is the price equation for market goods. Such prices are a weighted average of international prices and domestic wages. Equation (5.4) defines the wage dynamics, which depends on expected inflation, past inflation and the output gap. The restriction that the coefficients of expected and past inflation sum to one guarantees the verticality of the Phillips curve.

After differentiating equations (5.1) and (5.3), and substituting equations (5.3) and (5.4) into equation (5.1) we get the reduced-form Phillips curve:

$$\pi_t = \omega \cdot \delta \cdot \left[\psi \cdot E_{t-1}\pi_t + (1-\psi)\pi_{t-1} + \kappa \cdot h_{t-1}\right] + \omega(1-\delta)\Delta z_t + (1-\omega)\pi_t^{bl} \ . \tag{5.5}$$

The estimated coefficients presented the expected sign, and all were significant at conventional values. Wald tests also showed that the reduced-form coefficients were statistically different from zero at conventional significance levels.

Varying the value of ω, the weight of market prices in the consumer basket, generates a family of Phillips curves. We now define "market inflation equation" as the Phillips curve that results when ω = 1. Otherwise, we refer to the "headline inflation Phillips curve". Before comparing the two curves, it is necessary to model backward-looking prices. By assumption, they are a weighted average of past inflation and external price variation:

$$\pi_t^{bl} = \beta \cdot \pi_{t-1} + (1-\beta)\Delta z_{t-1} \tag{5.6}$$

Table 2 shows the difference between the estimated coefficients of the market and headline inflation equations, for different values of β. The degree of inertia, measured by the estimated coefficient of past inflation in the reduced form, depends positively on the value of β. When β increases, headline inflation shows stronger persistence, as evidenced by a larger coefficient of π_{t-1}, while for β = 0, market inflation is more lag dependent. The exchange rate pass-through is smaller for market inflation only if β = 1. Finally, as expected, the sensitivity of inflation to the output gap is larger in the absence of backward-looking prices (ω = 1). In this case, the transmission mechanism of monetary policy through the aggregate demand channel is relatively efficient.

Table 2

Difference between headline and market inflation coefficients

Variable	**Headline inflation coefficient minus market inflation coefficient**		
	β = 1	**β = 0.5**	**β = 0**
$E(\pi)$	– 0.073	– 0.073	– 0.073
π_{t-1}	0.086	0.017	– 0.052
h	– 0.031	– 0.031	– 0.031
$\Delta z_t + \Delta z_{t-1}$	– 0.012	0.056	0.125

A more reactive monetary policy is expected under strong inertia, as in the case β = 1, since the level of interest rates needed to reduce inflation by any amount is higher than in the case of weak inertia. On the other hand, since monetary policy is relatively inefficient in this environment and the Central Bank's loss function is assumed to include output gap and interest rate smoothing, monetary policy should not react strongly to deviations of inflation from the target, as Clarida et al (1999) point out.

Henceforth, we refer to these two factors as inertial and efficiency effects. Since they work in opposite directions, it is not possible to tell a priori in which case the Central Bank would be more aggressive.

Based on the equations for headline and market inflation, we ran simulations with the assumption that the economy starts from the initial conditions that prevailed at the end of 1999 and that the Central Bank chooses the interest rate path (from 2000 to 2002) to minimise the loss function presented in section 5.2:

$$\min_{\{i\}} L_t = \sum_{j=1}^{T} \rho^j \left[\omega_\pi D_{t+j} \left(E_t \pi_{t+j} - \pi^*_{t+j} \right)^2 + \omega_h \left(E_t h_{t+j} \right)^2 + \omega_i \left(\Delta i_{t+j} \right)^2 \right] \tag{5.7}$$

Tables 3 and 4 display the results of the simulations under two alternative rules for the adjustment of backward-looking prices, that is, different values of β. The first column in Table 3 presents the baseline case of year-end market inflation, generated from simulations using the estimated coefficients of the Phillips curve (ω = 1). The remaining columns show how the baseline results change in the presence of backward-looking prices, when their weights in the Phillips curve are restricted to 13% and 20%. These columns exhibit the difference between the cases of headline and market inflation for three variables: year-end inflation, and yearly averages of nominal and real interest rates. Finally, Table 4 shows the differences in results that arise when we simulate a faster disinflation, that is, instead of pursuing inflation targets of 6%, 4% and 3.5% from 2000 to 2002, the Central Bank would need to meet targets of 5%, 3% and 2.5%.

Table 3

Effect of backward-looking prices

Period	Market inflation ω = 1	Difference between the cases of headline and market inflation					
		β = 1			β = 0		
		Inflation	Interest rate		Inflation	Interest rate	
			Nominal	Real		Nominal	Real
Weight of backward-looking prices = 13% (ω = 0.87)							
2000	5.55	–0.03	0.55	0.55	–0.27	–1.59	–1.22
2001	4.05	0.16	0.58	0.39	0.03	–0.50	–0.52
2002	3.64	0.03	–0.15	–0.18	–0.10	–0.68	–0.55
Weight of backward-looking prices = 20% (ω = 0.80)							
2000	5.55	–0.01	0.93	0.90	–0.32	–2.39	–1.93
2001	4.05	0.24	0.80	0.52	–0.02	–0.95	–0.89
2002	3.64	0.01	–0.37	–0.36	–0.18	–1.05	–0.83

For 2000 and 2001, when the degree of inertia is the highest (β = 1), the inertial effect dominates the efficiency effect. Nominal and real interest rates would have to be about half a percentage point higher in the case of the headline inflation Phillips curve than in the case of the market inflation Phillips curve. The difference in interest rates would have to be even greater if the weight of backward-looking prices increased from 13% to 20%. This pattern is reversed for 2002, however: nominal and real interest rates are smaller under headline inflation than under market inflation.

Table 4

Effects of a faster disinflation (ω = 0.87)

Period	Market inflation			Headline inflation, β = 1			Headline inflation, β = 0		
	Inflation	Interest rate		Inflation	Interest rate		Inflation	Interest rate	
		Nominal	Real		Nominal	Real		Nominal	Real
2000	–0.97	–0.56	0.50	–0.98	0.06	1.10	–1.15	–1.75	–0.45
2001	–0.95	–0.85	0.19	–0.79	–0.24	0.61	–0.88	–1.04	–0.07
2002	–0.97	–0.89	0.12	–0.95	–1.10	–0.10	–1.04	–1.32	–0.22

We attribute this result to the offsetting nature of the inertial and efficiency effects. To achieve the target in 2000, inflation should be reduced by 2.9 percentage points, which is the difference between observed inflation in 1999 (8.9%) and the 6% target for 2000. For 2001, inflation would have to be reduced by 1.55 percentage points in the market inflation case. For 2002, however, the disinflation effort is significantly smaller, at 0.55 percentage points for market inflation. The inertial effect thus dominates the efficiency effect when annual disinflation is high. The figures in Table 4 are consistent with this interpretation. When disinflation is faster, the interest rate difference between headline and market inflation rises to 1.10 percentage points in 2000 and 0.61 percentage points in 2001, implying a stronger inertial effect.[19]

It is more difficult to compare the case of headline inflation with β = 0 with the baseline market inflation case. The higher pass-through may slow the reduction in interest rates, given the inflationary effects of the consequent exchange rate depreciation. On the other hand, the case of β = 0 presents a relatively small degree of inflation inertia and a reduced efficiency of monetary policy, which encourages the Central Bank to cut interest rates aggressively. According to Table 3, the balance of all these factors favours a faster reduction in interest rates when the Central Bank faces a headline inflation Phillips curve with β = 0.

6. Monitoring inflation targets under an IMF programme

This section focuses on alternative ways of assessing the monetary policy stance in inflation-targeting countries that have an ongoing programme with the IMF. Brazil was the first country to adopt inflation targeting while a financial support programme was under way. This raised some important issues with regard to assessment. The usual performance criterion on net domestic assets is not adequate for an inflation targeting regime, because it harms transparency and may induce unnecessary monetary movements.

We compare the behaviour of inflation, the output gap and interest rates under alternative criteria to evaluate the monetary policy stance, which may be more suitable for an inflation targeting country. We first describe four accountability alternatives:

I. Year-end inflation target. This is the original inflation targeting framework in Brazil. The Ministry of Finance sets the year-end target and the tolerance bands two years in advance. The current targets are 6%, 4% and 3.5% for 2000, 2001 and 2002, respectively, and the Central Bank is considered successful in achieving the target if actual year-end inflation falls within a ±2 percentage point band around the target.

[19] A faster disinflation allows the Central Bank to set relatively lower nominal interest rates. In the model, this results from the fact that a smaller target for inflation would also reduce inflation expectations and, hence, current inflation. Since the optimal real interest rates are higher, a faster disinflation still implies a tighter monetary policy.

II. Quarterly inflation targets, set by a linear convergence rule, as established in the fourth review of the current agreement with the IMF. According to this criterion, 12-month inflation for each quarter should equal the value obtained by linear interpolation of the adjacent year-end targets. For example, given the 6% and 4% year-end targets for 2000 and 2001, the target path from the first to the third quarters of 2001 should be 5.5%, 5% and 4.5%. A potential problem with this criterion is the fact that shocks in a given year contaminate the quarterly 12-month inflation figures of the following year, forcing the monetary authority to react unnecessarily to such shocks.

III. Quarterly inflation targets that take into account the actual outcomes observed in the previous year. Whereas the previous alternative outlines a quarterly target path based on year-end targets, this criterion is based on the actual inflation figures of the previous year. In logarithm terms, this target is set according to the formula below:

$$\tilde{\pi}^*_{T,i} = \sum_{\substack{j=i+1 \\ i<4}}^{4} \pi_{T-1,j} + \frac{i}{4}\pi^*_T$$

where $\tilde{\pi}^*_{T,i}$ is the 12-month inflation target for quarter *i* in year *T*; $\pi_{T-1,j}$ is the actual inflation observed in quarter *j* in year *T-1*; and π^*_T is the inflation target for year *T*. The target for the first quarter of a year would be the actual inflation observed in the last three quarters of the previous year, plus ¼ of the inflation target for the current year; the target for the second quarter would be actual inflation observed in the second half of the previous year, plus ½ of the inflation target for the current year; and so on. The target path should be reset at the beginning of each year, once the previous year's inflation is known. This criterion overcomes one of the major drawbacks of alternative II, namely, the fact that shocks in a given year contaminate monetary policy decisions in the following year, irrespective of the effects such shocks have on inflation. Both criteria, however, have the potential drawback of increasing the frequency of monetary performance evaluation, from yearly to quarterly.

IV. A Taylor-type rule.

The starting point of the analysis is to assume the Central Bank sets the nominal interest rate *i* to minimise the loss function:

$$\min_{\{i\}} L_t = \sum_{j=1}^{T} \rho^j \left[\omega_\pi D_{t+j} \left(E_t \pi_{t+j} - \pi^*_{t+j} \right)^2 + \omega_h \left(E_t h_{t+j} \right)^2 + \omega_t \left(\Delta i_{t+j} \right)^2 \right] \tag{6.1}$$

subject to:

$$\pi_t = \alpha_1 E_t \pi_{t+1} + \alpha_2 \pi_{t-1} + \left(1 - \alpha_1 - \alpha_2\right) \Delta\left(e_t + \pi^f_t\right) + \alpha_3 h_{t-1} + \varepsilon_{\pi,t} \tag{6.2}$$

$$h_t = \beta_0 + \beta_1 h_{t-1} + \beta_2 \left(i_{t-1} - \pi_{t-1}\right) + \beta_3 \theta_{t-1} + \varepsilon_{h,t} \tag{6.3}$$

$$\Delta e_t = \Delta i^f_t + \Delta x_t - \Delta i_t + \varepsilon_{e,t} \tag{6.4}$$

$$\Sigma = \begin{bmatrix} \sigma^2_\pi & \sigma_{\pi,h} & \sigma_{\pi,i} \\ \sigma_{\pi,h} & \sigma^2_h & \sigma_{h,e} \\ \sigma_{\pi,i} & \sigma_{h,e} & \sigma^2_e \end{bmatrix} = \begin{bmatrix} \sigma^2_\pi & 0 & 0 \\ 0 & \sigma^2_h & 0 \\ 0 & 0 & \sigma^2_e \end{bmatrix}. \tag{6.5}$$

Equation (6.1) is the loss function already discussed in Section 5.2. The value of the dummy variable, D, varies according to the alternative chosen. For alternative I, in which the Central Bank cares only about year-end inflation, D equals one in the last quarter of each year and zero in all other quarters. Under alternatives II and III, D equals one in all quarters, meaning that monetary policy should be evaluated every quarter.

Equations (6.2) to (6.4) are the constraints of the minimisation problem; they form a small structural macroeconomic model along the lines presented in Section 3. Condition (6.5) assumes a diagonal variance-covariance matrix. Additionally, the error terms are assumed to be independent, identically and normally distributed. The calibrated values for the standard errors were 0.5 percentage points for output gap, 0.3 percentage points for inflation and 5 percentage points for the exchange rate.

To run stochastic simulations, we assumed the Central Bank minimises the loss function taking into consideration eight periods ahead, with a discount rate of 1% (ρ = 0.99). This horizon might be considered relatively short by international standards, but it is a reasonable hypothesis for the Brazilian economy, which is characterised by a higher level of uncertainty, given it is still in transition to its steady-state inflation level. Furthermore, evidence shows that optimising periods beyond eight quarters do not yield gains in terms of efficiency in the output-inflation variability locus (see Freitas and Muinhos (2001)). Finally, this optimisation horizon is also in line with the *Inflation Report*, which releases the forecasts of inflation up to two years ahead.

In the stochastic simulations, we assumed that at the beginning of quarter *t*, when the interest rate is set, the central bank knows the realisation of all variables up to *t-1*, but does not know the shock. The results presented in Table 5 were obtained after 150 simulations. We performed the simulations as if the economy were at the beginning of 2000. All variables took their actual values as initial conditions, except for the output gap, which was set to zero at the end of 1999. This modification in the initial conditions regarding the output gap allows us to concentrate on the contamination effect described in alternative II above, since IPCA inflation in 1999 was 0.9 percentage points above the target.

Finally, the simulations for alternative IV do not need the optimisation procedure, since with the Taylor-type rule the interest rate is simply set according to observed outcomes. The specification of the traditional Taylor rule is:

$$i_t = i_t^* + 1.5(\pi_{t-1} - \pi_{t-1}^*) + 0.5h_{t-1} \tag{6.6}$$

where *i* is the annualised quarterly interest rate and *i** is the equilibrium nominal interest rate. To be consistent with the loss function, we introduced interest rate smoothing: the actual interest rate is the weighted average of the previous value of the interest rate and the one given by equation (6.6), with weights 0.60 and 0.40, respectively.

Table 5 shows that all alternatives lead to a level of expected year-end inflation that is well within the ±2 percentage point tolerance bands established in the Brazilian inflation targeting framework, despite the initial conditions (inflation was almost 1 percentage point above the target). Such results can be explained by the short lag of the transmission mechanism. Decisions regarding interest rates affect inflation contemporaneously through the exchange rate channel and take only two quarters to affect inflation through the aggregate demand channel. The output gap performance was also good, in the sense that it stayed within a band of ±1 percentage point during most of the period for all alternatives.

It is difficult to rank the alternatives by looking only at the variability of inflation and output. Only the Taylor rule (alternative IV) yielded generally higher volatility for both inflation and output. The figures for the other three alternatives do not prompt clear-cut conclusions, either because the qualitative pattern is not stable or because the differences in standard deviations are small. The results presented in Table 6 were calculated from the loss function for alternative I (in which only year-end inflation rates matter). The performance of the Taylor rule[20] was clearly the worst, while alternatives II (linear target path) and III (the target path based on the previous year's outcomes) yielded a relative loss of approximately 15%.

The similar performance of the first three alternatives is a surprising result. We expected alternative I to present a visibly better performance for year-end inflation, because it ignores inflation outcomes in the first three quarters of the year, while alternative II was expected to yield the worst outcome, since it forces monetary policy to react to large deviations of inflation from the target in the previous year. The presence of output gap and interest rate variation in the loss function in all quarters may have contributed to making the three alternatives more similar. Another possible explanation is related to the backward-looking component of inflation. To meet the year-end inflation target, the monetary authority needs to put a high weight on the inflation outcomes of the interim quarters. Therefore, the effect of changing the accountability frequency may have been mild.

[20] It is possible, however, that the performance of the Taylor rule could dramatically improve if a different set of parameters is chosen.

Table 5

Results of the stochastic simulations

Year	Q	12-month inflation				Output gap				Nominal interest rate				Std dev of inflation			
		I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
2000	1	8.28	8.26	8.27	8.14	1.05	0.98	1.05	1.04	20.2	20.5	21.0	24.9	0.51	0.50	0.53	0.56
2000	2	8.65	8.63	8.54	8.28	1.16	1.12	1.10	0.77	20.5	20.9	21.7	33.2	1.53	1.50	1.44	1.26
2000	3	7.62	7.59	7.49	7.19	0.77	0.65	0.62	–0.62	20.1	20.1	20.9	30.4	1.24	1.22	1.12	0.98
2000	**4**	**6.03**	**5.99**	**5.91**	**5.66**	**0.23**	**0.25**	**0.13**	**–1.50**	**19.0**	**18.4**	**19.0**	**20.3**	**0.60**	**0.55**	**0.53**	**0.72**
2001	1	5.22	5.22	5.14	4.89	0.06	0.09	0.01	–1.10	17.6	16.6	17.7	13.3	0.56	0.63	0.61	0.89
2001	2	5.11	5.12	5.11	4.72	0.01	0.19	–0.03	–0.25	15.9	14.9	16.1	13.4	0.68	0.67	0.67	0.74
2001	3	4.94	5.01	4.98	4.55	–0.02	0.18	–0.09	–0.07	14.2	13.3	14.4	14.7	0.82	0.87	0.83	0.81
2001	**4**	**4.29**	**4.40**	**4.29**	**3.95**	**–0.19**	**0.04**	**–0.31**	**–0.35**	**12.7**	**11.8**	**12.5**	**13.5**	**0.69**	**0.74**	**0.71**	**0.84**
2002	1	3.61	3.64	3.57	3.57	–0.37	–0.17	–0.41	–0.50	11.0	10.3	10.6	9.3	0.61	0.68	0.61	0.87
2002	2	3.28	3.33	3.31	3.48	–0.35	–0.14	–0.34	–0.14	9.4	8.9	9.1	8.4	0.79	0.73	0.75	0.84
2002	3	3.39	3.47	3.44	3.57	–0.21	0.04	–0.10	0.07	7.9	7.7	7.9	8.7	0.65	0.62	0.67	0.80
2002	**4**	**3.58**	**3.69**	**3.66**	**3.57**	**–0.05**	**0.18**	**0.01**	**–0.09**	**6.8**	**6.8**	**6.9**	**9.1**	**0.60**	**0.65**	**0.66**	**0.89**

Year	Q	Std dev of output gap				Prob (π - π *>1 pp)				Prob (π - π *>2 pp)			
		I	II	III	IV	I	II	III	IV	I	II	III	IV
2000	1	0.45	0.41	0.47	0.46	3.0	3.3	7.3	9.3	0.0	0.0	0.0	0.0
2000	2	0.52	0.52	0.55	0.61	67.0	72.7	66.0	43.7	13.0	10.7	10.0	8.7
2000	3	0.56	0.56	0.54	0.64	50.5	52.0	45.3	30.0	5.5	4.7	2.0	4.3
2000	**4**	**0.57**	**0.57**	**0.57**	**0.76**	**11.0**	**7.3**	**5.3**	**17.0**	**0.0**	**0.0**	**0.0**	**0.3**
2001	1	0.59	0.64	0.58	0.95	7.0	10.0	10.7	25.3	0.0	0.7	0.0	1.3
2001	2	0.66	0.65	0.53	0.96	14.0	11.3	12.7	20.0	0.0	0.7	0.0	0.0
2001	3	0.65	0.57	0.54	1.06	22.5	27.3	23.3	21.3	0.5	1.3	0.7	1.7
2001	**4**	**0.59**	**0.63**	**0.58**	**1.05**	**13.0**	**20.0**	**14.7**	**24.0**	**0.5**	**0.0**	**0.7**	**0.7**
2002	1	0.65	0.64	0.62	1.08	10.0	15.3	9.3	22.0	0.0	0.0	0.0	2.3
2002	2	0.66	0.57	0.66	1.12	20.5	14.7	17.3	22.3	1.0	0.7	0.7	1.3
2002	3	0.58	0.57	0.65	1.19	12.0	10.7	13.3	20.0	0.5	0.0	0.0	1.0
2002	**4**	**0.58**	**0.59**	**0.60**	**1.15**	**9.5**	**14.0**	**12.0**	**22.7**	**0.0**	**0.0**	**0.7**	**2.7**

Obs: (i) Alternative I: original Brazilian IT framework, with targets set only for year-end inflation. (ii) Alternative II: quarterly inflation targets set by a linear convergence rule. (iii) Alternative III: quarterly target path based on the actual inflation figures of the preceding year. (iv) Alternative IV: use of a Taylor-type rule. (v) The standard deviation of inflation refers to deviations from the target, not from the mean. Since there is no quarterly target defined for Alternative I, the standard deviation was estimated using the target set for Alternative II.

Table 6

Absolute and relative losses

	Alternatives			
	I	**II**	**III**	**IV**
Loss	0.85	0.99	0.97	5.29
Relative loss (%)	–	16.2	14.0	521.4

These findings, however, do not imply that the Central Bank should be indifferent in choosing among the first three alternatives. If the Central Bank is in fact concerned only with the year-end accumulated inflation, then setting a quarterly target path for inflation is not likely to severely alter the behaviour of macroeconomic variables. Should monetary policy be evaluated on a quarterly basis, however, there is a high probability that unnecessary false alarms would be triggered in the course of the year. In the context of the current agreement, an informal consultation with the IMF is triggered if inflation deviates from the target path by more than 1 percentage point, and a formal consultation is required if the deviation exceeds 2 percentage points. The probability of inflation deviating from the target by more than 1 percentage point falls significantly as the year progresses (Table 5). This is a particularly delicate issue for an emerging economy, because false alarms may trigger a confidence crisis and thus make the conduct of monetary policy more difficult. A compromise solution to this problem would be to increase the tolerance interval for the first three quarters of the year; this would preserve the quarterly accountability frequency while reducing the probability of triggering false alarms.

7. Conclusions

The relative success of economic policy in Brazil since the 1999 devaluation stems from a variety of factors, including the initial macroeconomic conditions, the strong international support, and the inflation targeting regime that provided an adequate and timely anchor for expectations. The most important factor, however, was the long-awaited fiscal reversal, which was a necessary (but obviously not sufficient) condition for the sustainability of the inflation targeting framework.

Despite the huge devaluation in early 1999, the year ended with single digit consumer price inflation, which fell within the target set by mid-year, and with nearly 1% GDP growth, which was well above the preliminary prospects. Inflation behaviour showed a very low pass-through, which can be in part attributed to the output gap in the period, the overvalued real just before the floating, and the low initial inflation. The inflation targeting regime guided expectations in line with the multi-year disinflation targets, allowing the relative price realignment after the devaluation to be processed without igniting overwhelming pressures on consumer prices.

However, the large swing in relative prices poses some idiosyncratic challenges for the monetary authority. The evolution of the backward-looking prices is of particular concern. Such prices correspond to around 25% of the IPCA and increased by 36.6% in 1999-2000, while all other prices taken together rose by only 8.8% in the same period.

The results of simulation using different assumptions regarding the adjustment rule and the weight of backward-looking prices in the IPCA show that when the adjustment of these prices is based on past inflation, the degree of inertia increases and forces the Central Bank to be more restrictive in order to disinflate the economy. Nominal and real interest rates are 0.5 to 1 percentage point higher when the Central Bank faces a Phillips curve with backward-looking prices. When inflation is closer to its steady-state value, however, the presence of administered prices in the IPCA does not alter the behaviour of monetary policy significantly.

We presented a brief description of the Brazilian experience, showing how monetary policy reacted to different shocks. In the inflation targeting period, all the shocks that hit the economy propagated their effects mainly through the supply side and financial markets. Although the shocks displayed some common features, such as rising oil prices, the rapidly changing overall economic conditions demanded different responses.

We confronted the theoretical policy prescriptions with estimated impulse responses to different kinds of shocks in a simple empirical model. As expected, the results showed that a central bank should be fairly restrictive when countering aggregate demand shocks, but it should partially accommodate supply and financial shocks by contemporaneously increasing nominal interest rates while allowing real interest rates to fall. Real interest rates eventually rise with the subsequent fall in inflation. This pattern, suggested by the impulse response functions, was observed in recent episodes in Brazil. When facing supply and financial shocks in the last two quarters of 1999, the Central Bank kept nominal interest rates constant at a level above long-run equilibrium and allowed real interest rates to fall. With inflation under control, real interest rates rose again in the following quarter, and the Central Bank resumed the trend of reducing interest rates.

Finally, the paper addressed the issue of how to monitor inflation targeting under agreements with the IMF. We used a simple structural model to show that except in the case of a Taylor rule, the behaviour of relevant macroeconomic variables does not change significantly when the frequency at which monetary policy is evaluated increases from yearly to quarterly. However, a central bank should not be indifferent when choosing between year-end accountability only and quarterly monitored accountability, such as that established in recent Brazilian agreements with the IMF. The reason is simple: if the relevant macroeconomic variables are initially out of equilibrium, then the probability of meeting the target by year-end may be high while the probability of breaching the tolerance bands in the intermediate quarters is also high. Monitoring quarterly inflation figures under such circumstances can send unnecessary false alarms, introducing unwarranted noise in the conduct of monetary policy by affecting expectations.

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Market liquidity and the role of public policy

Arnaud Marès,[1] European Central Bank

1. Introduction

Much attention has been devoted in the recent period, in both private and public circles, to the question of market liquidity. There are a number of circumstantial reasons for this heightened interest. One is the recognition that market liquidity cannot be taken absolutely for granted, even in normal times or in the deepest and most liquid segments of the financial system. The deterioration, admittedly limited, of liquidity in the US Treasury bond market, in a context of reduction of the public debt, is an example at hand. Another factor of interest stems from the behaviour of liquidity during and especially after financial market crises. Widespread market commentary that liquidity in a broad cross section of the financial system has never fully recovered to the levels prevailing before the financial crisis of autumn 1998 has raised a number of questions, not all fully answered as yet, as to the dynamics of market liquidity. The private benefits of secondary market liquidity for issuers of public debt have equally attracted a large amount of attention, especially in the context of the more competitive environment created in Europe by the introduction of the euro. Finally, many questions have been raised by the development of alternative trading systems and the effect they may have on market liquidity.

The interest in understanding the nature, the role and the dynamic of market liquidity also has deeper roots. The trend towards a larger role of markets in financing economic activity, as well as the prevailing use of market-based instruments for the implementation of monetary policy, suggest that market liquidity may be increasingly relevant to public policymakers in general, and central banks in particular.

This paper is intended as one among many contributions to the broad-based investigation of the multiple facets of market liquidity. Its focus is on the role of market liquidity from a public policy point of view, and on the various types of public policies aimed, directly or indirectly, at enhancing market liquidity. This version of the paper constitutes a starting point rather than an outcome of the investigation of this issue, and was prepared for the Autumn Meeting of Central Bank Economists hosted by the Bank for International Settlements in October 2001.[2]

The following section of the paper proposes a simple conceptual framework to approach the issue of market liquidity, according to which market liquidity is defined as the output of financial intermediation. Section 3 raises the question of the public benefits provided by market liquidity, and to what extent the existence of such benefits justifies an active involvement of public authorities in fostering the provision of liquidity. The fourth section describes a number of actual policies through which public authorities have actively supported the provision of market liquidity over the years. Section 5 concludes.

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1 Directorate General Operations, European Central Bank.

2 The paper strongly benefited from extensive discussions with S Grittini and V Brousseau at the ECB as well as from substantial comments by F Papadia (ECB) and B Cohen (BIS). The views expressed by the author remain his own, however, and cannot be attributed to the ECB or to the BIS.

2. A simple conceptual framework for the analysis of market liquidity

2.1 Definition of market liquidity

Market liquidity is a notion that everybody seems to understand intuitively, but that is considerably more difficult to translate into a universally accepted definition. One reason for this is that market liquidity covers not one, but several concepts, more or less tightly linked. Muranaga and Shimizu (1999) provide a survey of different interpretations of market liquidity and quote in particular the definition offered by Black in 1971, according to which:

"A liquid market is a market in which a bid-ask price is always quoted, its spread is small enough and small trades can be immediately executed with minimal effect on price."

The definition proposed by Muranaga and Shimizu is close to that of Black and is also the definition retained, inter alia, by the study group on market liquidity established by the Committee on the Global Financial System in December 1997.[3] This definition reads as follows:

"A liquid market is a market where a large volume of trades can be immediately executed with minimum effect on prices."

These definitions call for a number of remarks. Firstly, while it is clear that a market may be more or less liquid, it is much less clear that two markets can always be ranked in terms of their degree of liquidity. According to the definitions proposed here, liquidity has several dimensions, the most traditionally presented being tightness and depth.[4] Whereas tightness refers to the ability of the market to match supply and demand at a low cost, depth refers to the size of transactions that a market can absorb without any noticeable impact on prices.

As long as these two dimensions are positively correlated, as is traditionally assumed, they should not create significant problems in interpreting the degree of liquidity of a market. The assumption of a positive correlation between tightness and depth has, however, recently been challenged by market participants. In the context of the foreign exchange market, in particular, a number of active dealers have reported that the increased tightness of the market brought about by the development of electronic brokerage systems has been accompanied by a reduction in the depth of the same market.

These statements may deserve to be substantiated by conclusive research.[5] They illustrate, however, the difficulty of fully encompassing the notion of market liquidity in one single quantitative indicator, be it the bid-ask spread, turnover or any of the other indicators often used as proxies for liquidity. This also suggests that liquidity may change qualitatively, in a way that makes it difficult to conclude that it has improved or deteriorated altogether. This would be the case, for instance, if a market had become tighter but at the same time shallower, as suggested above.

Another remark relates to the question of what would be an infinitely liquid market. Extrapolating from the definition proposed above, one may infer that an infinitely liquid market would be a market where it is possible to immediately execute a transaction of any volume at zero cost and without any impact on prices. One may, however, question whether a market where the preferences of participants, reflected in their transactions, have no effect whatsoever on price would still be an efficient market, or indeed a market at all.

It follows from this that a perfectly liquid market may not be a market where any transaction can be executed without any impact on prices, but one where the price impact of a transaction is not out of

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[3] In December 1997, the CGFS established a study group of central bank researchers, under the chairmanship of the Bank of Japan, to study the determinants and dynamics of market liquidity. The conclusions of the group were published by the CGFS in May 1999 under the title *Market liquidity: research findings and selected policy implications*.

[4] Kyle (1985) provides another review of the definition of market liquidity and describes it as including "tightness (the cost of turning around a position over a short period of time), depth (the size of an order flow innovation required to change prices a given amount) and resiliency (the speed with which prices recover from a random, uninformative shock)".

[5] Muranaga and Shimizu (1999) provide an example of such research. They provide a theoretical model that leads to the conclusion that, under certain assumptions, an increase in depth comes with a deterioration of tightness and vice versa.

proportion to its information content. Incidentally, the common use of the phrase “deep *and* liquid markets” suggests that the notion of depth and that of liquidity overlap, but do not entirely coincide.

A similar definition of market liquidity is that a market is liquid if uncertainty as to the execution price of a transaction is low. This does not necessarily imply that the execution price is identical to the mid-price prevailing in the market at the time of the transaction, but rather that the deviation between the two is predictable. In practice, this is likely to be associated with low and stable bid-ask spreads, as well as with significant depth.

It is noteworthy that all definitions of market liquidity implicitly or explicitly (as in the case of Black’s definition) assume it is always possible to execute transactions immediately. This suggests that market liquidity encompasses two elements, one of which is discrete, and the other continuous:

A market is only truly liquid insofar as it is always possible to execute a transaction.

The less the execution price of a transaction deviates from the mid-price prevailing at the time of the transaction, the more liquid is the market.

The first condition, in particular, is of key importance. It is not enough that turnover is high for a market to qualify as liquid. A market must be able to absorb any (reasonable) flow such that, whenever a participant decides to enter into a transaction, there exists another participant or group of participants ready to act as counterparty, albeit possibly at the cost of a variation of the price.

2.2 Market liquidity defined as the output of financial intermediation

Based on the definitions proposed in the previous section, one may elaborate a simple conceptual framework for the analysis of market liquidity. This relies in particular on the conclusion that the notion of liquidity is closely connected to the possibility of executing a transaction at any time.

According to this simple framework, liquidity is the output of financial intermediation on the secondary market. Financial assets, such as bonds for instance, are not produced by dealers. They are produced by the issuers (ie the debtor or the originator of the asset) and ultimately purchased by investors. What dealers produce is the ability for investors to buy or sell assets at any point during their lifetime. In other words, dealers produce liquidity and the end users of the market purchase it.

This framework may appear so obvious that its presentation is completely superfluous. Yet it provides a good basis for the analysis of liquidity. In particular, it allows us to introduce the concept of the production cost of liquidity, and to link the various factors traditionally described as having a bearing on liquidity to the technology used by dealers for its production.

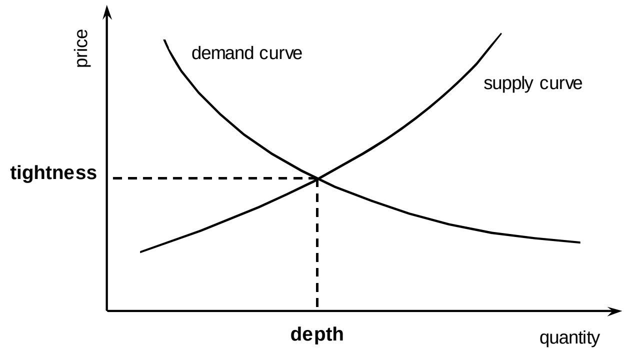
This simple framework can be further described as follows. A unit of liquidity is defined as the ability to execute a transaction for a value of, say, €1, in a given market, with no impact or only a negligible impact on price. The more units of liquidity are produced, the deeper the market is.

The price of liquidity is the price that end users are willing to pay to ensure that they can execute a transaction.[6] The cost of production of liquidity is the amount of capital that a dealer requires, given technology, to guarantee that he can quote two-way prices at a given time. Under this framework a simple demand curve, as well as a supply curve, for liquidity can be defined. The degree of liquidity in a market, whether approached from the point of view of tightness or depth, is defined by the intersection of the two curves, as illustrated in the chart below.

[6] This price is not exactly equal to the transaction cost, because there are other means through which end users may be willing to pay for liquidity. The yield that investors forgo in return for holding more liquid assets is one example.

Chart 1

Equilibrium of liquidity supply and demand



This representation of a supply and a demand curve can be used either at the scale of the market as a whole, or at the scale of each individual transaction. This paper generally adopts the first approach. However, adapting the same concept to each individual transaction would possibly allow us to better encompass elements such as returns to scale in the production of liquidity.[7]

2.3. Dealers' capital input and absorption capacity of the market

The framework proposed here allows analysis of the various factors having a bearing on market liquidity, such as market or product design, through their contribution to the technology used to produce liquidity. Before engaging in this discussion, it should be underlined that the main and essential input in this production process is capital. No market can be truly liquid unless a sufficient amount of capital is devoted to its functioning by participants.

The reason for this is that liquidity, as defined earlier, depends on the fact that, whenever a participant decides to enter into a transaction, there is another participant willing to act as counterparty. The first agent is the consumer of liquidity, the second is the producer, or provider. The provider, by agreeing to enter into a financial transaction, agrees, by definition, to be exposed to a financial risk. His ability to enter into a transaction therefore depends on his capital base, and the more liquidity he provides, the more capital, all things equal, he has to consume (ie immobilise) for that purpose.

The notion of capital consumed can be interpreted in several ways, all of which are encompassed in the rest of this paper. For instance, it can be interpreted in the sense of providing coverage for risk limits in derivatives transactions and other margined positions. It can also be interpreted in the sense of inventory management: just as entering into a derivatives position increases the dealer's risk exposure and consumes some of his capital, entering into a cash transaction either consumes some of his inventory (in the case of a sale of an asset) or consumes some of his funding capacity (in the case of a purchase).

Another point worth underlining here is that liquidity suppliers need not be "professional" market-makers. They may be end users of the market, such as relative value traders for instance, as long as they are willing to enter into transactions at the request of other participants. From this point of view, liquidity may be produced as a by-product of another activity (arbitrage for instance). Users of liquidity may also under certain circumstances become producers of liquidity (and vice versa).

To illustrate the link between the capital committed to a market and its shock absorption capacity, take a market, say a foreign exchange market, with a very large number of end users and a certain number

[7] The - very basic - underlying idea here is that the higher the degree of liquidity in the market, the less additional capital would be required to produce a marginal unit of liquidity, and therefore the lower the average cost of production of each unit would be as the overall amount grows. One may further refine this - still extremely basic - model to propose that expectations that a market is liquid are a factor of production of liquidity. Self-fulfilling expectation mechanisms, whereby if market participants expect a market to be liquid, it is likely to become liquid, could be analysed in this context.

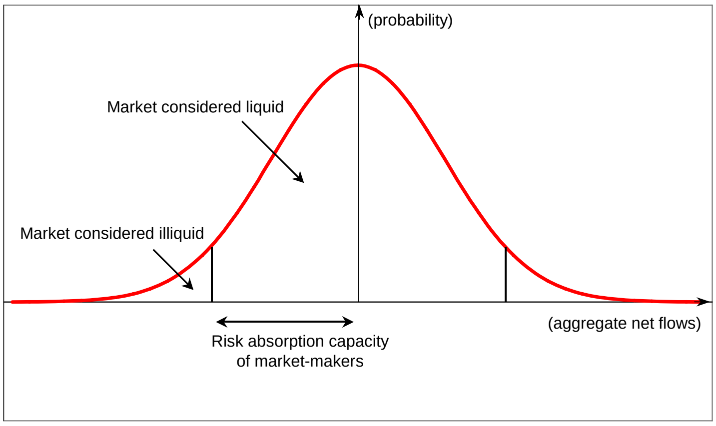
of market-makers. The role of the market-makers in this model is to act as counterparty to any transaction initiated by an end user. It is clear that, since this activity implies that the market-makers are willing to take a risk, their ability to do so will be constrained by their overall risk limits. Market-makers can therefore play their role only to the extent that the aggregate flows from all end users at one point in time do not exceed the aggregate risk limit of all the market-makers,[8] or, for practical purposes, their capital base.

The end users may be corporate treasurers or institutional asset managers, all of whom have to conduct daily foreign exchange business related to their core activities. For the purpose of illustration, it is assumed that these end users conduct their transactions passively, ie without taking directional views on the level of the exchange rate, and independently of whatever transactions are carried out by other participants in the market. By means of simplification, it is assumed that all these agents have a flat probability of buying or selling at any moment in time any amount of euros, up to €1 billion. In such circumstances, the aggregate net flows resulting from the passive activity of all these individual agents would follow a normal distribution, with an average of 0 and a standard deviation of €500 million.

As long as net flows do not exceed the risk limit of the market-makers, no problem would arise, and the market would be considered liquid. Should, however, the aggregate net flows from end users exceed the risk absorption capacity of market-makers, the latter would no longer be able to play their role. There would be end users willing to enter into a transaction but unable to find a counterparty. To the extent that liquidity is defined by the ability to execute a transaction on request, the market would effectively become illiquid.

Chart 2

Representation of the probability of endogenous "jamming" of the market



The probability of such a situation, under the assumptions used here, is admittedly low. For instance, the probability of the aggregate net flows exceeding €2.5 billion at any time would here be only 0.0006%. However, the probability of these aggregate flows exceeding €1.25 billion, half the previous amount, rises to 1.2%.

The illustrative amount highlighted and the assumptions used here are of course unimportant. The important points can be summarised as follows. Firstly, however small, there always exists a probability of a market "jamming" at any time. Secondly, all things equal, this probability rises considerably if and when the absorption capacity of the market is reduced, even moderately. Thirdly, this absorption capacity is a direct reflection of the amount of capital committed to the market by liquidity providers.

[8] In this model, the number of market-makers is irrelevant. It could just as well be assumed that there is only one large market-maker.

The model used here is of course simplistic. For one thing, it ignores entirely the complementary role of dealer capital and price adjustments in rectifying imbalance. If the strain on capital from an increase in purchases (or sales) is too high, the price will have to rise (or fall) until the imbalance is eliminated. The underlying concept is, however, unchanged. The fact that price adjustments allow the elimination of imbalances implies that there are participants in the market who are willing to enter into a transaction if the price deviates from its perceived equilibrium value. In a way, it can be said that these participants are willing to provide liquidity by taking a position, at a certain cost, which is the difference between the price initially prevailing (equilibrium value) and the one at which they are ready to trade.

Another qualification is that the amount of capital necessary to ensure the liquidity of a market may not necessarily increase as the number of end users increases. In fact, providing there exists a sufficient diversity of behaviours among end users, the required amount of capital may be largely independent of the overall turnover of the market. The scenario presented above is one such example, where it is the average size of transactions, rather than their number, that determines the capital requirement of a liquid market.

The discussion on the necessity for a certain amount of capital to be devoted to trading activities for a market to be liquid is, however, central in some of the ongoing developments in several markets. A first observation in this regard is that dealers will only commit capital to liquidity provision if this activity is profitable. In fact, it is probably not sufficient that liquidity provision is profitable per se. It needs to be at least as profitable - when adjusted for risk - as other lines of business of the financial institutions involved.[9] It has often been suggested that a reduction in transaction margins has been accompanied by a reduction in the profitability of liquidity provision, and accordingly by a withdrawal of capital from these activities. The result would be a lower capacity of main markets to absorb shocks.

The *71st Annual Report* of the BIS, for instance, underlines that "there are currently no more than 20 global players in foreign exchange markets" that can provide two-way prices on a wide range of currency pairs. This is probably a generous estimate, if it refers to the ability of dealers to quote prices even under volatile market conditions. In addition, individual dealers have often reported that, especially after the financial crisis of autumn 1998, they had very significantly downsized their risk limits, ie equally their risk absorption capacity.

Indeed, dealers have sometimes reported an increased frequency of micro-stress episodes, or "gaps", defined as situations when a random flow occurring in the market exceeds the risk absorption capacity of market-makers at that time. As market-makers are unable to absorb the transaction, its execution is contingent on finding an "external" source of liquidity. This would explain sudden rises or falls in prices that only stop at levels where contingent orders had been placed by customers ex ante,[10] as it is these orders that act as external sources of liquidity. Anecdotal reports of an increased frequency of gaps may, however, need to be better substantiated by facts.[11]

There are, by contrast, also good indications that the risk-adjusted return on capital of trading firms remains healthy, at least for some market segments. A study published by McKinsey in the summer of 2001 suggests that a number of banks "are realising a return on equity of well over 20% from making markets for traditional cash equities".

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[9] Alternatively, dealers may commit capital to the supply of liquidity if there is synergy with other business lines, say brokerage, bond/equity syndication, M&A consultancy, etc. This would imply that liquidity is vulnerable to prospective return in these other businesses (see also D'Souza and Lai (2001) for an excellent analysis of this problem).

[10] Contingent orders are instructions from customers to dealers to execute on their behalf a certain transaction if and when market prices reach a certain level.

[11] See Chaboud and Weinberg (2001) for a particularly useful analysis of very short-term volatility in the foreign exchange market that sheds light on this particular question.

2.4 Technology and the liquidity production process

A considerable amount of work has already been done to identify the various determinants of market liquidity, and it is not the purpose of this paper to add to these efforts. Rather, this section briefly recalls some of the well known factors that have a bearing on liquidity, and suggests that they can be interpreted as contributing to improving the productivity of the production of liquidity, ie reducing the amount of capital consumed per unit of liquidity produced.

The five headings below are directly extracted from the note entitled *How should we design deep and liquid markets? The case of government securities*, published by the CGFS in October 1999. Other factors, not covered under these headings, that have a bearing on liquidity can also be interpreted through the angle of their contribution to "technology".

(a) Competitive market structure

The idea that it is important that dominant market players can be challenged by new entrants is not directly related to productivity, but rather to the desirability that liquidity services are priced to customers at their marginal cost. Indirectly, this also means that, all things equal, productivity improvements in the production process directly translate into an increase in liquidity.

(b) Level of fragmentation of the market

A common finding of studies on market liquidity is that it benefits from a high substitutability of instruments, or from a high outstanding amount of fungible assets. This is typically the case for government bonds, for instance, where large benchmark issues tend to be more liquid. The same argument underpins the idea that the liquidity of government bonds is likely to increase across the curve if these bonds can be stripped, and if similar coupons issued from the stripping of different bonds are fully fungible.

An interpretation of this finding is that the easier it is for a liquidity producer to hedge his position, the less capital he will consume when agreeing to enter into a transaction at the request of an end user. This ability to hedge one's position rapidly and effectively may depend on the availability of assets in the market where liquidity is produced, on the number of potential counterparties in this market, etc. It may also depend on how easy it is to hedge one's risk through another - related - market. In this context, liquidity in one market may be used as input for the production of liquidity in another market segment, which allows saving on capital. One example of that is the case of strips mentioned above.

Another example is the role of highly liquid futures markets to generate liquidity for the cash market, not only for bonds deliverable against the futures contract, but also for the rest of the yield curve. If a dealer can properly and rapidly hedge any bond through a linear combination of positions in a small number of highly liquid instruments, he will be more likely to enter into transactions on any of these bonds, for the same consumption of capital.

(c) Transaction costs

Another standard finding of studies on market liquidity is that transaction costs tend to be negatively correlated with liquidity. The simple interpretation under the model proposed here is that the cost of liquidity provision, which includes transaction costs, must ultimately be entirely charged by producers to the consumers. Accordingly, transaction costs, and in particular transaction taxes, raise the price of liquidity for end users and therefore, all things equal, reduce consumption.

(d) The role of infrastructure

The role of infrastructure in the production cost of liquidity would deserve a study of its own. This heading encompasses at least two issues, the in-house infrastructure of the liquidity producers and the market infrastructure itself.

The execution of a transaction requires a full range of operations, from front-end order capture to back office clearing and settlement. Each of these steps has a cost, and this cost has ultimately to be charged by the liquidity producer to the consumers. Wherever technological improvement allows the cost of these operations to be reduced, it also allows more units of liquidity to be produced per unit of capital. Economies of scale are typically possible in this field. The McKinsey study quoted earlier suggests that emerging technologies will allow only a small number of institutions to increase dramatically the number of transactions they can process while lowering their costs and increasing their profitability.

Another aspect of infrastructure is the “public” part of market infrastructure, such as payment and settlement systems. The soundness and efficiency of this part of the infrastructure are plainly crucial to the risk associated with any transaction, and hence its cost in terms of capital.

(e) Behaviour and diversity of market participants

The CGFS note upon which this section draws concluded that “heterogeneity of market participants in terms of transaction needs, risk assessments and investment horizons enhances market liquidity”. Once again, this can be interpreted as the fact that the more diverse end users are, the more likely that flows received by liquidity producers will offset each other instead of adding to each other, ie that a lower amount of capital is necessary to execute a larger volume of transactions.

2.5 The volatility of production cost and the insurance function of market-makers

To conclude this section, a few questions may be raised as to the difference between true and apparent liquidity and the consequences of volatility in the cost of production of liquidity. It has often been heard, over the past few years, that liquidity has changed in nature, insofar as it is very good in normal conditions but tends to evaporate rapidly whenever market conditions become slightly unstable. This is the pattern known under the name of “fair weather liquidity”. Once again, these comments may need to be substantiated by facts. There have been, even in the very recent past, numerous occasions where exogenous shocks to the financial system or an increase in market volatility do not seem to have markedly affected market liquidity in a negative way in the main markets.

The notion of fair weather liquidity nonetheless deserves a few remarks, or at least questions. Under the analytical model presented in this paper, it seems reasonable that the production cost of liquidity can be highly volatile, and closely correlated to asset price volatility itself. An important part of the production cost of liquidity includes the consumption of capital generated by the financial risk incurred by a liquidity producer between the execution of a transaction with an end user and the execution of an offsetting transaction with another participant. The more volatile the market, the more costly this risk is to bear.

The consequence of this is that, if liquidity is priced at each moment on the basis of its current production cost, the consumption of liquidity will be extremely volatile. Fair weather liquidity may therefore, to a certain extent, be the consequence of an efficient pricing of liquidity.

The question that arises is whether the service that consumers are willing to pay for is not the ability to execute a transaction at a specific moment, but rather the ability to execute a transaction at any moment. In that case, the price they will be willing to pay for liquidity will not be based on its current production cost, but rather on an average production cost, taking into account future potential volatility. If part of the service sold by liquidity providers is to ensure a constant price of liquidity over a certain period, they will charge a price higher than the production cost during “normal” periods and lower than that during “stress” times. Thus, the production and consumption of liquidity will be smoothed, and market-makers will effectively play a role of insurance with respect to the degree of liquidity of the market.

Adding this intertemporal dimension to the question of liquidity immediately raises a number of questions with respect to the existence of contractual arrangements between producers and consumers of liquidity. In particular, the possibility of free-riding behaviour raises the question of coordination problems between the producers and consumers of liquidity and this, in turn, leads to the question of the justification, or lack thereof, for intervention by the public authorities in the field of market liquidity. The following section touches upon some facets of this question.

3. The public benefits of market liquidity

One of the commonly accepted benefits of market liquidity is that it provides a number of positive externalities, both within the financial system and from the financial system towards the rest of the economy. A liquid foreign exchange market, for instance, may facilitate international trade, and therefore equally the process of industrial specialisation based on comparative advantages. The same assessment, as regards the benefits of liquid government bond markets, is expressed in the following terms in the international capital markets report published by the IMF in August 2001:

"Partly because of their unique characteristics, especially their minimal credit risk, government securities and the deep, liquid markets in which they are traded have come to play important, if not critical, roles in facilitating aspects of private finance. In particular, they have facilitated the pricing and management of financial risks associated with private financial contracts."

The existence of positive externalities does not necessarily justify an involvement of the public authorities in the provision or distribution of market liquidity. To the extent that there exist market failures that prevent all the social benefits that these externalities can provide from being extracted, a public involvement may, however, be justified in certain conditions. In other words, the primary justification of an involvement of the public authorities would be to ensure that the external costs and benefits of liquidity are properly priced by the private sector, not to supply liquidity per se.

The trend towards an increased role of markets in financing economic activity may also suggest that market liquidity, or at least liquidity in some key segments of the financial system, is assuming increasingly global relevance. Two of the merits of market-based financing are that it facilitates the pricing of financial services and that it allows providers of capital as well as borrowers to manage their assets and liabilities more flexibly. Both these aspects relate to the concept of liquidity.

Another possible argument for involvement of the public authorities in the field of market liquidity is the role it plays in allowing them to implement their policies in the first place, or in improving the conditions in which these policies are implemented. Monetary policy is one example, since it is now predominantly implemented through market-based instruments in developed economies. In addition, the transmission process of monetary policy might benefit from the linkages between markets, efficient price discovery, etc that market liquidity brings about, or to which it contributes.

Some of these arguments are discussed in the following paragraphs.

3.1 Private benefits of liquidity for fiscal policymakers

Paradoxically, a first public benefit of market liquidity may be the private benefits it entails for the issuers of public debt. To the extent that assets are liquid, investors may be - and in practice are - willing to pay a premium for holding these assets. A direct externality of market liquidity is that it lowers the funding cost for the issuers of such assets.

Traditionally, government securities have tended to be highly liquid (at least relative to private assets) and therefore to benefit from a significant premium. This high degree of liquidity derives from a combination of factors, such as the relatively large outstanding amount of fungible securities, the existence of a well developed market infrastructure, including associated repo and futures markets, etc. The investor base of government securities markets also tends to be fairly wide and well diversified, in particular because the minimal credit risk associated with these assets makes them valuable for a multitude of purposes.[12] All these factors contribute to lowering the production cost of liquidity in government securities markets.

While the lower funding cost of the government is in itself a private benefit, it may be interpreted as a public benefit because of the nature of the issuer. A lower funding cost increases in principle the

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[12] The minimal credit risk of government bonds qualifies them as an appropriate benchmark for valuation - and to a certain extent hedging - of the credit risk of other issuers. It also qualifies government bonds as highly desirable collateral for cash management operations in the secured money market (repo). Low or inexistent credit risk and long maturities may also be crucial in enhancing demand for government bonds from these investors, who may have a very low preference for the present or even possibly a preference for the future, such as retired persons, or the pension funds that manage their assets.

effectiveness of fiscal policy, as it increases the amount of current government investment for a given amount of future liabilities. To the extent that fiscal spending aims by definition at achieving public benefits, the liquidity of government bond markets is indirectly a matter of public interest.

3.2 Benefits of liquidity associated with the implementation of monetary policy

Another type of public benefit originating from a proprietary source relates to the role of market liquidity in allowing an efficient and effective implementation of monetary policy. This has also gained importance with the generalisation of market-based instruments for that purpose. There are two ways in which market liquidity may be crucial to the implementation of monetary policy.

The first relates to the market in which the central bank executes its operations. This market, or market segment, must be deep enough to absorb the operations of the central bank. Alternatively, the central bank can (and in practice does) choose the market in which it intervenes on the basis of whether it is deep and liquid enough to absorb whichever size of transactions the central bank may need to execute.

As an illustration, the operational framework of the Eurosystem includes the establishment of a "sui generis" market, where central bank credit is provided against adequate collateral, according to conditions defined by the central bank. This specific feature partly reflects the fact that the large size of the open market operations of the Eurosystem would have made it difficult to implement them in any specific existing market segment. By contrast, the Federal Reserve System executes its operations more directly in the interbank repo market. The decision to split these operations between three segments of the repo market (those for Treasury securities, agency securities and mortgage-backed securities) also reflects the difficulty that would have arisen if repos had continued to be conducted in one single market segment, in a context of reduction in the availability of collateral. A third example, possibly even more explicit, is provided in the Annual Report for 2001 of the Reserve Bank of Australia, in which the rationale for the increased use of currency swaps, in addition to the standard domestic repos, for monetary policy operations is presented as follows: "The usefulness of foreign exchange swaps for domestic market operations reflects the fact that the foreign exchange market is very deep and liquid."

The second way in which market liquidity may be crucial to the implementation of monetary policy relates to the market in which central bank money is redistributed within the entire banking system, typically the unsecured money market. Insofar as the redistribution of central bank money and the equalisation of its price across the jurisdiction of the central bank is the first step in the whole transmission process of monetary policy impulses, the public benefits provided by the liquidity of this market are fairly obvious.

In principle, the liquidity of the unsecured money market is rarely a serious matter for concern. One rare case where it could have been was the introduction of the euro. The unprecedented need to integrate 10[13] national money markets into one had led to some ex ante uncertainty as to the degree of liquidity of the single unsecured money market at the beginning of Stage Three of monetary union. This concern was addressed in two ways. Firstly, the Eurosystem set up its own infrastructure for cross-border payments between banks across the euro area (TARGET). Secondly, during the first three weeks of January 1999, the ECB set the width of the corridor between its two standing facilities, which effectively determine boundaries for the fluctuation of the overnight rate, to a mere 50 basis points. The purpose of this measure was to facilitate the adaptation of credit institutions to the new operational framework and to avoid insufficient market liquidity in the unsecured money market resulting in excessive differences in pricing of central money across the euro area. In practice the single market effectively integrated within days of the introduction of the euro, and its very high depth and liquidity from the start has allayed all concerns.

[13] Eleven countries adopted the euro on 1 January 1999, but two of them, Belgium and Luxembourg, had already participated in a currency union since 1922 and accordingly already had a single money market between them.

3.3 Other public benefits of market liquidity

The two types of benefits of market liquidity discussed in the previous two sections are probably small in comparison with the much broader benefits it brings about to the economy at large, if only by improving the efficiency of the allocation of resources, or through its contribution to financial stability. There is little discussion over the merits of market liquidity in this context, as underlined by the CGFS in October 1999 in the following terms:

"There seems to be a growing consensus that deep and liquid financial markets, especially government securities markets, are needed to ensure a robust and efficient financial system."

Market liquidity may not qualify as a pure public good per se.[14] The strong positive externalities that it induces, from one segment of the financial system to others, and from the financial system towards the rest of the economy, may, however, be a sufficient justification for policies aiming at enhancing market liquidity. This would be the case in particular if these externalities cannot be properly charged by liquidity producers to all those who benefit from them, so that all the social benefits that can be derived from its existence cannot be reaped through market forces alone.

Alleviating the negative effects of market failures of this type is, almost by definition, the role of public policy. In the specific field of the efficient functioning of the financial system, of which liquidity is a core component, some central banks have a mandate expressed only in very general terms, while some others have a much more explicitly defined mandate. One of the clearer examples is provided by the Bank of England, which, as a core purpose, is mandated to "seek to ensure the effectiveness of the UK's financial services". This is further defined in the following terms:

"The Bank wants a financial system that offers opportunities for firms of all sizes to have access to capital on terms that give adequate protection to investors, and which enhances the international competitive position of the City of London and other UK financial centres. It aims to achieve these goals through its expertise in the market place; by acting as a catalyst to collective action where market forces alone are deficient; by supporting the development of a financial infrastructure that furthers these goals (...)."

By contrast, the mandate of the Federal Reserve System does not make explicit reference to the effectiveness of the financial system as a (even a subsidiary) policy objective. The Eurosystem is perhaps in something of an intermediate position, insofar as its constitution explicitly places the actions of the central bank in the context of the principles of an open market economy with free competition and efficient allocation of resources. In addition, without prejudice to its primary objective of price stability, the Eurosystem is mandated to support the general economic policies of the European Community, inter alia "to promote economic and social progress". Insofar as insufficient liquidity were deemed likely to result in a loss of economic welfare, there is a case to say that most public authorities would find in their mandate justification for policies aiming at relieving this insufficiency.

There are numerous examples of the efforts of the public authorities to enhance market liquidity, and some are presented in Section 4 of this paper. In practical terms, however, it is noteworthy that many policies implemented by the public authorities to enhance market liquidity, in particular in the field of government securities markets, seem to have originated in direct private interests rather than from the recognition of its public value. This is perhaps particularly evident in the euro area, given the restructuring of many government bond markets in the context of the more competitive environment brought about by the introduction of the euro. Against this background, the importance of a deep and liquid secondary market to lower (or to maintain at low levels) the cost of funding of governments on the primary market has been presented as the main rationale for reforms in product design in particular. The acceleration of reforms immediately ahead of or after the introduction of the euro may, however, raise the question of why they had not been initiated before. One answer may be that the

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[14] Market liquidity may or may not be excludable, depending on whether the public community considered is that of market participants alone or the entire jurisdiction of a country. But it is even less likely that market liquidity is non-rival, insofar as it relates to the absorption capacity of a market. In the context of the simple framework proposed in the first section of this paper, if an end user enters into a transaction with a liquidity producer, he "consumes" a certain amount of the capital allocated to the market by that producer. This therefore reduces the ability of another end user to initiate another transaction in the same direction with the same producer. Accordingly, the consumption of liquidity by one end user reduces the potential consumption of liquidity by another.

existence of a more or less captive source of domestic funding at the time limited the private benefits - for the issuer - of a higher degree of liquidity of government bonds. It may also mean that the public benefits this liquidity entails had not been fully recognised, despite the example of countries such as the United States, where the benefits of liquid government bond markets had been evidenced for many years.

The trend towards the creation of more or less autonomous government agencies responsible for the management of the public debt, with clearly defined mandates, may also be interpreted as a reflection of the pre-eminence of the private approach to market liquidity. As an example, the Swedish National Debt Office has a statutory objective to minimise the direct cost of funding of the government. It is not entitled to incur any cost (including presumably an opportunity cost) for the explicit purpose of generating positive externalities from the government bond market to the rest of the economy. The same applies to a large extent to many treasuries, which admit that their decisions, with respect in particular to product design and/or infrastructure, answer essentially to proprietary motives.

Under such an approach, it might not be possible to create assets that provide benefits by, for instance, completing financial markets,[15] unless these assets provide a clear and immediate funding cost reduction for the government.

The focus on the private interests of the government does not mean that the optimal level of liquidity is not generated, in particular as the same good tends to provide both private and public benefits. In addition, a reflection on the desirability of public policies aiming at enhancing liquidity needs to start with an assessment of which are the key segments of the financial system, where liquidity generates the most significant externalities. For instance, it is likely that the existence of at least one liquid interest rate market is desirable for the purpose of facilitating the valuation of other assets, for the management of financial risk associated with these other assets, for cash management purposes, etc. It is by no means certain that it must be the government bond market that fulfils this role. To the extent that market forces alone do not bring about the desired level of liquidity in at least one market segment, however, public policymakers may need to become involved. In practice, they have in many cases, through a multitude of different actions. These form the subject of the next section.

4. A taxonomy of public policies aiming at enhancing market liquidity

Just as the various determinants of market liquidity could presumably be interpreted in the light of the simple analytical framework presented in Section 2 of this paper, the various policies aiming at enhancing market liquidity can probably be interpreted with the same framework. In the following paragraphs, three types of policies are identified. Firstly, there can be policies whereby public authorities directly produce a certain amount of market liquidity. Secondly, there are policies whereby the authorities subsidise the production of liquidity by a selected number of private providers. Thirdly, there are policies whereby the authorities contribute to a technological improvement available to all producers, which effectively lowers production costs.

4.1 Direct production of market liquidity by public authorities

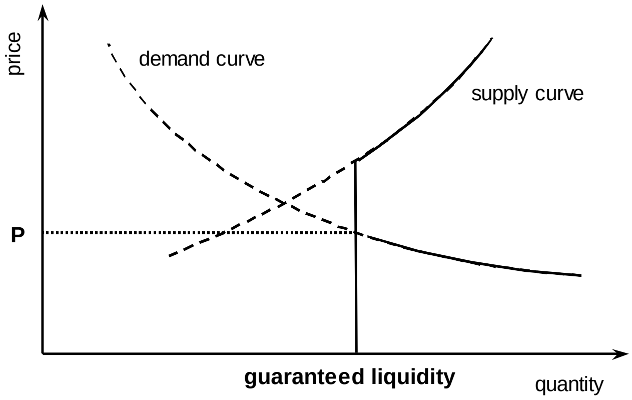
A first type of policy by which public authorities can influence the degree of liquidity of a market is if they themselves produce liquidity. This implies that the authorities are willing to enter into a transaction (and to take the associated financial risk) on request by end users. Such a policy would amount to setting a floor to the amount of liquidity in a particular market, even when the production cost of liquidity for private producers is too high and liquidity should accordingly dry up. In essence, such a policy would qualify the authorities as a market-maker of last resort.

Using the small analytical model proposed in Section 2 of this paper, one can graphically represent the situation with the following chart.

[15] Inflation-linked bonds, for instance, could possibly be considered as such an asset. The possibility of stripping government bonds probably also qualifies in this category.

Chart 3

Production by the public authorities of a guaranteed amount of market liquidity



If the authorities wish to ensure that the degree of liquidity of the market is at least equal to a guaranteed amount, they should be able to provide liquidity at a maximum cost equal to *p* on the chart, ie the price for which demand will be equal to the desired amount. In that case, to the extent that the cost of production of the same amount of liquidity would exceed the price charged to end users, the difference between the two would have to be subsidised by public funds. Such a policy would only make sense if the externalities created by the existence of a guaranteed amount of liquidity exceed this subsidy.

A possible justification for such a policy would be if a particular market took on systemic importance in the public authorities' jurisdiction, so that a total dislocation of that market could have massive repercussions on the whole financial system and economy. In that case, a role of market-maker of last resort could *in theory* be likened to the traditional role of central banks as lenders of last resort in the event of a run on banks.

In practice, such types of situations or policies are of course very rare, but there are some examples which conform more or less precisely to this situation.

A related example may be the situation of exchange rate arrangements, such as the ERM and ERM II, which imply potentially unlimited interventions of the central banks at the margin. In a way, these policies imply that central banks produce unlimited (or quasi-unlimited) amounts of market liquidity at the margin. Of course, the purpose of such currency arrangements has very little to do with liquidity provision per se.

More to the point, several national treasuries conduct trading activity on their own government debt, notably so as to ensure that retail investors are guaranteed the possibility to buy or sell government bonds at all times and at "fair" prices. The Fonds des Rentes established by the Belgian Treasury is one example at hand. This activity constitutes, in its own way, a guaranteed (if limited) liquidity-providing service.

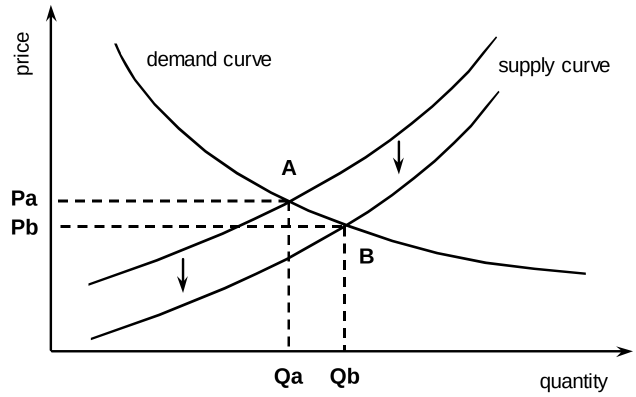
Many treasuries have also created special facilities to give market participants the possibility to borrow, or purchase outright, government securities in short supply, with a view to alleviating price volatility or preventing market manipulation. Insofar as these policies imply that the authorities are willing to enter into such a transaction more or less on request, they are similar in essence to guaranteeing a certain amount of liquidity in the repo market. The IMF, in its international capital reports for 2001, suggested that such a policy could be applied with benefits to the segment of German government bonds deliverable against the bund and bobl futures contracts. The justification for advocating such a policy is that squeezes in the government securities markets reduce the efficiency of the bond, derivatives and repo markets and, in turn, of all the markets in which these instruments are used for the purpose of valuation, hedging, etc.

4.2 Public subsidies to the production of liquidity

Another type of public policy that can enhance liquidity consists in subsidising the provision of liquidity by private producers. Once again, this can be illustrated graphically as indicated in the chart below.

Chart 4

Public subsidies to the production of liquidity



In this case, the public subsidy lowers the net production cost per unit of liquidity, and therefore, all things equal, is likely to both reduce its price for end users and increase the amount produced and consumed. To the extent that the social benefits exceed the cost of the subsidy for the public authorities, this policy would be justified.

The one example of such a type of policy that springs to mind is the primary dealership or official market-maker status established in many countries for a variety of markets, ranging from foreign exchange to government securities, inter alia. Market-making arrangements typically function as subsidies because the market-makers, as a group, normally benefit from an oligopolistic rent. This rent can take several forms. Commonly, primary dealers have privileged access to the primary market (hence their name). In Spain, for instance, they also have access to a "second round" of bidding in government-held auctions, which takes place after competitive bidding has been closed. Primary dealers also typically hold a monopoly over the activity of stripping government bonds. Official market-makers may also be the only counterparties the official sector uses for its commercial transactions, for central bank operations or for other purposes.

The counterpart to this rent is the obligation to quote two-way prices, with maximum bid-ask spreads, to end users. In other words, the production of liquidity is subsidised.

It may be underlined here that subsidies to the production of liquidity may not necessarily originate from the public sector. They may also originate from the private sector, if the issuer of the assets traded in the market is in a position to impose a solution to what is essentially a coordination problem. In the case of government securities, the end users are willing to pay for the liquidity of the assets by giving up a yield premium, which is therefore "earned" by the government. By surrendering this income to the market-makers in the form of a rent, the government only completes the market for liquidity. Insofar as the rent paid by the government to market-makers is lower than the income it received from investors, a coordination problem within the three groups has been solved and this need not affect the rest of the community. A similar solution applies when, for instance, private issuers enter into a contract with the lead managers of a bond issue, whereby the banks agree to make a market for these issues.

Subsidies take on a fully public character when the subsidy required by the producers to make a market exceeds the private benefits earned by the issuer through a yield premium. In that case, the decision to subsidise market liquidity may still be justified if there are sufficient externalities to be earned from the existence of liquidity, outside the group of direct end users, market-makers and issuer.

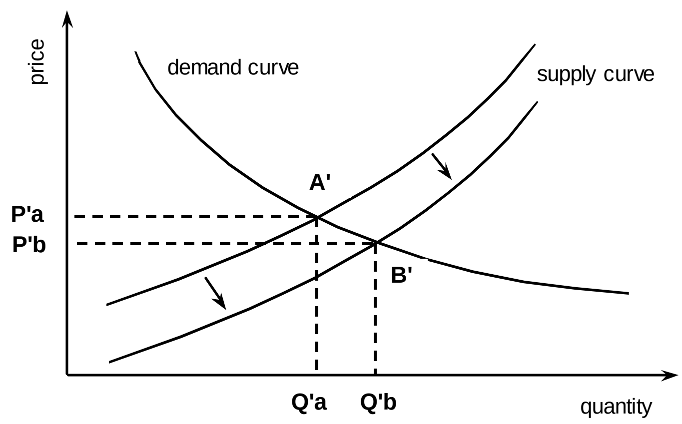
4.3 Contribution to technology

The third, and probably the most frequent policy by which authorities can enhance the production of liquidity is by contributing to improvements in production technology. Productivity improvements lead to a lowering of the production cost of liquidity (always in terms of the amount of capital immobilised by this production) and therefore allow more liquidity to be produced at a lower price. By reference to the model used throughout this paper, this situation is fairly similar to the previous one. It results in a downward translation of the supply curve, which leads to a presumably more favourable equilibrium. There are, however, two differences between this type of policy and direct subsidies. Firstly, while subsidies tend to be restricted to a limited number of liquidity producers, improved technology in principle benefits all producers. Secondly, while subsidies must be paid in each period, technological improvements may require an initial investment but thereafter yield permanent benefits.

One example of a contribution to technology that lowers the production cost of liquidity is product design. It is generally agreed that the concentration of issuance in a few large benchmarks well distributed along the maturity spectrum tends to enhance the liquidity of government bonds. In that case again, not only governments but all issuers may be able to promote liquidity by providing dealers with assets for which it is relatively easier and cheaper to produce liquidity. Jumbo Pfandbrief issuance and US agency benchmark programmes fall into that category.

Chart 5

Effects of technological improvement on liquidity



To the extent that the larger the free-float of a type of assets, the cheaper it is to produce liquidity, another way in which authorities may contribute to enhancing liquidity is by avoiding reducing this free-float in the context of their own operations. This applies in particular to monetary policy operations and is summed up by the statement by the Reserve Bank of Australia that, had it not changed its operating procedures, it "would now be holding about 40% of the combined total of securities issued by the Commonwealth and State governments. Clearly, this would not be a viable situation as the market would have great difficulty functioning in such circumstances".

Market design can also contribute to a more capital-efficient technology. The introduction of, in particular, electronic trading platforms, in some cases combined with market-making requirements for participants, is generally understood to have positively contributed to market liquidity. The electronic inter-dealer market(s) MTS and the electronic interbank money market MID created in Italy in 1988 and 1990 respectively both contributed to enhancing market liquidity and efficiency. Public authorities fostered these initiatives in both cases. In a broadly similar manner, national treasuries have been instrumental in the establishment of other national MTS markets across Europe, eg in Belgium.

More generally, one can interpret the five recommendations issued by the CGFS for the design of deep and liquid markets as measures aimed at improving the productivity of liquidity production by reducing the amount of capital this production requires. These recommendations apply to government bond markets, but the underlying principles may apply to all markets.

The first of these recommendations refers to the desirability of an appropriate distribution of issues along the maturity spectrum and to the establishment of large benchmarks, as discussed above. The second refers to the desirability of minimising the liquidity-impairing effect of taxes (discussed also in Section 2.4). The third refers to the desirability of transparency of information regarding issuance and trading, with due attention to the anonymity of market participants. The fourth refers to the benefits of safety and standardisation in trading and settlement practices, ie to the capital-saving benefits of lower operational risks. Finally, the fifth recommendation refers to the desirability of developing repo, futures and option markets related to government securities markets, all of which enlarge the options offered to a liquidity provider to hedge his positions, and hence lower his risk per transaction.

While in principle technology improvement does not require public intervention, it might arguably be useful or necessary in some situations. This would be true in particular when technological improvement itself is a public good within the community of dealers, ie when in particular it is non-excludable (the fact that it is non-rival is taken for granted). In such cases, there may be disincentives for one market participant to develop (at a cost) a technology that will benefit all of his competitors. That would typically be a situation that could require action defined by the Bank of England as “acting as a catalyst for collective actions when market forces alone are deficient”.

Another case for public involvement refers to the situation where the improvement in technology is by definition a privilege of the authority, such as the avoidance of transaction taxes, sound supervision of financial institutions and the oversight of payment systems, etc.

5. Conclusion

This paper was initiated as a discussion paper and therefore is intended more to raise questions than to provide answers. A few conclusions may, however, be proposed.

Firstly, there is a wealth of examples of public policies aiming directly or indirectly at enhancing liquidity in key segments of the financial markets. While some of these policies do have the proprietary interests of the government or the central bank in mind, many aim at achieving more global social benefits.

Secondly, if market liquidity entails significant positive externalities across the financial system at large and, through it, to the entire economy, such policies are not only justified, but may even be necessary.

Thirdly, the question of the desirability or otherwise of such policies is likely to gain importance along with the share of market-based financing in the economy, especially for those economies which tend to be lagging in this process. This includes emerging economies, but also some large developed economies, such as the euro area.

Fourthly, the appropriateness of policies aiming at enhancing liquidity should be assessed on the basis of a comprehensive cost-benefit analysis for the public sector. This implies in particular the identification of those markets in which market liquidity provides the strongest externalities.

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The monetary policy decisions of the ECB and the money market

Vítor Gaspar, European Central Bank, Gabriel Perez-Quirós, Bank of Spain
and Jorge Sicilia, European Central Bank[1]

1. Introduction

The Eurosystem's operational framework provides the key link between the ECB's monetary policy strategy[2] and the money market. The operational framework is the means to implement policy, which is based on the control of very short-term money market interest rates. The same applies in most industrial economies. For the European single monetary policy, it was recognised already in 1997 (see EMI (1997a)) that very short-term interest rates were to be regarded as the first step in the transmission mechanism of monetary policy.

The operational framework of the Eurosystem is based on three main instruments: reserve requirements, standing facilities - a marginal lending facility and a deposit facility - and open market operations. Open market operations are mainly conducted through repurchase agreements, through which the Eurosystem provides liquidity to the market in exchange for eligible collateral assets.[3]

Almost immediately after the introduction of the euro on 1 January 1999, the money markets in the euro area integrated smoothly and rapidly. After just a few days a single money market in the euro area was in place. This illustrates how quickly financial institutions, in particular banks, have adapted to the new operational environment. For a systematic account of the performance of the operational framework see Hartmann et al (2001), Manna et al (2001) and Perez-Quirós and Rodriguez (2001).

The ECB announced the stability-oriented monetary policy strategy on 13 October 1998 (ECB (1998b)). The strategy includes three main elements: first and foremost, a precise definition of price stability - this makes clear the ECB's commitment to maintaining price stability, which is enshrined in the European Union Treaty itself; second, analyses assigning a prominent role to money; third, analyses based on a multiplicity of models and indicators (see Issing et al (2001)).[4]

The strategy is used to structure the internal decision-making process. It is also used for external communication. It induces a systematic pattern of policy responses compatible with the maintenance of price stability over the medium term. This may be regarded as rule-like behaviour. Allan Meltzer (1993) defined a policy rule as "nothing more than a systematic decision process that uses information in a consistent and predictable way." Gaspar et al (2001) argued that the announcement of the stability-oriented monetary policy strategy aimed at reducing *strategic uncertainty*.

The increasing importance of forward-looking behaviour has important methodological consequences for macroeconomic modelling, in general, and for the monetary transmission mechanism, in particular (see McCallum (1999, 2001)). The issue is made more complicated when one recognises that knowledge about the economy is necessarily imperfect. The patterns of interaction between a central

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[1] The views expressed in this paper are those of the authors and do not necessarily represent the views of the European Central Bank, the Bank of Spain or the Eurosystem. The paper was presented at the Autumn Meeting of Central Bank Economists at the BIS and is a shorter version of the authors' paper "The ECB monetary policy strategy and the money market", published in the *International Journal of Financial Economics* 6 (2001), pp 325-42. It is reproduced here by permission of the copyright owner John Wiley & Sons. The authors would like to thank the EBF (European Banking Federation) for permission to use the data from the individual banks reporting to the EONIA panel. The authors also thank Peter Bofinger, Hans-Joachim Klöckers, Casper de Vries, Roberto Schiavi, Lars Svensson and seminar participants at Erasmus University and the Exchange Rate and Monetary Policy Issues Workshop for helpful comments and suggestions.

[2] See Issing et al (2001) and also ECB (2001) for a complete account of monetary policy strategy of the ECB.

[3] For a complete account of the Eurosystem's operational framework see ECB (2001) and ECB (2000a).

[4] See ECB (1999, 2000b), Angeloni et al (1999) and Gaspar et al (2001) as complementary references.

bank, forward-looking private agents and imperfect knowledge are potentially very intricate and therefore potentially costly. The public (and detailed) announcement of the strategy is meant to foster the understanding of the objectives, decision-making and instruments of the central bank. In this way the possibility of monetary policy becoming an independent source of uncertainty is prevented.

The ECB's strategy is therefore seen as a means to bolster the *credibility* and *predictability* of the single monetary policy. On *credibility* it may be worth just pointing out that medium-term expectations have been consistently in line with price stability, according to the ECB's definition, despite significant shocks pushing headline inflation above 2%.

This paper aims at contributing to the understanding of how the ECB conducts monetary policy as seen from a money market perspective. More specifically, it will look at how well money markets predict monetary policy. Here it tries to answer the question posed by, among others, Poole and Rasche (2000). If the market usually anticipates the systematic behaviour of the central bank then the market should adjust to news (that is information innovations) but not to the central bank's announcements of monetary policy decisions. In the United States the issue has been investigated using Fed funds futures prices. However, following Perez-Quirós and Rodriguez (2001), this paper follows a different approach. It starts from a simple model of interest rate behaviour inside a reserve maintenance period. These authors have found that the time-series behaviour of overnight interest rates may be properly modelled as a modified martingale. This paper looks at whether the announcement of monetary policy decisions - to maintain or change the key ECB interest rates[5] - impacts significantly on the stochastic behaviour of overnight rates.

2. How predictable are money market interest rates within reserve maintenance periods?

This section looks at the question of how well market participants predict monetary policy decisions and their impact on short-term market interest rates. The main idea is that if the market usually anticipates the behaviour of the central bank then the market rates should adjust to news (that is information innovations) but not to the central bank's announcements of monetary policy decisions. In the US the issue of how well the markets are able to anticipate the Fed's monetary policy moves has been investigated using Fed funds futures prices[6] (see Krueger and Kuttner (1996), Kuttner (2000), Poole and Rasche (2000) and Roley and Sellon (1998)). However, building on the model developed in Perez-Quirós and Rodriguez (2001), this paper takes a different approach to address the questions about predictability in the very short run in order to take advantage of the characteristics of the institutional framework for the implementation of monetary policy in the euro area.

The interest rates on the main refinancing operations (MRO) play a pivotal role in pursuing the aim of steering interest rates and signalling the stance of monetary policy. The fixed rate of these tenders until June 2000 and the minimum bid rate thereafter, both with a maturity of two weeks, have played the role of signalling the stance of monetary policy in the euro area since January 1999. Notwithstanding the fact that the interest rates that best signal the monetary policy stance have a two-week maturity, it should be noted that the overnight rate plays a pivotal role in the modus operandi of the ECB. Among the basic tasks of the Eurosystem, the Treaty establishes the need to "promote the smooth operation of payment systems". As argued in Manna et al (2001), the smooth functioning of the payment systems requires, inter alia, the existence of an equilibrium between the demand for and the supply of funds at the time the daily clearance takes place. As the ECB does not have an official operating target for the overnight rate (or any type of interbank rates), the main refinancing operations ensure this equilibrium by satisfying demands for central bank balances in a smooth fashion over the course of each maintenance period. This smoothness is complemented by the existence of a corridor on standing facilities which, besides signalling the general stance of monetary policy, provide and

[5] The interest rate on the main refinancing operations and the interest rates on the marginal lending facility and the deposit facility are the key ECB interest rates, ie the interest rates which determine the stance of the monetary policy of the ECB and which are set by the Governing Council of the ECB.

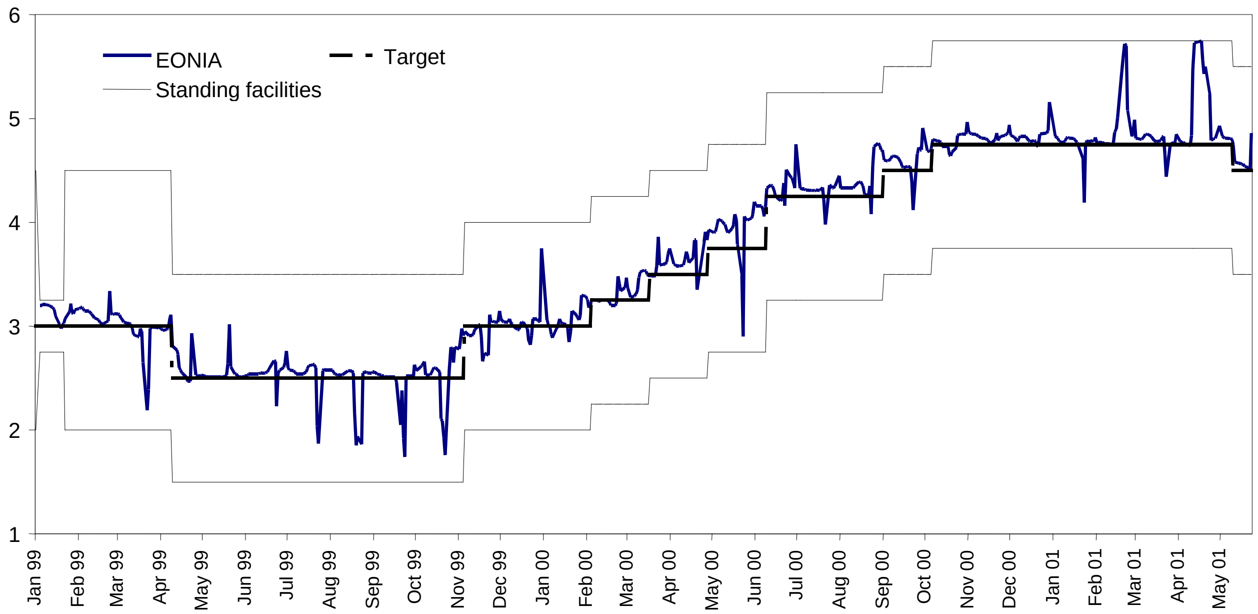
[6] This indicator has been available since the Fed funds futures market was set up by the Chicago Board of Trade in 1989.

absorb liquidity overnight and act as bounds to overnight market interest rates. Graph 1a depicts the evolution of the EONIA and of the key ECB interest rates.

Before trying to explore the evidence in a more systematic way it is useful to take a cursory look at the available evidence on the path of money market rates and the forward rate of the one-month interest rate in one month. This is plotted in Graph 1b.

Graph 1a

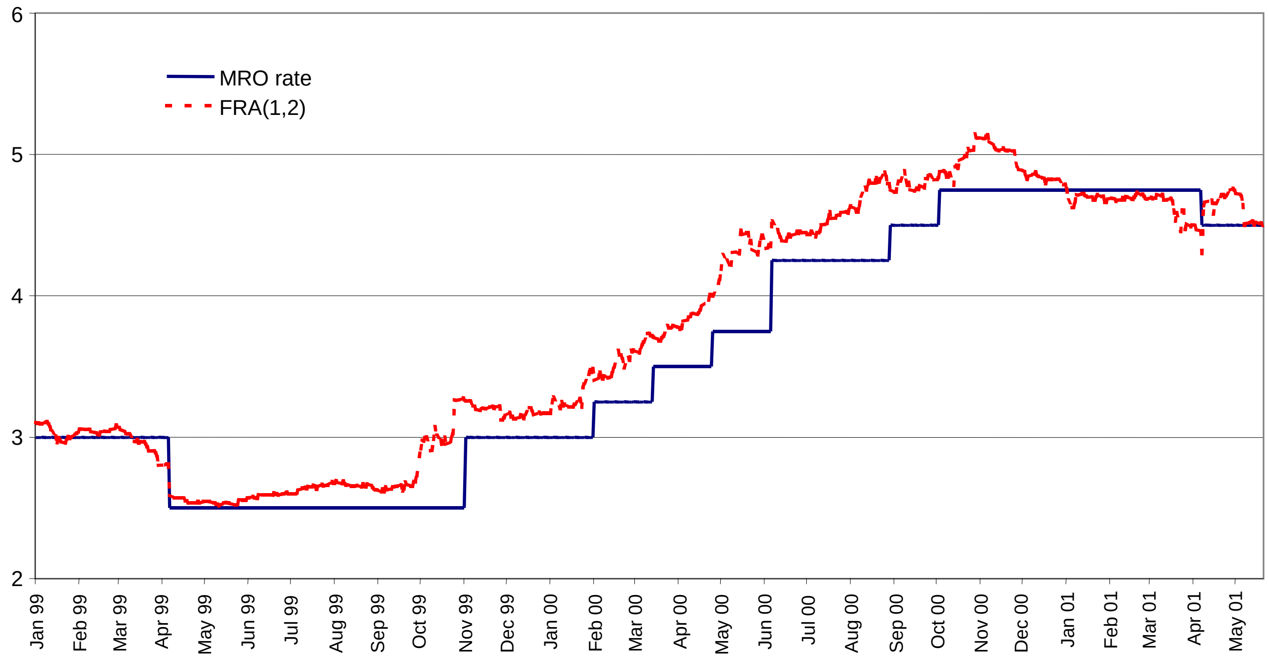
EONIA and key ECB interest rates



The solid line represents the EONIA rates. The thin lines represent the rates on the marginal lending and deposit facilities. The broken line represents the rates for fixed rate tenders up to June 2000 and minimum bid rates since. Source: ECB.

Graph 1b

MRO rates and one-month rates



The FRA(1,2) is the one-month in one-month rate as calculated with the EONIA swap curve. Source: ECB.

It appears from Graph 1b that markets are able to predict the process generating money market interest rates fairly accurately. Is this first impression correct?

This question may be approached in different ways. In the first subsection, the paper analyses formally whether the announcements of monetary policy decisions to maintain or change interest rates impact on the stochastic behaviour of the EONIA. The second part of this section will simply try to calculate using short-term money market rates to what extent the market has anticipated interest rate decisions taken by the Governing Council of the ECB.

2.1 Measuring the impact of ECB monetary policy decisions on money market rates

This subsection focuses on the behaviour of overnight rates inside a reserve maintenance period. The basic idea is that the existence of a reserve maintenance period with an averaging provision makes funds to be very close substitutes for days within the same maintenance period. If funds were perfect substitutes then overnight interest rates would have to follow a martingale. If this were not the case, banks would arbitrage away any expected difference between the current and future cost of funds.

However, as time goes on, the reserve maintenance period gradually nears its end. As banks accumulate reserves through the reserve maintenance period the likelihood that they will find themselves with excess reserves increases as well.[7] This induces banks to be cautious; more specifically, banks will reduce the demand for funds at the beginning of the reserve maintenance period. Given the need to comply with the reserve requirement on average this, in turn, leads to an increasing demand profile for reserves within the maintenance period. This leads, ceteris paribus, to an increase in overnight rates as banks approach the end of the reserve maintenance period.

Perez-Quirós and Rodriguez (2001) have explored this basic idea. They consider a model of identical, risk neutral banks which exchange reserves in a perfect and competitive money market. Perfect markets rule out asymmetric information, transaction costs, credit limits, etc. For this purpose, it is sufficient to assume a passive management of liquidity on the part of the central bank in the sense of abstaining from intervening to deliberately change the total liquidity of the system. This allows the authors to concentrate on the modelling of liquidity demand. The supply of liquidity in their model is driven by autonomous factors that constitute a shock to the aggregate level of reserves (in their model this is equivalent to a shock to the level of reserves of *each* bank).

For the purpose of this paper the only point of relevance is that it may be important to allow for the possibility that overnight interest rates follow a modified martingale. Again Perez-Quirós and Rodriguez (2001) provide empirical evidence using such a model. In what follows we will be using their model in order to look at whether the announcement of monetary policy decisions - to maintain or change key ECB interest rates - impacts on the stochastic behaviour of overnight rates. The basic idea is to model the reserve maintenance period as a unit. Expectations about overnight interest rates within the maintenance period should affect spot overnight rates from the beginning of the reserve maintenance period. For example, if an interest rate reduction is expected nobody will be willing to borrow above the expected future rate. So if the current rate were above the expected future rate, banks would try to postpone satisfying reserve requirements to later in the reserve maintenance period while lending their available funds in the market.[8]

Based on this idea it is possible to test whether the ECB is predictable. Specifically, if the market is able to predict ECB moves accurately then the transformed martingale behaviour of overnight rates inside a reserve maintenance period should not be significantly affected by monetary policy announcements following ECB Governing Council meetings. In order to test this hypothesis it is necessary to extend the Perez-Quirós and Rodriguez (2001) model by including dummies that capture the monetary policy announcements of the Governing Council of the ECB (meeting days and the days after the meeting of the Governing Council). The model may be written as:

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[7] Excess reserves means here liquid funds held for purposes other than compliance with reserve requirements.

[8] For simplicity of argument a simple martingale for overnight rates is assumed (see above for qualifications following Perez-Quirós and Rodriguez (2001)).

$$i_t = i_{t-1} + \beta' X_t + \varepsilon_t$$

$$\frac{\varepsilon_t}{\sqrt{h_t}} \sim pN(0,1) + (1-p)N(0,\sigma^2)$$

$$\ln(h_t) = \lambda' V_t + \sum_{j=1}^{n}\left[\delta_{j,1}(\ln(h_{t-j}) - \lambda' V_{t-j}) + \delta_{j,2}\frac{\varepsilon_{t-j}}{\sqrt{h_{t-j}}} + \delta_{j,3}\left(\frac{|\varepsilon_{t-j}|}{\sqrt{h_{t-j}}} - E\left(\frac{|\varepsilon_{t-j}|}{\sqrt{h_{t-j}}}\right)\right)\right]$$

where i_t is the EONIA rate.[9] X_t and V_t are vectors of dummy variables which may affect the martingale behaviour.

In particular:

X_{1t} = constant

X_{2t} = end MP dummy

X_{3t} = beginning MP dummy

V_{1t} = constant

V_{2t} = end MP dummy

V_{3t} = beginning MP dummy

V_{4t} = end-year dummy

V_{5t} = end-month dummy

V_{6t} = Friday

The key variables for our analysis are:

V_{7t} = meeting day dummy

V_{8t} = day after meeting dummy

The sample used for the estimation is from 1 January 1999 to 23 May 2001. The specified model is an EGARCH to capture the dynamics of volatility transmission from one day to the other. For the distribution of the error term a mixture of two normal distributions is used. This allows modelling fat tails and excess kurtosis (see Perez-Quirós and Rodriguez (2001) for details and also Hamilton (1996)).

The first important result to report (see Table 1) is that the dummies capturing the meetings of the Governing Council are not included in the "mean" equation because they are not statistically significant. This means that monetary policy announcements do not affect the level of overnight money market interest rates. This is consistent with a view that the market does not make systematic errors with respect to monetary policy decisions. This perception is confirmed by looking at the results for the variance. It can be seen, from Table 2, that neither the meeting day dummy nor the day after meeting dummy has a significant impact on the variance of overnight rates. If one looks at the magnitude of the point estimate for the parameters one sees that the effect on volatility associated with monetary policy announcements is less than 20 times smaller than volatility associated with the end of the reserve maintenance period.

This result on the variance is remarkable. Indeed, before the meetings of the Governing Council market participants may have only an ex ante distribution of possible outcomes from the Governing Council meeting. To take the simplest possible case, imagine that there are only two possible outcomes from the meeting. After the policy announcement one of the possibilities has been confirmed and the other one excluded. This will be reflected in the market overnight rate. So some impact on volatility had to be expected. Graph 2 illustrates this point. Starting from day 1, when it is assumed that markets were anticipating even odds of interest continuing at the current level and being raised by 25 basis points, we assume that the Governing Council meeting takes place on day 9. As the day of the meeting approaches, the probability of a change in key ECB interest rate increases by 0.04. On the day of the meeting the new interest rate is announced to the market. As shown in the graph, despite a very high likelihood of the rate change it is clear that there is a "small jump" in the interest rate on the

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9 At the beginning of the reserve maintenance period the interest rate variable on the right-hand side of the equation is replaced by the Eurosystem's main refinancing operations (MRO) interest rate. This means that at the beginning of each reserve maintenance period the daily change in the EONIA interest rate is replaced by the spread between EONIA and MRO rates.

announcement due to the realisation of the expectations. Such a jump creates an increase in volatility on meeting days.

Table 1

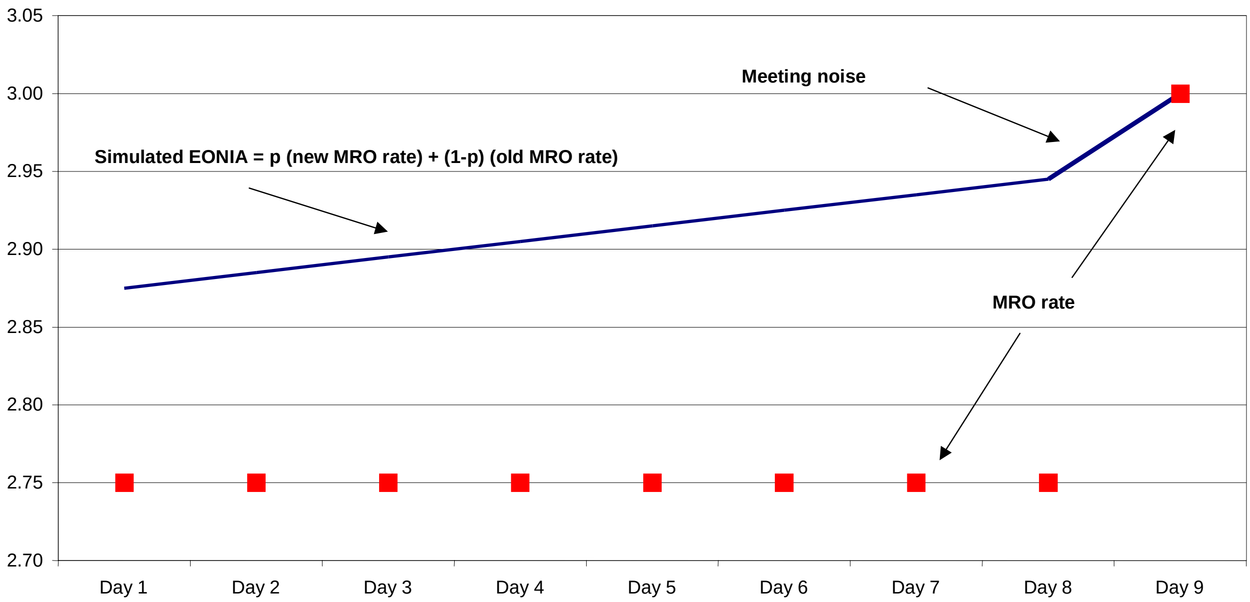
Mean parameters		
X_{1t}	– 0.217	(0.090)
X_{2t}	– 1.689	(1.245)
X_{3t}	5.092	(0.869)
Variance parameters		
V_{1t}	– 11.048	(0.375)
V_{2t}	3.806	(0.247)
V_{3t}	1.446	(0.301)
V_{4t}	4.726	(1.126)
V_{5t}	2.507	(0.360)
V_{6t}	0.082	(0.243)
V_{7t}	0.212	(0.405)
V_{8t}	0.732	(0.385)
Other variance parameters		
d_{11}	0.264	(0.045)
d_{12}	0.093	(0.023)
d_{13}	0.235	(0.043)
d_{21}	0.032	(0.079)
d_{23}	0.211	(0.067)
p	0.700	(0.013)
σ	3.660	(0.068)

Sample: 1 January 1999 to 23 May 2001. The model has been estimated by maximum likelihood. Standard errors are displayed in parenthesis.

The argument, however, is that there are many other sources of disturbance which impact on EONIA rates. Obvious examples are liquidity shocks or economic data releases. Our results show that the announcement of ECB monetary policy decisions has had an insignificant impact relative to the fundamental determinants of market volatility in the sample analysed.

Graph 2

Volatility associated with expected changes in rates



Note: The chart illustrates a change in the MRO rate from 2.75% to 3%. The simulated EONIA rates have been calculated using a sequence of probabilities "p" that started in 0.5 and were adjusted by a daily increase of 0.04. The bold line represents the associated volatility to the realisation of the expectation.

2.2 Have money markets anticipated interest rate decisions within reserve maintenance periods? Some insight of further intuition

The aim of this subsection is to complement the previous analysis with a different, more heuristic approach. Looking at all the monetary policy decisions on key ECB interest rates taken since the beginning of Stage Three, we analyse to what extent the market has anticipated the interest rate changes (or decisions to keep interest rates unchanged) taken by the Governing Council of the ECB.

Short-term interest rates contain information about the expected future path of policy rates. Among other interesting uses for monetary policy purposes, the extraction of interest rate expectations can provide information on whether an interest rate decision taken by a central bank has been anticipated or not by financial markets. To pursue this analysis, different interest rates (or prices) of market instruments can be used, either through spot rates or with a calculation of forward rates. (For a general overview on the extraction of market expectations from financial instruments, see Soderlind and Svensson (1997).)

It could be argued that the desirable way of determining interest rate expectations of a move in key ECB interest rates would be through the derivation of forward rates that correspond to future ECB two-week reverse transaction rates. However, from a practical point of view, there are no instruments that quote forward two-week collateralised rates on the dates where the MROs take place, so they would have to be derived. Although the repo market could be a good candidate to perform such role, at least for certain maturities, the existence of different institutional frameworks and several segmented repo markets coexisting in the euro area do not make it yet the best tool for analysing expectations in the euro area, all the more so as this market is not as deep and liquid as the euro area money markets (see Santillan et al (2000)).

However, as already argued, if banks are risk neutral, the existence of the reserve maintenance period in a world without market frictions should drive funds to be substitutes among days of the same maintenance period. In that framework, banks would arbitrage away any expected differences between the current and future costs of funds. In addition, according to the expectations hypothesis of the term structure, any interest rate can be derived as an average of expected future overnight rates. As the overnight interest rate is the rate at which the payment system clears, any financial transaction between two agents, irrespective of its maturity, ultimately has an impact on the overnight interest rate. In other words, it could be argued that within maintenance periods, in the absence of unforeseen liquidity shocks or news that modify expectations, the expectations of changes of the key ECB interest rates should be reflected in the overnight interest rates at the beginning of the maintenance period. Due to their euro area representativity and liquidity, EONIA interest rates have become an appropriate tool to extract market expectations (as is also the case with EONIA swaps). Given that there are money market instruments, there is a need to take into account credit, financing or term premia factors in order to compare money market rates (non-collateralised) to MRO rates, which are collateralised.

The money market data used are, as before, EONIA rates from 1 January 1999 to 23 May 2001 (the results are nonetheless practically unchanged when using one-week EONIA swap rates). In order to homogenise information in an easily interpretable way, we consider that the EONIA overnight rate is a linear combination (β, $1-\beta$) of two possible events. The results provided are calculated using as the two events either a "no move" or a "25 basis point move" in key ECB interest rates.

$$i_t = \beta i_{25} + (1-\beta) i_0$$

β can be interpreted as the (linear) probability of *at least* a 25 basis point change, against the alternative of no change in key ECB interest rates. Actually, for our purposes, the value for β will become the benchmark: if it is above 50% (in absolute value) it will be considered that the market expected the ECB to change interest rates.

To take account of different estimations of the "natural" or "structural" spread between the EONIA rate and the MRO rate, the calculations were done with different magnitudes: a spread of 3, 5 and 7 basis points between the EONIA rate and MRO rates.[10]

As maintenance periods are considered as a unity, the calculations were done with the EONIA rates (although the results were cross-checked using the EONIA one-week swap rate) at the beginning of the maintenance periods.[11] Table 2a shows the results for the different "natural" spreads considered.

Table 2a

Have money markets anticipated ECB decisions?

Spread	**3 bp**	**5 bp**	**7 bp**	**Observations**
At the beginning of the maintenance period (in %)	79	82	79	28
One day before the meeting (in %)	85	85	81	48

Note: Percentage of occasions on which markets correctly anticipated the ECB's last decisions for different values of "natural spread" between the EONIA and the MRO rates. Meetings held in the last four days of the period are not considered, nor are where underbidding was present.

Sample from 1 January 1999 to 23 May 2001.

As can be seen, at the beginning of the maintenance periods, markets anticipated the ECB's decision on interest rates 79-82% of the time. However, one should also consider that it might be important to take into account the possible arrival of information between the beginning of the maintenance period and the day of the meeting, which could potentially change market expectations. To do so, we replicate the same calculations for the day before each meeting of the Governing Council (although we gain more observations, to avoid the potentially distorting liquidity effects, if those days correspond to the last four days of the maintenance period they are taken out of the sample). According to the results obtained, the rate of success of the money market in predicting the ECB's interest rate changes increases slightly to 81-85%. More precisely, Table 2b shows how many times the market anticipated

[10] The average of the spread in the sample used was 7 basis points (6 basis points during fixed MROs and 10 basis points during variable rate tenders). However, these results might be an overestimation of the actual spread, as the sample is dominated by a cycle of expectations of interest rate increases. One approach within this sample (apart from estimating the risk premia) is to calculate this spread in a period where expectations of an interest rate move were non-existent. This was the case after the interest rate cut in April 1999. Taking the first three working days of the two maintenance periods following that decision, the spread turns out to be on average 3 basis points (and never higher than 4 basis points).

[11] In particular, an average of the "β" obtained for the first three days of each maintenance period was used.

the central bank decision one day in advance of the meeting, distinguishing between the times when the Governing Council changed interest rates, and those when it announced that its key interest rates were not changed. As can be seen, of the nine times the ECB decided to change its interest rates (none of these meetings were held the last four days of a maintenance period), only on two occasions (22%) did the market fail to anticipate the move, namely the decision to change key ECB interest rates in April 1999 and May 2001. As regards the meetings in which the Governing Council decided to keep the key ECB rates unchanged, only on five out of 39 occasions did the market expect a change in interest rates.

Table 2b

Have money markets anticipated ECB decisions?

	Market expectations		**Observations**
	Change	No change	
ECB changed rates (in %)	78	22	9
ECB did not change rates (in %)	13	87	39

Note: Percentage of occasions on which markets correctly anticipated the ECB's decisions for a "natural spread" between the EONIA and the MRO rates of 3 basis points. Meetings held in the last four days of the maintenance period are not considered.

Sample from 1 January 1999 to 23 May 2001.

3. Conclusion

Our research suggests that the behaviour of EONIA rates within a reserve maintenance period provides an interesting starting point for analysing the predictability of monetary policy decisions of the ECB. Our empirical results show that the monetary policy announcements after the meetings of the Governing Council have not affected the mean interest rates in a statistically significant way. This is consistent with markets not making systematic mistakes in anticipating the announcements. This perception is confirmed by looking at the results for the variance. It can be seen, from Table 1, that neither the meeting day dummy nor the day after meeting dummy has a statistically significant impact on the variance of overnight rates. Moreover, the effect on volatility associated with monetary policy announcements is significantly smaller than the volatility associated with the end of the reserve maintenance period. The interpretation suggested is that the announcement of ECB monetary policy decisions has had an insignificant impact on the volatility of market interest rates relative to fundamental determinants of market volatility. In addition, using a more heuristic approach it is shown that markets are able to predict the ECB's interest rate decisions quite accurately.

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Recent changes in fixed income markets and their impact on reserve management by the Netherlands Bank

Ad Visser,[1] Netherlands Bank

1. Introduction

This paper describes some modifications that have taken place in the management of the foreign exchange reserves of the Netherlands Bank (DNB) in the last few years. These changes were made in response to several external developments. Firstly, there have been major changes in the American and European fixed income markets. In the United States, continuous budget surpluses and the prospect of a big reduction in the amount of outstanding government debt raised the question of the extent to which US government debt will be able to retain its benchmark status in the US fixed income markets. In Europe, too, the issuance of government debt has been showing a decreasing trend. At the same time, the advent of the euro has given rise to a substantial increase in euro-denominated debt by private market participants. Secondly, with the arrival of monetary union in the euro area, the character of the foreign exchange reserves of the Netherlands Bank has changed. For instance, the reserves formerly denominated in Deutsche marks have been transformed into domestic currency assets. In response to these developments the main focus of reserve investment gradually shifted from liquidity and absolute safety alone to a more return-oriented approach. This led to a decrease in the importance of government bonds in our portfolios and an increase of investments in less liquid, but higher-yielding spread products. Moreover, the investment and risk management framework of the portfolios has been changed in the sense that spread products have been included in the benchmark portfolios and that several limits have been established with regard to spread exposure.

2. Diminishing issuance of US Treasuries

For the last couple of years, the US government has been running budget surpluses. Recent forecasts by the Congressional Budget Office (CBO) continue to project surpluses in the foreseeable future, albeit a slower pace than expected. In its August 2001 estimates the CBO foresees for the period 2002-06 a total surplus of USD 1,082 billion, compared to USD 2,002 billion in May 2001.[2] It must be noted that almost all of the expected budget surpluses in the next few years are foreseen to be in the so-called off-budget surpluses, comprising surpluses in the Social Security trust funds and the net cash flow of the Postal Service (Graph 1). The reduction in the expected total surpluses compared to previous forecasts is to a large extent connected to the recent tax rebates by the Bush administration and a less favourable economic outlook. Nevertheless, the surpluses will lead to lower financing needs of the US government and a reduction in the level of outstanding government debt. The amount of outstanding debt with the public is projected to decline from USD 3,294 billion in 2001 to USD 876 billion in 2011 (ie from 32.1% to 5.2% of GDP; Graph 2). After the publication of the August CBO data many market participants still expect the Treasury to cease issuance of new Treasury debt in the not too distant future. For instance, investment bank Lehman Brothers expects the auction of the last 30-year bond to happen in August 2002 and it expects the complete elimination of Treasury note issuance in the fiscal year 2006.[3] The recent terrorist attacks in the United States may lead to some changes in the budgetary outlook: it is likely that government spending for, amongst others, defence, airline support and reconstruction may increase, whereas at the same time tax income may decrease because of the further deterioration in the short-term economic outlook.

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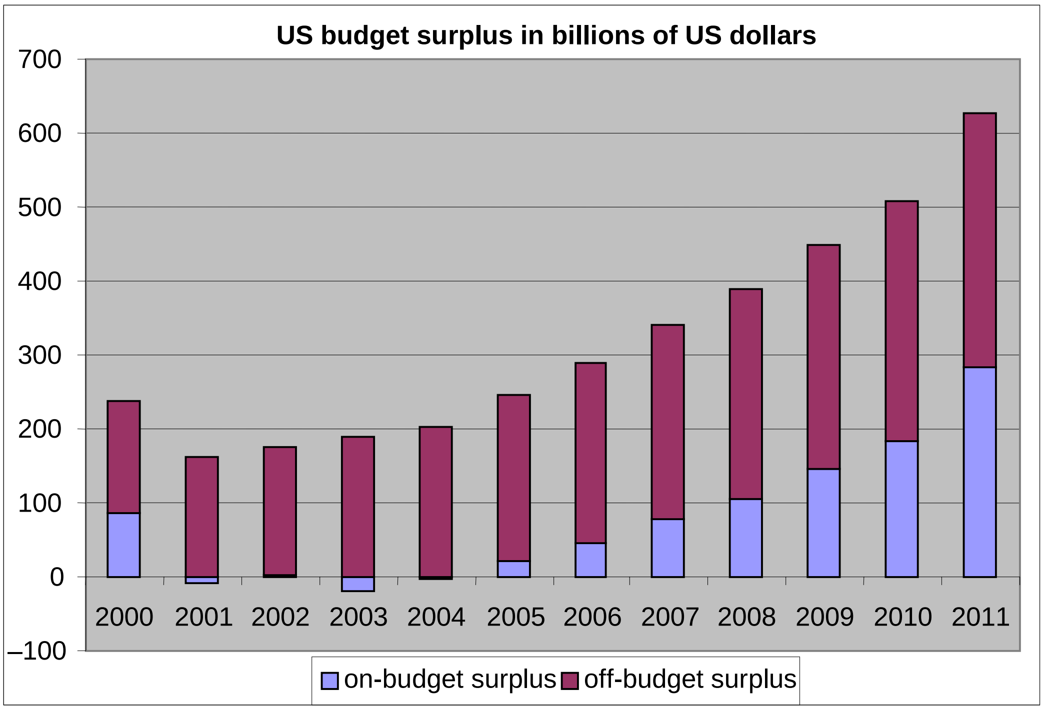
1 De Nederlandsche Bank NV, Financial Markets Department. The views expressed do not necessarily reflect those of the Netherlands Bank. Comments by P Dijkstra, W T A van Veen and L M T van Velden are gratefully appreciated.

2 *The Budget and Economic Outlook: an Update*, The Congress of the United States Congressional Budget Office, Washington DC, August 2001.

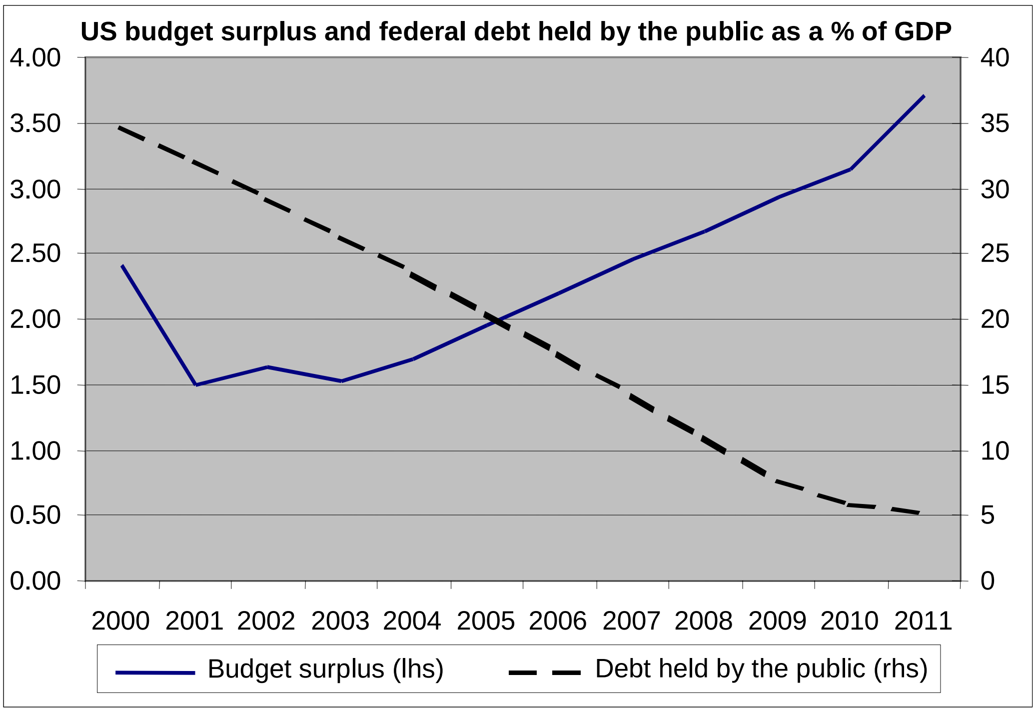
3 Lehman Brothers Global Economics, 28 August 2001.

Graph 1



Source: Congressional Budget Office, August 2001.

Graph 2



Source: Congressional Budget Office, August 2001.

During the last few years, the decreased need for funds has already led to significant changes on the Treasury market and in the US Treasury's debt management policy. Firstly, the US Treasury has decreased the size of its new issues. Secondly, it has reduced the number of different issue maturities. For instance, the three-year note and the year bill were cancelled in 1998 and 2001 respectively. Thirdly, as from 1999 the US Treasury has decreased the number of auctions of new paper. At the same time it has increased the number of reopenings of older issues. For instance, five-year notes are issued on a quarterly basis instead of a monthly one. The May and November auctions concern new issues whereas the February and August auctions concern reopenings of the November and May issues respectively. In this way the Treasury tries to maintain reasonably large auction sizes and thereby the liquidity of on-the-run benchmark issues. Finally, in early 2000, the Treasury announced a programme of regular buybacks of old and less liquid debt issues. In practice, these buybacks concentrate on the longer end of the Treasury curve, ie issues maturing in 2015-30.

3. Role of Treasuries as benchmark securities

Traditionally, the market for US Treasuries has had several features that contributed to its benchmark status in the US fixed income market.[4] First of all, Treasuries are considered default risk-free as they carry the full faith and credit of the federal US government. Because of their default risk-free nature, Treasuries are heavily used as a pricing vehicle for credit products like corporate bonds. Prices of such bonds are quoted as a yield spread over a similar maturity benchmark Treasury bond. Furthermore, Treasury rates are often used for analytical purposes such as forecasting market movements. By looking at movements in Treasury rates as opposed to rates on spread products, one can clearly distinguish premia in credit and liquidity risk from fluctuations in the general level of interest rates. Secondly, Treasuries are widely used as a hedging vehicle by issuers of and traders in debt securities. By buying or selling Treasuries or derivative Treasury products such as bond futures, they can hedge for general movements in interest rates. In this regard it is important to note that the Treasury market is very liquid. This means that large blocks can be traded at relatively small bid-ask spreads and without causing price movements. In addition, well-developed bond and notes futures contracts on Treasury securities provide for even greater liquidity for the underlying Treasury products as well. Furthermore, there is a well-developed repo market for Treasuries, which facilitates short selling. The existence of repo markets in Treasuries makes it possible for market participants to either borrow funds by repoing out Treasuries (thus funding a position) or to manage liquidity safely by repoing in securities for cash, thereby using the Treasuries as collateral. For the latter reason repo rates are lower than unsecured interbank rates.

4. Diminishing role of Treasuries as US benchmark?

In the course of the year 2000, the debate heated up as to whether US Treasuries will be able to retain their benchmark status in the US fixed income markets. This happened especially after the announcement of the details of the treasury buyback programme in January 2000.[5] The details of the programme revealed that the Treasury would buy USD 30 billion of Treasuries with a maturity of longer than 10 years. This amount was larger than expected and it had not been foreseen that the Treasury would concentrate the buybacks in the longer maturities. Investors began to think that with the decreased financing needs and the possibility of a complete elimination of Treasury debt outstanding in the medium term, the Treasury might very well eliminate the issuance of new 30-year bonds: it was thought that it might be a little peculiar if the Treasury continued to issue such long-maturity debt, which would be bought back well before maturity.

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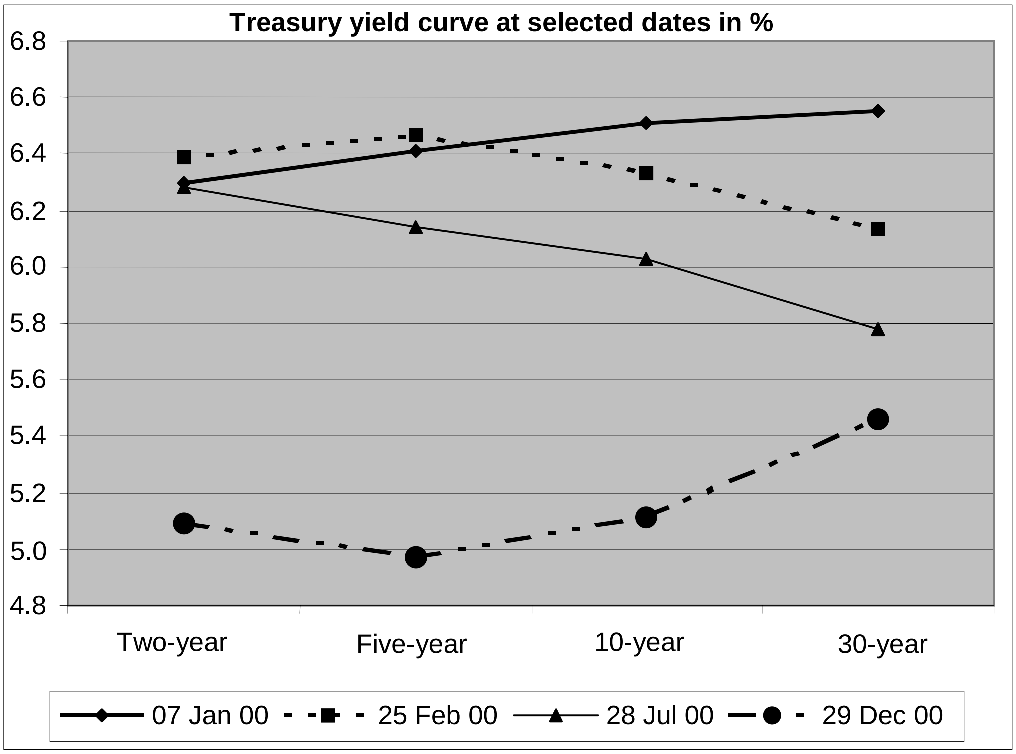
4 For an extensive discussion of the role of US Treasuries as a benchmark and reserve asset, see Michael J Fleming (2000): "Financial Markets Implications of the Federal Debt Paydown", *Brookings Papers on Economic Activity* 02, Brookings Institution, Washington DC.

5 "Marketable Treasury Securities Redemption Operations", US Department of the Treasury, January 2000.

Price action in the Treasury market after the announcement of the buybacks showed that Treasuries were acquiring a scarcity premium compared to other fixed income products. In particular, investors such as insurance companies and pension funds with longer-dated liabilities increased their demand for long bonds, thereby bidding up their price and decreasing their yield. The perceived future scarcity of longer-dated Treasuries led to a significant inversion of the Treasury yield curve in a rather short time. The yield on the 30-year Treasury bond declined by 40 basis points from 6.55% early January to 6.15% in late February. During the same period the yield on the two-year note increased by 10 basis points to 6.4% (Graph 3). In other words, the yield curve, usually measured as the yield differential between two- and 30-year bonds, inverted from plus 25 basis points to minus 25 basis points in less than two months. It was only later in 2000 that the yield curve became less inverted and eventually positively sloped again. This had mainly to do with increased expectations of near-term monetary policy loosening, which led to a decrease in shorter-term yields. Furthermore, 30-year bonds underperformed after comments by the US Treasury that it was important to retain a complete Treasury interest rate curve, thereby implying that it might continue to issue new 30-year debt in the foreseeable future.

Graph 3



Source: Bloomberg.

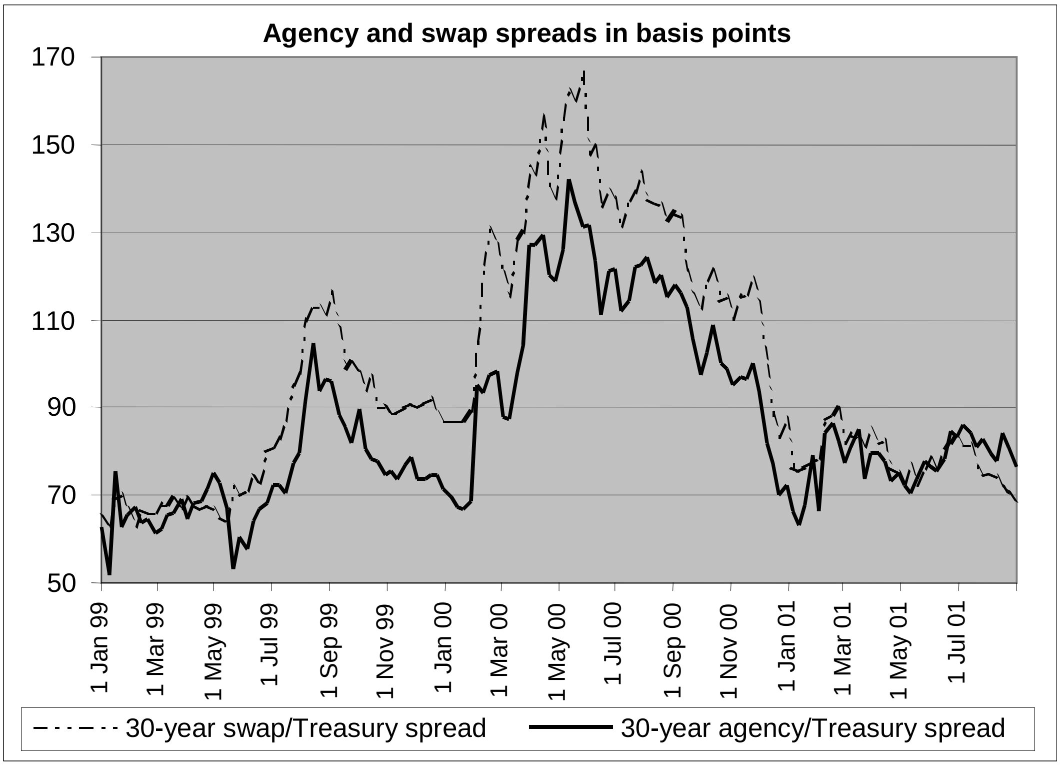
In early 2000, a second, strongly related, important movement on the US fixed income market happened in the spreads of Treasuries vis-à-vis other high-quality fixed income products such as agency bonds[6] and interest rate swaps.[7] These spreads widened significantly in the days and weeks

[6] Agency bonds are issued by so-called Government Sponsored Enterprises (GSEs), of which the housing GSEs Federal National Mortgage Association (Fannie Mae), Federal Home Loan and Mortgage Corporation (Freddie Mac) and Federal Home Loan Bank System (FHLB) are the three most important. These agencies are private banks which are closely involved in the US mortgage market. They were created by the US government and Congress and enjoy a special status that means that market participants consider them almost as good a credit quality as the US Treasury. The agencies have a triple-A credit status. It must be noted, however, that they do not carry the full faith and credit of the US government. For a further explanation see, for instance, Lehman Brothers, *Guide to Agency and Government-Related Securities*, 2001.

[7] An interest rate swap is an agreement whereby two parties agree to exchange periodic interest payments. One party makes fixed interest payments at designated dates for the life of the contract. The other party makes payments based on a floating

after the announcement of the buyback programme. The yield differential between the 30-year Treasury bond and 30-year agency bonds increased from 70 basis points in early January 2000 to about 100 basis points at the end of February (Graph 4). The differential between 30-year bond yields and 30-year interest rate swap rates showed a similar pattern. During the remainder of the year spreads widened even further. Apart from the perceived future scarcity of Treasuries, this further spread widening in the spring of 2000 was also connected to proposals in the US Congress for an overhaul of the legislation with regard to the US agencies. Investors considered the proposals a threat to the credit status of the agencies. Up until then these government-sponsored entities were considered as virtually default risk free because of their perceived implicit guarantees by the US government. As the proposals would set the agencies further apart from the government, credit risk was perceived to be larger than before. Hence agency spreads widened. Later in 2000 spreads tightened considerably as the chances of the legislative proposals being actually adopted by Congress diminished significantly.

Graph 4



Source: Bloomberg.

5. Swaps or agency bonds as new benchmarks?

With the reduction in the issuance of Treasury paper, an important question within the US fixed income market has become whether Treasuries will be able to retain their benchmark status. If Treasuries are getting scarcer, they may very well lose some of their favourable characteristics.[8] For

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rate, usually six-month Libor. For example, at any point in time the 10-year swap rate indicates what fixed rate a bank is prepared to pay at that time in exchange for receiving six-month Libor during the 10-year lifetime of the contract. For a further explanation see, for instance, Frank J Fabozzi, *Handbook of Fixed Income Instruments*, Irwin Professional Publishing, Burr Ridge, 5th edition, 1997.

8 For an extensive discussion see Garry J Schinasi, Charles F Kramer and R Todd Smith, *Financial Implications of the Shrinking Supply of U.S. Treasury Securities*, International Monetary Fund, March 2001.

instance, if Treasuries have a volatile scarcity or liquidity premium, they will move not only because of general changes in interest rate expectations but also because of changes in their perceived scarcity and/or liquidity. This will make them less attractive as a hedging and pricing vehicle. In practice, issuers of and traders in corporate debt already largely see interest rate swaps as the vehicle of choice as far as hedging is concerned. Agency bonds, too, are widely used for hedging purposes. Interest rates on agency bonds and interest rate swaps move more closely in line with each other and with corporate bonds than Treasury rates do. The use of Treasuries as a hedging vehicle has been declining for a few years and not just since early 2000. The crisis surrounding the hedge fund Long-Term Capital Management (LTCM) in the autumn of 1998 is often mentioned as an important watershed in this respect. During that crisis Treasuries were heavily used as a safe and liquid haven, so in the flight to quality and liquidity, Treasury yields declined significantly compared to agency bond yields and interest rate swap rates. Consequently, the correlation between Treasury rates and other fixed income rates declined notably, thereby making Treasuries less interesting as a hedging vehicle. This episode taught traders in and issuers of corporate debt that it might be better to hedge their interest rate exposure by using swaps or agency bonds rather than Treasuries.

Both the shrinking supply of Treasuries and their decreased use as a hedging vehicle seem to have reduced liquidity in the Treasury market in recent years, as witnessed by increased bid-ask spreads and a reduction in trading activity and market turnover.[9] There are also other factors that may explain the reduced market liquidity. The number of primary dealers in Treasury debt has decreased considerably during the last few years because of continued consolidation in the financial industry. Incidentally, this consolidation may affect dealing not only in Treasuries but also in agency securities. Furthermore, banks seem to be less willing to commit capital to market-making activities. Consequently, dealers are holding smaller inventories of Treasuries and are less willing to take large positions and risks. This trend is probably reinforced by increased price transparency and concomitant reduced profit margins due to the strong growth of electronic trading platforms. These platforms have probably also influenced liquidity in the markets. So far the rise of electronic trading platforms has consolidated rather than fragmented the fixed income markets. Going forward, fragmentation may become an issue, thus hampering liquidity.[10] On the other hand, it may be argued, that increased market transparency enables a better insight into market depth, thus increasing liquidity.

For various reasons several investment banks think that interest rate swaps are a likely candidate to become a new benchmark in the US fixed income markets.[11] First, interest rate swaps have a high credit quality, as they are based on Libor rates. As such they represent generic high-quality (double-A) bank credit rather than a specific name, such as, for instance, a US agency. Ultimately, the credit quality of interest rate swaps is sensitive to the credit quality of the banking panel that is behind the Libor fixing. In addition to this generic risk, an interest rate swap bears counterparty risk vis-à-vis the bank with which the contract was concluded. This risk concerns the replacement cost of the contract in the event the counterparty defaults. Second, the swap market is very liquid, although off-market swaps may not always be easy to unwind. The outstanding notional amount of interest rate swaps was estimated at USD 44,000 billion at the end of 1999, compared to about USD 3,500 billion of government debt held by the public. It is worth noting that, in contrast to securities, the supply of interest rate swaps is infinite, since new contracts can be concluded all the time. Average daily turnover in swaps has been estimated at more than USD 60 billion of 10-year note duration equivalents, compared to about USD 100 billion of 10-year note duration equivalents in Treasuries.[12] Trading in interest rate swaps involves bid-ask spreads of about 1-2 basis points, which is higher than for on-the-run Treasuries and about comparable to agency debt. That swaps are increasingly used as a hedging and pricing vehicle is illustrated by the fact that many new corporate debt issues are already marketed on a spread to swaps/Libor basis rather than as a spread over Treasuries. Moreover,

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9 See Michael J Fleming, "The Benchmark U.S. Treasury Market: Performance and Possible Alternatives", *FBRNY Economic Policy Review*, Federal Reserve Bank of New York, April 2000.

10 Committee on the Global Financial System, *Implications of Electronic Trading in Financial Markets*, Bank for International Settlements, Basel, 2001.

11 John Youngdahl, Brad Stone and Hayley Boesky, "The Implications of a Disappearing Treasury Debt Market", *Goldman Sachs Global Economic Paper* no 48, July 2000.

12 "The Outlook for Swaps as a Hedge Vehicle", JP Morgan Securities, January 2000. Turnover data for swaps concern 1998 and for treasuries 1999.

relative value analysis in high-quality credit products is more and more being conducted against swaps rather than Treasuries. In this sense the US fixed income market is converging with European fixed income market practice, where pricing and comparisons on Libor basis have been common for a long time. This is probably due, to a large extent, to the non-existence of real European benchmark government securities, with a lot of relatively small government issuers instead.

Agency debt with a bullet structure is a second candidate to gain some of the advantages of benchmark status in the US fixed income market.[13] Compared to swaps, agency notes have the benefit that there is no need to sign all kinds of documentation with counterparties.[14] Furthermore, agency debt has an advantage for investors with real money to invest because they can use it to actually put away their money. In the case of swaps, on the other hand, interest rate risks are traded but actual underlying notional amounts are not exchanged and even not needed. Therefore, agencies may be a more appropriate investment vehicle for so-called real money investors than for leveraged investors.[15] For a couple of years, two of the major agencies, Fannie Mae and Freddie Mac, have been issuing large (USD 3-10 billion) liquid bullet issues in several maturities (two-, three-, five-, 10- and 30-year debt) on a regular basis. With the programmes for these so-called benchmark and reference notes the two agencies have more or less copied the issuance practices of the US Treasury and tried to establish themselves as the new benchmarks and a substitute for Treasuries, with the ultimate goal of lowering their funding costs. The large liquid agency debt issues trade at about a 1-2 basis point bid-ask spread for trade amounts up to USD 250 million. Liquidity in agency debt trading is enhanced by an increased activity in repo markets for agency debt, with issues trading both as general collateral and as specials. Liquidity was even further reinforced by the creation of futures and option contracts on agency debt in the spring of 2000.

The amount of outstanding debt with a maturity greater than one year of the three largest agencies (Freddie Mac, Fannie Mae and FHLB) has grown very rapidly in recent years, from USD 438 billion at the end of 1997 to USD 1,037 billion at the end of 2000 (ie an average annual growth rate of 33%). During the same period gross issuance of long-term debt by the three largest agencies (from almost USD 300 billion to over USD 400 billion) started to outpace that of the US Treasury (from about USD 500 billion to about USD 250 billion). Investment bank Salomon Smith Barney estimates that under reasonable assumptions the agency debt market could be larger than the tradable supply of Treasuries by the year 2004.[16]

Up until now it has not really been possible to say what product will become the future benchmark instrument in the US fixed income market. Some commentators say that benchmark status might be divided between different products for different purposes. There is no logical alternative to Treasuries as far as lack of credit risk is concerned. Analysts at Goldman Sachs expect swaps to replace Treasuries as the main benchmark for hedging, pricing, reference and analytical purposes.[17] On the other hand, they expect agency bonds to be an important cash instrument. Furthermore, agency bonds will continue to be used as a hedge vehicle as well. If Treasuries disappear, agency bonds will be the largest remaining asset class with a triple-A credit status and with well-developed large, liquid issuance. Because, compared to interest rate swaps, agency bonds have a relatively easy legal structure and a close resemblance to Treasuries, they may appeal to “real” investors who used to invest heavily in Treasuries. Swaps may become the vehicle of choice for financial intermediaries and leveraged investors instead.

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[13] Securities with a bullet structure have a complete redemption of the principal at a fixed end date. This stands in contrast to paper with a redemption of the principal spread over several dates (based on, for instance, a lottery mechanism) or to callable securities, which may be redeemed earlier if certain conditions are met.

[14] To conclude swap trades it is necessary to have signed legal documentation with the counterparty. Moreover, to mitigate counterparty credit risk exposure, use is made of bilateral netting and collateral agreements. This may require additional legal documentation.

[15] In the market, accounts with money to invest, like pension and mutual funds, insurance companies and central banks, are called “real money accounts” as opposed to “leveraged accounts” and “fast money accounts”. The latter two types of investors trade in the fixed income market but do not have real “own” money to invest. They use borrowed money instead. Money may be raised by borrowing from banks or by repoing out securities.

[16] Salomon Smith Barney, *2001 Guide to Agency Debt Securities*, August 2001.

[17] John Youngdahl, Brad Stone and Hayley Boesky, ‘The Implications of a Disappearing Treasury Debt Market’, *Goldman Sachs Global Economic Paper* no 48, July 2000.

6. Central banks as holders of US Treasuries

Traditionally, central banks and official institutions have been large holders of US dollar-denominated assets. According to IMF figures and estimates by UBS, central banks collectively held USD 2,050 billion of foreign exchange reserves in January 2001. During the 1990s about 65% of these foreign exchange reserves were held in US dollars. Historically, as much as 70% of the foreign exchange reserves have been invested in the corresponding government bond market. Central banks and official institutions have invested a very large share of their exchange reserves in Treasuries because of their favourable benchmark features described above. It is important to note that, in comparison with other investing institutions such as pension funds, insurance companies and the like, central banks have somewhat different needs for their fixed income investments. In deciding on their investment of foreign exchange reserves, central banks tended and still tend to focus more on features like liquidity, reliability, lack of default risk and the ability to own and trade large amounts, especially also in times of market unrest, rather than on return per se. It must be noted that central banks own their investments in exchange reserves to a large extent for other reasons than institutional investors. Central banks hold their dollar reserves to be able to fund foreign exchange interventions whereby dollars are sold in exchange for local currency. Moreover, exchange reserves may serve as a monetary policy tool. By buying or selling foreign currency, the central bank can loosen or tighten conditions in the domestic money market (the collective balance held by commercial banks at the central bank). Furthermore, exchange reserves may be used to finance balance of payments deficits, or to fulfil obligations vis-à-vis institutions like the IMF.

A common feature of the above reasons for holding exchange reserves is that the events that may give rise to the use of reserves can happen at (very) short notice. Therefore, many central banks feel that it is important that their exchange reserves can be liquidated easily at short notice without incurring too many costs. With the shrinkage of the supply of Treasuries and a possible decrease in the liquidity of the Treasury market, central banks, like other investors, have started to look for possible alternative or complementary instruments in which to invest their exchange reserves. Agency debt is clearly one of the important alternatives that central banks, including the Netherlands Bank, have looked at.

7. Specific developments affecting national central banks in the euro area

In recent years, national central banks (NCBs) in the euro area have been confronted with specific developments that have influenced their foreign exchange reserve management. With the start of the so-called third phase of European monetary union on 1 January 1999 the European System of Central Banks (ESCB), comprising the European Central Bank and the NCBs, took over monetary policy decision power from the 11 euro area NCBs. From that moment on monetary policy decisions for the euro area were taken by the Governing Council of the ECB, consisting of the six members of the ECB Executive Board, located in Frankfurt, and the presidents and governors of the 11 euro area NCBs. In 2001 Greece joined EMU: thus the euro area expanded to 12 countries and the governor of the Greek central bank joined the ECB Governing Council. An important feature of the setup of monetary and foreign exchange policy in the euro area is that the ECB owns its own gold and foreign exchange reserves for monetary and foreign exchange policy purposes. At the start of monetary union the 11 NCBs contributed in total EUR 40 billion worth of reserves to the ECB. This was done in the form of gold, US dollars and Japanese yen. The ECB reserves are managed by the NCBs on behalf of the ECB. Between the ECB and the NCBs there exists a "Guideline on the management of the foreign reserve assets of the European Central Bank by the national central banks". This guideline contains, amongst others, regulations governing the way NCBs can invest the reserves they manage on behalf of the ECB.

The ECB can use its reserves for foreign exchange and monetary policy purposes, just like NCBs in the euro area used to do in the past. It is worth noting that when the ECB intervenes on the foreign exchange markets it uses its own foreign exchange reserves and not the reserves held by the NCBs. The same also holds in cases where NCBs carry out interventions as members of the ESCB. For instance, the interventions in the autumn of 2000 were carried out by both the ECB and NCBs using the ECB's foreign exchange reserves. However, if the value of the ECB's reserves were to fall below a certain threshold, the ECB may make an additional call on the NCB in order to replenish its reserves.[18] Except for the possibility of an additional call for reserves, NCBs also hold their own exchange reserves for other purposes.[19] For instance, they can be used for the fulfilment of obligations towards organisations such as the IMF. They may be used, within certain limits, for operations carried out when acting as an agent for customers, including national governments. And they may be used for portfolio investment transactions as part of general asset management operations.

Another consequence for euro area NCB reserves that stemmed naturally from the start of monetary union is the fact that reserves denominated in the former euro area currencies ceased to be foreign exchange reserves but were transformed into local currency assets. This has probably been an important development for several NCBs. Many NCBs were holders of substantial amounts of Deutsche marks before the start of monetary union. In most countries, monetary policy before monetary union consisted of a very close peg of the domestic currency to the Deutsche mark. In order to be able to maintain that peg, NCBs considered it necessary to own substantial amounts of Deutsche mark reserves, which might be sold in the foreign exchange market if need be. In the case of the Netherlands Bank, the run-up to monetary union and the concomitant loss of the need for Deutsche marks for monetary and foreign exchange policy was used as an opportunity to scrutinise the balance sheet, taking into consideration, amongst others, the foreign exchange and interest rate risks on both the assets and the liabilities side. It is likely that other NCBs undertook similar exercises and made changes in the composition of their reserves in the run-up to monetary union, for instance by reducing the overall size of reserves or by selling Deutsche marks for other currencies. Nevertheless, after the introduction of the euro some NCBs retained considerable amounts of euro-denominated former foreign exchange reserves.

Because of this changed nature of NCB reserves, the importance of features like liquidity, the ability to own and trade large amounts and a very high default-free risk nature have probably diminished in favour of an increased importance of return on investment. In the case of the Netherlands Bank, there have been significant changes in the management of its own US dollar reserves and in the euro-denominated assets that used to be Deutsche mark reserves. The Bank conducted a reassessment of its fixed income investment framework and specifically of the role of spread products within it. This exercise resulted in a decision to add spread products to the benchmarks of the fixed income portfolios. Furthermore, it was decided to implement additional risk measures to contain the risks stemming from spread products.

One important consideration behind the decision to substantially increase the exposure to spread products was that research shows that in the longer run investments in high-quality credit products yield a higher return and lower return volatility than investments in government bonds.[20] The higher return is compensation for lower liquidity and the risk of default and downgrades. The lower return volatility of high-quality spread products may be a result of the fact that the interest rate spread differential between spread products and government bonds tends to be negatively correlated to the level of interest rates of government bonds. This negative correlation is probably connected to the fact that economic growth tends to increase yields on government bonds whereas at the same time credit quality tends to improve in periods of a booming economy. Consequently, credit spreads often narrow when government bond rates rise and vice versa. It is important to note, however, that other factors, too, may play a significant role in explaining spreads between Treasuries and high-quality spread products. In recent years, for instance, the relative actual and expected supply of agency versus Treasury securities seemed to account for much of the spread development as well.

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[18] See Council Regulation (EC) No 1010/2000 of 8 May 2000 concerning further calls of foreign reserve assets by the European Central Bank.

[19] In this regard Articles 23 and 31 of the Statute of the ESCB are of importance.

[20] See "How much Credit?", JP Morgan, London, May 1999 and "Introducing total return swap indices", JP Morgan, London, June 2000.

8. Benchmark structure of the DNB fixed income portfolios investment framework

Until 1999, the fixed income portfolios of the Netherlands Bank were in US dollars, Deutsche marks, Japanese yen and Dutch guilders. The Dutch guilder investments were part of the own funds portfolio of the Bank, which also includes fixed income instruments in foreign currencies and equities. The size of this portfolio is equal to the size of the Bank's own capital and reserves. Since the start of monetary union in 1999, the Netherlands Bank has managed the "Dutch part" of the ECB dollars and yen on behalf of the ECB. These investments are regulated within a management framework established by the Governing Council of the ECB. Apart from "ECB reserves" the Bank manages its own dollar and yen reserves and one euro portfolio and its own funds portfolio. The own foreign exchange reserves, the euro portfolio and the own funds portfolio are managed according to the Bank's own investment framework. In remainder of this paper we focus on the dollar portfolio.

Since the early 1990s, the framework for the management of the reserves of the Netherlands Bank has consisted of several layers with the use of so-called benchmark portfolios. In general, benchmark portfolios fulfil two aims. First, they give guidance to the investment policy. The overall duration or interest rate risk position, yield curve position and spread risk position of the benchmark determine the positioning of the actual portfolio to a large extent. The degrees of freedom given to the managers of the actual portfolio are expressed in modified duration terms. Second, the benchmark portfolio serves as a point of reference for the return of the actual portfolio. Differences between the return of the actual portfolio and the benchmark portfolio give an indication of the quality of the management of the actual portfolio. Of course, the differences in return are also dependent on the extent to which the managers make use of their degrees of freedom.

In the case of the Netherlands Bank there are two benchmark portfolios for each actual portfolio. First, there is a strategic benchmark portfolio. It is set yearly by the Governing Board of the Bank and reflects longer-term preferences. Then there is a tactical benchmark portfolio, which is set monthly by an Investment Committee.[21] Within certain limits, this portfolio can deviate from the strategic portfolio in terms of, amongst others, interest rate exposure and yield curve exposure. The aim of the tactical benchmark portfolio is to be able to take advantage of shorter-term developments and opportunities in the fixed income markets. Finally, there is the actual portfolio, managed by several portfolio managers. The actual portfolio can deviate from the tactical benchmark within certain limits as well. It is important to note that the Bank's benchmark portfolios do not consist of individual instruments. Instead, they consist of indices for different maturities, so-called grid points, for different types of instruments. These indices provide for the total return of different maturities and they are based on specific bonds. The strategic and tactical benchmark portfolios are allocated to different maturities. Up until the year 2000, the indices used in the dollar benchmarks concerned eurodollar bank deposits for one- and three-month maturities, Treasury bills for three-, six- and 12-month maturities and Treasury notes and bonds for two-, three-, four-, five-, seven-, 10- and 30-year maturities. The benchmark portfolios did not contain spread products like agency bonds.

9. Incorporation of interest rate risk and yield curve risk in the benchmarks

The interest rate risk of the benchmark portfolios is expressed in terms of modified duration.[22] The overall modified duration of the strategic dollar benchmark portfolio is decided upon once per year. The modified duration is allocated to different maturities and instruments (bank deposits and government bills, notes and bonds) along the yield curve. The overall modified duration and the

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[21] Chaired by a member of the Governing Board and further consisting of a Deputy Executive Director, members of the Asset Management division of the Financial Markets Department and a member of the Econometric Research and Special Studies Department of the Bank. A member of the Risk Management division of the Financial Markets Department is present as well, but she or he does not take part in the decision-making process.

[22] Modified duration is a measure for the interest rate sensitivity of a fixed income portfolio. A modified duration of 1 means that if the level of interest rates increases by 100 basis points, the market value of the portfolio will decrease by 1%.

distribution over the curve are based on an optimisation of risk/reward characteristics without explicitly incorporating a view on interest rates over a year horizon. The calculations take into account several restrictions with regard to, amongst others, a minimum desired return and maximum VaR. The resulting strategic benchmark sets the basis for the interest rate risk and risk resulting from movements in the shape of the yield curve. Around the strategic benchmark there exist degrees of freedom for the tactical benchmark. The tactical benchmark is set once a month by the Investment Committee, based on a proposal by the portfolio managers. The degrees of freedom for the tactical benchmark concern both the overall modified duration and partial modified durations per maturity grid point. The modified duration of the tactical benchmark portfolio is allowed to deviate from the modified duration of the strategic benchmark to a certain extent. In a similar vein, there exist degrees of freedom around the different maturity grid points. Finally, the actual portfolio may differ from the tactical benchmark within certain bands as well. The degrees of freedom for the tactical benchmark vis-à-vis the strategic benchmark and for the actual portfolio vis-à-vis the tactical benchmark are set once per year. They are based on an allowed maximum VaR vis-à-vis the strategic and tactical benchmark, respectively.

Table 1 gives an example of how a strategic benchmark portfolio with a modified duration of 1.4 might be allocated over different maturities along the yield curve. The table also illustrates the degrees of freedom for the Investment Committee, which is responsible for the tactical benchmark. In the example the overall modified duration of the tactical benchmark may deviate from the strategic benchmark by a certain amount (dfict) of duration points. Per maturity grid point the Investment Committee is allowed to deviate from the partial modified duration by another amount (dfic) of duration points. The data further illustrate the degrees of freedom for the portfolio managers who manage the actual portfolio. Their overall modified duration is allowed to deviate from the tactical benchmark's modified duration by a certain amount (dfpmt) of duration points, while the partial modified duration per grid point is allowed to deviate by another amount (dfpm) of duration points. It is worthy of note, however, that the limits set for the tactical benchmark vis-à-vis the strategic benchmark are the maximum limits for the actual portfolio as well. So, if the tactical benchmark deviates from the strategic benchmark by +0.15 duration points in a specific maturity, then there are only dfpm–0.15 duration points left over for the actual portfolio to go long vis-à-vis the tactical benchmark.

Table 1

Example of an allocation of an overall modified duration over maturity grid points and of the degrees of freedom for the strategic and tactical benchmark and the actual portfolio

	Strategic benchmark	Tactical benchmark	Actual portfolio
1-month	0.05	0.05 ± dfic	TB ± dfpm
3-month	0.10	0.10 ± dfic	TB ± dfpm
6-month	0.10	0.10 ± dfic	TB ± dfpm
12-month	0.20	0.20 ± dfic	TB ± dfpm
2-year	0.25	0.25 ± dfic	TB ± dfpm
3-year	0.15	0.15 ± dfic	TB ± dfpm
4-year	0.10	0.10 ± dfic	TB ± dfpm
5-year	0.20	0.20 ± dfic	TB ± dfpm
7-year	0.10	0.10 ± dfic	TB ± dfpm
10-year	0.10	0.10 ± dfic	TB ± dfpm
30-year	0.05	0.05 ± dfic	TB ± dfpm
Total	1.40	1.40 ± dfict	TB ± dfpmt

TB = tactical benchmark modified duration; dfic = partial modified duration degrees of freedom for Investment Committee; dfpm = partial modified duration degrees of freedom for portfolio managers; dfict = modified duration degrees of freedom for the Investment Committee for the total modified duration of the tactical benchmark; dfpmt = modified duration degrees of freedom for the portfolio managers for the total modified duration of the actual portfolio.

Modified duration of the actual portfolio may not exceed the limits for the tactical benchmark vis-à-vis the strategic benchmark.

Table 2 illustrates how the Investment Committee may take a position vis-à-vis the strategic benchmark in order to express its views as to the direction of interest rates and the shape of the yield curve. In the example the Committee expects interest rates to decrease and the yield curve to steepen. Therefore, it takes an overall long position in modified duration terms of 0.2 duration points. Moreover, it establishes a long position in the shorter-term maturities and a short position in the longer-term maturities. This way the portfolio will benefit if interest rates decline in general and if the curve steepens and shorter-term maturities outperform longer-term maturities. The table also illustrates the degrees of freedom left over for the managers of the actual portfolio. It can be seen that for some maturities the room for manoeuvre for the portfolio managers is less than dfpm duration points vis-à-vis the tactical benchmark since the tactical benchmark is already using up some of the discretion versus the strategic benchmark. This is for example the case in the two- and 10-year grid points.

The allocation of the strategic benchmark is the same as in Table 1. However, the Investment Committee expects interest rates to come down. It therefore increased the overall modified duration by 0.2 duration points to 1.6. Moreover, the Committee expects the yield curve to steepen between the six-month to three-year part of the curve on the one hand and the seven to 30-year part on the other hand. Therefore, it increased the modified duration in the first maturity area and decreased it in the second.

Table 2

Example of an allocation of the overall modified duration over maturity grid points

	Strategic benchmark	**Tactical benchmark**	**Deviation**	**Degrees of freedom actual portfolio vs tactical benchmark**
1-month	0.05	0.05	0	±dfpm
3-month	0.10	0.10	0	±dfpm
6-month	0.10	0.20	+ 0.10	– dfpm – +dfpm–0.10
12-month	0.20	0.30	+ 0.10	– dfpm – +dfpm–0.10
2-year	0.25	0.35	+ 0.10	– dfpm – +dfpm–0.10
3-year	0.15	0.25	+ 0.10	– dfpm – +dfpm–0.10
4-year	0.10	0.10	0	±dfpm
5-year	0.20	0.20	0	±dfpm
7-year	0.10	0.05	– 0.05	– dfpm+0.05 – +dfpm
10-year	0.10	0.00	– 0.10	– dfpm+0.10 – +dfpm
30-year	0.05	0.00	– 0.05	– dfpm+0.05 – +dfpm
Total	1.40	1.60	+ 0.20	

Dfpm = partial modified duration degrees of freedom for portfolio managers.

10. Eligible investment instruments and credit limits

The Bank's US dollar-denominated foreign reserves are invested in a range of financial instruments. The eligible instruments are bank deposits, US Treasury paper, certain US agency securities, certain types of sovereign paper (dollar-denominated securities issued by certain governments, not being the US Treasury), supranational paper, certain asset-backed securities and several products issued by the BIS. Other instruments at the disposal of portfolio managers are foreign exchange swaps, interest rate swaps and eurodollar interest rate, note and bond futures. Characteristic of the spread products that the Bank invests in is that they have a very high credit quality. In the case of the US dollar reserves this mainly concerns agency paper and so-called Medium-Term Instruments (MTIs) issued by the

BIS.[23] The spread of these instruments compared to comparable government bonds is mainly a reflection of liquidity risk, rather than credit risk. Compared to government bonds the liquidity of agency bonds is lower. Moreover, in times of tensions in the market the liquidity of agency bonds often tends to decrease compared to the liquidity of government bonds.[24]

Until 2001 the strategic and tactical benchmark portfolios did not contain spread products, except for bank deposits. The actual portfolios, however, were allowed to invest in spread products. In order to contain credit risks, limits are in place for bank deposits. These concern both limits for the overall exposure to bank deposits as well as limits for individual banks. Worthy of note is that the limit size is dependent on the remaining maturity of the deposit. So, a USD 100 million bank deposit with a remaining time to maturity of six weeks has a greater impact on the limit usage than a USD 100 million bank deposit with just one week to go before maturity. Furthermore, limits are in place for individual issuers like the US agencies, supranationals and sovereigns. The sizes of these limits are not dependent on the remaining time to maturity of the investment. These limits are set for two reasons. First, they mitigate default risk, although it is recognised that the chances of these very high quality credits going into default are negligible. Second, they aim to prevent the portfolio from being too concentrated in a few issuers: that would make the portfolio vulnerable to negative events surrounding specific issuers, such as a possible downgrade.

11. Inclusion of spread products in the benchmark and risk management framework

A consequence of the fact that spread products were not included in the benchmark portfolios was that the actual portfolio could only position itself neutral or overweight spread product. It was not possible to take a short position vis-à-vis the benchmarks. In the past this was not felt as too big a problem for several reasons. First, the limit sizes for spread products were not that large compared to the size of the overall portfolios. Second, particularly in the case of the US dollar portfolio, the investments in spread products used to be in shorter-term maturity instruments. Therefore, spread risk (to be explained below) was considered limited. Until the late 1990s most of the agency limits were used to buy so-called agency discount notes. These are bills issued by the agencies with a maximum maturity of one year. However, with the start of the benchmark note and reference note programmes by Fannie Mae and Freddie Mac, the focus of attention increasingly shifted to longer-term agency paper. Additionally, the advent of the euro and the ECB reserves rendered the liquidity needs of the Bank's own exchange reserves somewhat less important. At the same time there was the prospect of a significant shrinkage of Treasury issuance in the foreseeable future with an increased agency paper issuance. All these factors combined led to the above-mentioned reassessment of the fixed income investment framework and specifically of the role of spread products within it.

As of early 2001 spread products were included in the new strategic benchmark for the dollar portfolio and the tactical dollar benchmark. On a strategic level, the Governing Board decided to implement an investment mix of 60% government paper and 40% credit products for the dollar fixed income portfolio. This mix was based, amongst others, on longer-term risk/return considerations. In addition, the Board took into account considerations such as the possibility of a call of reserves by the ECB and obligations vis-à-vis institutions like the IMF. These considerations argued in favour of retaining a substantial amount of the portfolio in highly liquid Treasury paper. The new strategic dollar benchmark portfolio was constructed in a similar way to before. There were two main differences. First, the 60/40 government/credit mix was taken into account. Second, calculations were made taking into account both the Treasury and the agency yield curve (three-, six- and 12-month discount notes and two-, three-, four-, five-, seven-, 10- and 30-year notes), as well as eurodollar bank deposit rates for the very short maturities. Agency securities were used as a proxy for all eligible spread products, including

[23] The BIS issues MTIs in USD, EUR and GBP. The USD MTIs are comparable to US Treasuries in terms of interest calculations, coupon payments and the like. They are available along the yield curve from one to five years. They are priced at a stable margin below the Libor swap curve. See 'USD MTIs: An Investment Opportunity for Central Banks', Bank for International Settlements, 1999.

[24] Developments in the US fixed income markets after the recent terrorist attacks on the United States are a case in point. Liquidity in the agency bond market was more severely hit than liquidity in the Treasury market.

MTIs, supranationals and the like. This approximation was done for simplicity reasons and because the majority of investments in spread products are in agencies. The strategic benchmark's overall modified duration and the distribution over the Treasury and agency curve are based on an optimisation of risk/reward characteristics without explicitly incorporating a view on interest rates over a one-year horizon. Furthermore, like before, the calculations take into account several restrictions with regard to, amongst others, a minimum desired return and maximum VaR. The resulting strategic benchmark determinates the interest rate risk and risk resulting from movements in the shape of the yield curve.

With the inclusion of spread products in the benchmark portfolios and thereby in the investment framework, a new risk was explicitly taken on board in the framework as well: spread products carry spread risk, which is clearly distinct from interest rate risk and yield curve risk. Spread risk may be defined as the risk resulting from a change in the interest rate differential between a spread product and a benchmark interest rate. Usually, government bonds with a similar maturity or modified duration are taken as a reference point. As a risk measure for credit spread movement one can use spread duration. This measure is fairly similar to modified duration as a measure for interest rate risk. Spread duration is defined as a credit bond's percentage price movement given a percentage point change in the interest rate differential between the credit bond and its reference bond. If, for instance, the spread between a three-year maturity credit bond with a modified duration of 2.8 and a three-year government bond with a similar modified duration narrows by 10 basis points, the price of the credit bond will increase by 0.28% (10 basis points times 2.8).

In the new benchmark and risk management framework the Bank took into explicit consideration various risks of spread products. Default risk was dealt with in the same fashion as in the past, namely with limits. These were both limits for individual banks with regard to bank deposits and limits for specific issuers of paper such as agencies and supranationals. Some new measures to contain spread risk were introduced. Spread risk was contained by introducing deviation bands for the overall spread duration of the portfolios. Spread duration is that part of the total modified duration of the portfolio that is accounted for by spread products. It was decided to give the Investment Committee's tactical benchmark portfolio a certain amount of spread duration points leeway around the overall spread duration of the strategic benchmark portfolio. This way the Investment Committee is able to go short spread products vis-à-vis the strategic benchmark if it expects spreads to widen and vice versa. For similar reasons, the portfolio managers were given the same amount of spread duration points leeway vis-à-vis the tactical benchmark portfolio. However, the portfolio managers were not allowed to have the actual portfolio deviate more spread duration points from the strategic benchmark than the maximum deviation allowed between the strategic and tactical benchmark. For the sake of simplicity, there was no introduction of partial spread duration limitations per maturity grid point. Instead, deviation bands remained for the partial overall modified duration (duration stemming from government bonds and spread products combined) per maturity grid point.

12. Summary

This contribution has discussed some developments that have taken place in fixed income markets, and specifically in the high-quality US fixed income markets, in recent years. The probable sharp shrinkage in the amount of outstanding US government debt is a big challenge for many market participants. Traditionally, US Treasuries have played a significant role in the market as a safe and liquid investment vehicle and as a pricing and hedging vehicle. It is likely that under current policy prospects, Treasuries will lose some, if not all, of these benchmark features during the years to come. Debt issued by the so-called agencies is a candidate to take over part of the benchmark status of Treasuries. The same holds true for interest rate swaps.

For central banks the possible disappearance of Treasuries in the longer run and the possible decreased liquidity of Treasury debt in the shorter run is an important development. Central banks have always invested substantial amounts of foreign reserves in US Treasury debt. In the future they may face the task of finding alternative means to invest their money. Agency debt and other high-quality spread products are likely to be important candidates for this. For central banks in the euro area there are some specific developments. The liquidity needs of their own reserves are probably lower than in the past and Deutsche mark reserves have been transformed into domestic currency assets.

For the Netherlands Bank the above-mentioned events led to a reassessment of its reserve and risk management framework. More specifically, the importance of high-quality spread products in the own dollar portfolio increased significantly. High-quality spread products were also included in the benchmark portfolios. For portfolio managers this meant that they were given the possibility to go both long and short spread products. The inclusion of spread products in the benchmarks implied that spread risk was also explicitly included in the benchmark framework. In order to contain spread risk, several limits and degrees of freedom were introduced for both the Investment Committee and the actual portfolio.

Bank of England open market operations: the introduction of a deposit facility for counterparties

William A Allen, Bank of England

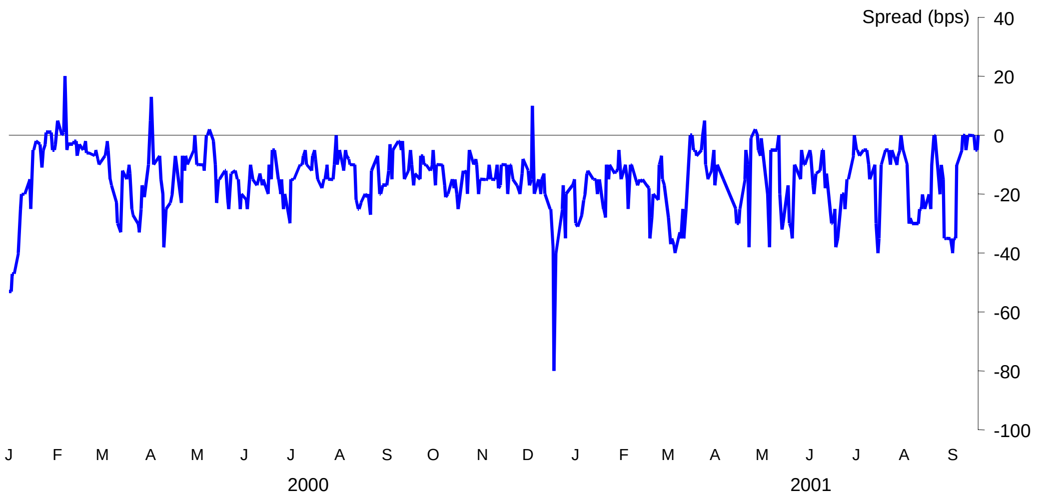
Introduction

The Bank of England implements monetary policy by lending money for two weeks at the official repo rate determined by the Monetary Policy Committee. The market two-week repo rate is not the same as the official rate. It and other short-term market interest rates fluctuate around the official repo rate in response to market forces. The fact that this is so does not represent a policy problem of any kind. As the phrase “open market operations” suggests, central banks expect to be dealing in an open market with active trading by participants other than themselves.

It is important, however, that market rates, even if they fluctuate, should remain within an acceptable range around the official rate. Over a long period, this has been the case in the United Kingdom, though there have been unusually wide fluctuations in periods of seasonal or special effects, such as year-ends and the century date change. Over the past three years or so (1998-2001), the market two-week repo rate has been on average around 20 basis points below the official rate, but, until late 2000, fluctuations around this norm were usually limited and temporary, with periods of relative softness and tightness broadly offsetting each other (see Chart 1).

Chart 1

Deviation between the market two-week repo rate and the official rate



In late 2000 and the first half of 2001, however, the deviations of the market two-week repo rate from the official rate seemed to have become larger. At times they were as large as 35-40 basis points. The increased fluctuations in the two-week repo rate were accompanied by increased fluctuations in shorter-term rates, notably overnight rates, which were of larger amplitude than the fluctuations in two-week rates (see Chart 2). The volatility of overnight rates was sufficient to elicit complaints from some market participants. Moreover, at times the fluctuations in rates became large enough to have some apparent impact on rates for maturities as long as a month (see Chart 3), though not for maturities longer than that. Of course deviations between two-week and one-month market rates and the official rate were subject to other influences as well, notably the market expectation about the outcome of the next MPC meeting.

Chart 2

SONIA vs BoE repo rate[1]

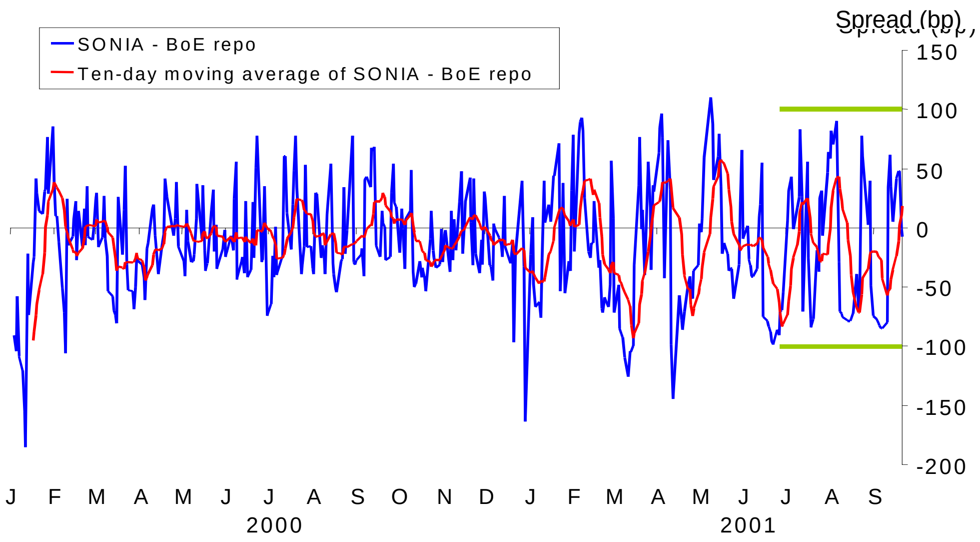
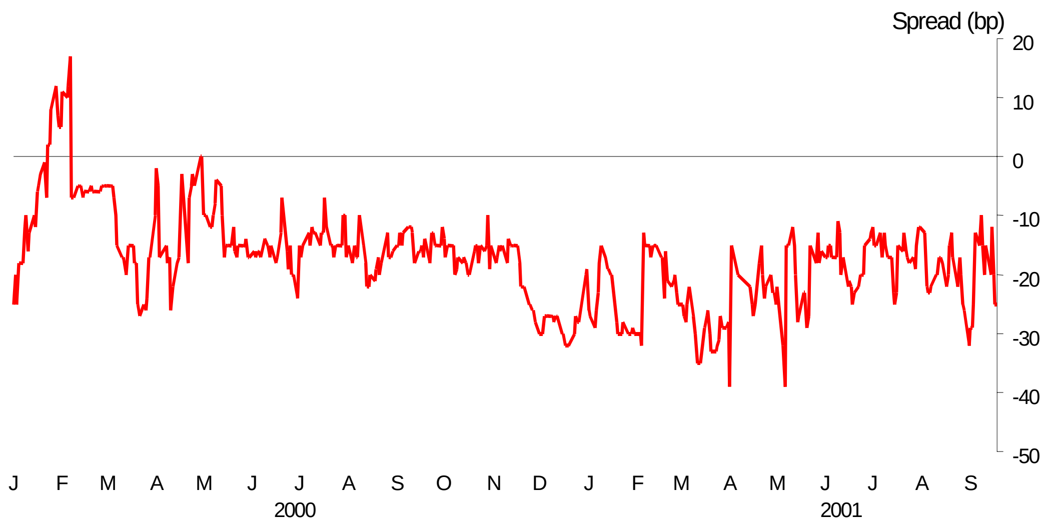


Chart 3

Deviation between the one-month repo rate and the official rate



There was little volatility in the deviation between market rates at maturities of a month and over and the official rate, both in absolute terms and relative to deviations at shorter maturities. Moreover, the one-month-plus deviations in the United Kingdom were of similar amplitude to analogous deviations in the United States and the euro zone. This suggests that the fluctuations in short-dated interest rates did not have a significant impact on the transmission mechanism of monetary policy.

Nevertheless, there were reasons to suspect that the volatility of short-dated interest rates might betray some microeconomic inefficiency in the sterling money market. To help assess whether such inefficiencies existed, and if so what they were, it was necessary to consider the possible causes of the volatility in short-dated rates.

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[1] SONIA - the Sterling OverNight Interbank Average rate - which is an average of interest rates at which overnight unsecured funds are traded.

A range of possible causes was suggested to the Bank of England by market participants. Some were more compelling than others, but the suggestions were not mutually exclusive.

One view was that market activity had become more concentrated in the hands of a few large players, who were consequently able to exert more power over the structure of short-term rates. The recent and prospective commercial bank mergers and the withdrawal, late in 2000, of a small but previously active counterparty were tangible examples of this: they illustrated the general trend towards consolidation among money market participants. Participation in open market operations became more concentrated, though this appeared to have been a long-term trend.

A second view was related to the changes in cash management in April 2000, in which the function of managing the Government's cash flow was transferred from the Bank of England to the Treasury's Debt Management Office (DMO). After April 2000, exchequer payments and receipts - previously the most volatile element of the Bank's liquidity forecast - were handled by the DMO. Consequently, the market's daily liquidity need from the Bank became more predictable, thereby reducing one element of uncertainty for market participants attempting to influence the overnight and short-dated interest rate structure (the large expansion of eligible collateral in 1999 could also have been a factor in enabling participants to build greater influence).[2] Another strand of this argument was that the very large receipt of funds from the sale of 3G telecom licences during 2000 led to a change in the DMO's relationship with the market: it became a regular large *placer* of funds in the market, thereby potentially adding to the softening influences on rates.

The third view was that volatility of short-term interest rates in the first half of 2001 was a function of market conditions and strong expectations of future rate reductions, as bulls' positions had to be funded, possibly forcing down rates at the short end.[3] Very strong expectations of interest rate cuts in February, April and May 2001 led to "pivoting" *up* of short-dated interest rates ahead of MPC meetings - reluctance to take funds from the Bank of England at the official repo rate when there was a strong expectation that the rate would be lowered within the two-week repo period. Such pivoting is a normal, temporary phenomenon when rate cuts are expected (the same happens in the euro area) but it *may* have been followed by a similar downward move of market rates after the meeting. A further strand of this argument was that equity weakness/volatility had led to a flight to liquidity at the short end, forcing short-term deposit rates down.

A common feature of all three views was the assumption that it was possible for one or a few large counterparties to exploit their market dominance to force short-dated interest rates down to abnormally low levels. How and why they were able to do so was something of a mystery. The mechanism by which they did so was as follows. They purchased a very large amount of high-quality short-term assets (eg gilt repos, or high-quality certificates of deposit), so that they had a day-to-day financing need that might be a multiple of the daily shortage of funds in the market, which the Bank of England needed to relieve. They would take from the Bank of England all of the funds that were needed to relieve the system shortage, at the official repo rate. That would not be enough to meet their own financing need, so they would bid for funds in the overnight money market (or in other short-dated markets) at a rate far below the official repo rate. They were likely to be the only substantial bidder in this market, and seemed able to use that market to obtain the rest of their financing at low cost.

The mystery in this is the behaviour of the lenders of money in the overnight and short-dated money markets. It would have been open to any substantial lender simply to refuse to accept the rate at which the single borrower was bidding. The borrower had an absolute need for the funds and would have no option but to pay more.

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2 This, like the other arguments, is contestable. The underlying exchequer flows have not changed since the transfer of cash management, but the financing flows are different.

3 There is an obvious challenge to this argument since it need not have implications at the key two-week horizon.

A deposit facility?

Given the evidence that rates had become more volatile, and more prone to periods of softness, the Bank of England considered what, if anything, should be done about it. We reviewed, and in degree utilised, various options, such as scaling so as to provide a smaller proportion of the funds supplied in open market operations earlier in the day and a correspondingly larger proportion later in the day; and introducing greater variability in the daily pattern of shortages. These devices appeared to have only temporary effects on short-dated interest rates.

We therefore concluded that we should incorporate in our standard daily operating procedures a variation of the “mopping” facility we already use on occasions to absorb excess market liquidity when the market is in surplus, ie a daily deposit facility available at the end of the market operating day at 3.30 pm. The aim would be to put a floor under overnight interest rates to moderate excessive softness (and downward volatility) in the overnight interest rate. Such a facility would match the end-of-day lending facilities that we already operated (see below) to moderate upward spikes in rates, and hence would remove an asymmetry in the existing operational framework.

Our operational techniques normally involve two invitations to our open market counterparties to borrow funds from us on repo for a (roughly) two-week maturity. These invitations are extended at 9.45 am and 2.30 pm. We moderate upward spikes in overnight rates by being ready to supply overnight funds to our counterparties at 3.30 pm (against collateral) if the shortage of funds has not been fully relieved in our main 9.45 am or 2.30 pm rounds. At the end-of-day stage, our operations are concerned not so much with implementing the MPC's repo rate as with the more routine task of squaring off any residual market imbalance in as orderly a manner as possible. The rate charged on 3.30 pm lending is penal - the official repo rate plus 100 basis points (though we can vary this margin) - in order to encourage banks to borrow in the market wherever possible. If, after the market has closed, the system is still out of balance, we will lend off-market to the settlement banks to enable them to square off their end-of-day settlement with each other, at an even more penal rate of the official repo rate plus 150 basis points (again, this margin can be varied). These facilities are designed to eliminate excessive spikes in overnight interest rates at the end of the day, and have been successful in doing so. They are akin to the ceiling in a corridor system of rates, but not exactly so for two reasons. First, they are not standing facilities available at all times to all market participants. Second, funds are normally limited to the amount of the remaining daily shortage (though we reserve the right to supply more). Both these limitations are motivated by our desire to ensure that banks are subjected to the discipline of having to finance themselves in the market to the maximum extent possible.

In the past there were no facilities to limit the extent to which short-dated rates can fall below our official repo rate. Effectively the floor rate has been set at zero, since bankers’ operational balances left at the Bank of England at the end of the day are unremunerated. We considered a variety of different options for providing a “floor” for market interest rates. There is a whole family of deposit-type facilities that could attempt to do this. Many of these approaches would have serious drawbacks, or might fail to work in practice because of the structural features of the UK money market. For example, deposit facilities operating towards the end of the day (eg at 4.20 pm or on end-of-day balances) would have the disadvantage of being limited to a small group of counterparties (settlement banks) and consequently might be less likely to influence rates during the trading day. They would also be potentially costly to central bank income. A full-scale (standing) deposit facility, available to all banks, operating earlier in the day, would also be costly to central bank income, and could lead to the central bank becoming much more heavily involved as a dealing counterparty in the money market. Moreover, it would be inconsistent with the practice of conducting open market operations through a group of intermediaries rather than directly with all banks. In any case, regardless of their merits or deficiencies, these solutions would have taken time and imposed costs on the Bank of England and on commercial banks, because it would have been a major logistical exercise to open up deposit accounts for all banks. In any case we did not need to go that far. Instead, we adapted the existing operating facilities slightly, by making a small change that was simple to implement and was unlikely to affect central bank income much.

As indicated above, we were already prepared to supply (collateralised) overnight funds at 3.30 pm if the market shortage was not relieved by our main operations at 9.45 am and 2.30 pm. This was “normally” up to the amount of the shortage - so it was not an unlimited facility. We introduced in addition a parallel (collateralised) overnight deposit facility at 3.30 pm (we called it a “deposit” facility for simplicity, but in practice it is a repo operation, like most of our other operations). Providing collateral had an advantage over offering unsecured deposits since, though settlement timings are tight, the collateral we supply at 3.30 pm could be used by the placer of funds for other transactions.[4] The deposit facility is available to all OMO counterparties. We pay a fixed, penal (sub-market), rate, and ultimately retain discretion over whether to accept the funds at all - though would normally expect to do so. In this last respect there is a degree of residual asymmetry in the permissiveness of our deposit and lending facilities at 3.30 pm, in that, in the deposit facility, we will normally take whatever amount our counterparties want to deposit with us, whereas, if we are lending, we will normally only lend the market's remaining shortage.

If we operate at 3.30 pm using this deposit facility, we recycle the funds in the 4.20 pm late facility to settlement banks in order to rebalance the market. That means that we generate a positive operating margin for the Bank. That represents a disincentive to using the facility, but the facility does nevertheless provide an escape route for those long of money should they need one. The attractiveness of the facility depends on the width of the band. Before the facility was introduced, banks that were long of money had no such escape mechanism since rates were not “floored”, while those that were short had the advantage of knowing that there was a ceiling. This was an asymmetry that at least some OMO participants seemed able to take advantage of. In introducing the facility, we did not expect much activity in the deposit facility with the Bank, but we expected that overnight rates would generally be constrained within the band and might perhaps gravitate towards the centre of the band - close to the official repo rate. We also thought that we might see a wider range of counterparties participating more actively in our operations, as they were incentivised by a more symmetric market rate structure.

Deciding on the width of the interest rate corridor was difficult. A wide corridor or band would not bind on many days and might not have much effect. A narrower band would have more effect and would have been likely to generate more business with the Bank of England, but it would erode incentives for borrowers and lenders to meet in the commercial market. We did not want our operations to overshadow normal market trading: a key feature of our current money market arrangements is that banks must test their name in commercial credit markets regularly. Related to that, any corridor would need to allow for credit tiering, since widening credit spreads are an important signal of potential financial stress.

We thought that there would be merit in maintaining symmetry, ie having an overnight deposit rate which is the same amount below the repo rate as the overnight lending rate is above it. Our judgment, informed by statistical analysis, was that the deposit rate should be 100 basis points below the official repo rate. On this basis, we did not expect the deposit facility to have an effect on the money market on more than 5-10% of days. We retained the option to change the margin if we think it would be desirable.

Experience with the facility

From 27 June, when the facility was introduced, up to 15 October 2001, eight deposits were placed with the Bank of England on seven days. Of these eight deposits, two or three were for small amounts and were placed for the purposes of testing systems and procedures, rather than for immediate market-related reasons. As would have been expected, the days when substantial deposits were placed with the Bank were days when short-dated interest rates were below the official repo rate by an unusually large margin. On those days, the existence of the facility presumably prevented the margin between the official repo rate and short-dated market rates from being even wider. Even if no deposits were placed, however, the existence of the facility would be expected to affect market behaviour.

A provisional judgment, based on a few months’ experience, is that the existence of the new facility has somewhat narrowed the range of fluctuation of short-dated interest rates around the official repo rate. Indeed, the range of fluctuation has been contained within 100 basis points either side of the repo rate, as Chart 2 shows. The fact that five or six deposits have been placed for market-related

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[4] It could not be resupplied to us at our 4.20 pm facility however, because of the relative timings of deliveries-by-value and member-to-member repo transactions.

reasons, mainly fairly early in the life of the facility, suggests that the facility has had some impact on the market, and that the placing of the deposits has been part of a process of learning about the effect of the facility. However, the causes of the fluctuations in short-dated interest rates seemed to be unaffected by the facility and remained in some degree unclear.

The monetary transmission mechanism in the United States: some answers and further questions

Kenneth N Kuttner and Patricia C Mosser,[1]
Federal Reserve Bank of New York

Introduction

What are the mechanisms through which Federal Reserve policy affects the economy? And has financial innovation in recent years affected the monetary transmission mechanism, either by changing the overall impact of policy, or by altering the channels through which it operates? These are the questions which were addressed by a conference on "Financial Innovation and Monetary Transmission" sponsored by the Federal Reserve Bank of New York on 5 and 6 April 2001.[2] The goal of this article is to provide a general summary of the papers presented at that conference, and to distil from those papers some tentative answers to the questions posed at the outset.

The overall conclusion to be drawn from the research is that the impact of monetary policy on real activity appears to be less than it once was - but the *cause* of that change remains an open issue. The conference papers considered three possibilities. The first candidate explanation attributes changes in the linkage to the financial innovations that motivated the conference, such as the growth of securitisation, shifts between sources of financing for residential investment, or changes in the strength of wealth effects. But this is not the only possibility: other papers considered the hypothesis that a change in the conduct of monetary policy can explain what *appears* to be a change in the effectiveness of policy. A third hypothesis considered is that the fundamental structural changes affecting the economy's stability (and by implication, monetary transmission) are non-financial in nature. Research supportive of each of these three hypotheses was presented at the conference, suggesting that a useful area for future research will be to determine more precisely the role each has played in the evolution of the monetary transmission mechanism.

Negative findings are often as informative as positive ones, however, and the conference succeeded in identifying three areas where financial innovation has left the monetary transmission mechanism largely unchanged. The first of these is the reserves market, which has changed profoundly in recent years. Yet in spite of these changes, the Fed has retained its ability to influence overnight interest rates - and indeed has actually become more accurate in hitting the Fed funds target. Changes in the reserves market therefore may have had an effect on the day-to-day *implementation* of policy, but they have not diminished the Desk's leverage over short-term interest rates. Second, there is no evidence to suggest that the quantitative importance of the wealth channel has changed much in recent years. Its contribution to the impact of monetary policy has always been modest, and that contribution has, if anything, decreased somewhat since 1980. And third, while the parallel trends of financial consolidation and globalisation have had a dramatic impact on financial services industries, the trends appear to have had no perceptible effect on monetary transmission.

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[1] Research Department, Federal Reserve Bank of New York, 33 Liberty Street, New York, NY 10045. E-mail: kenneth.kuttner@ny.frb.org and patricia.mosser@ny.frb.org. The views expressed here are solely those of the authors, and not necessarily those of the Federal Reserve Bank of New York or the Federal Reserve System.

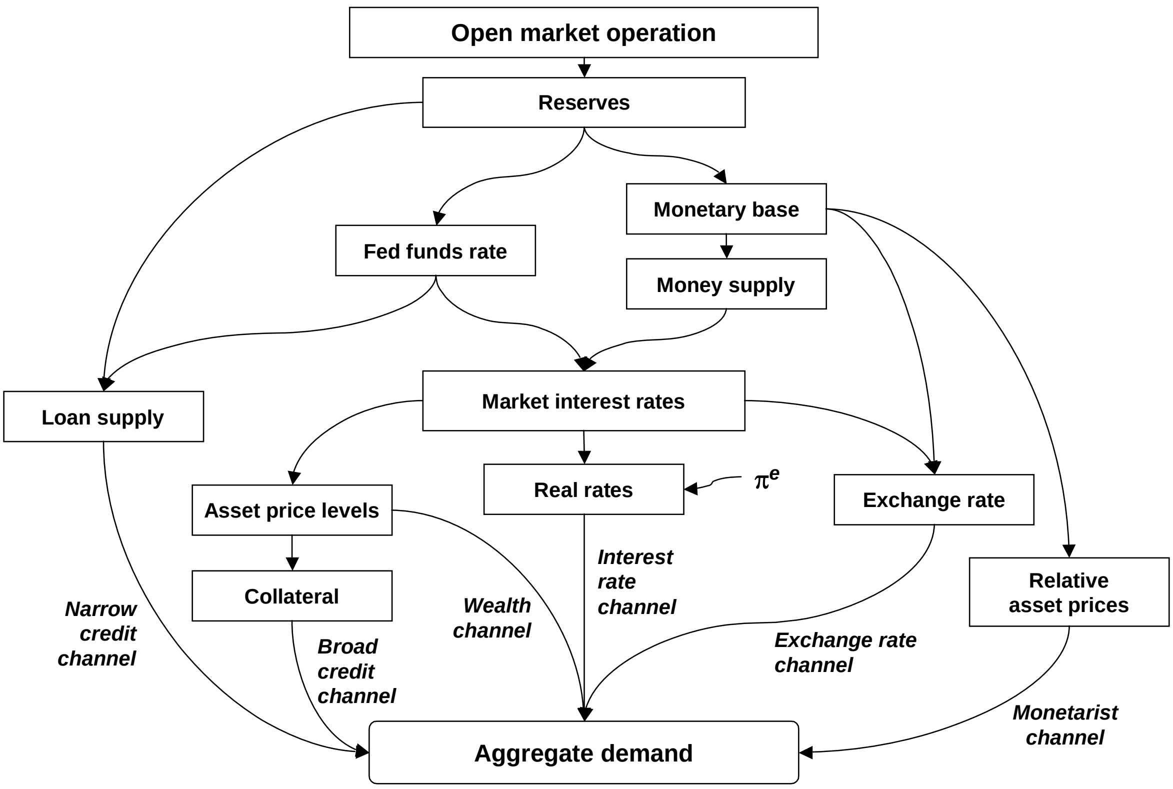
[2] The papers are available online from http://www.newyorkfed.org/rmaghome/econ_pol/2002/, and will be published in a forthcoming issue of the Federal Reserve Bank of New York *Economic Policy Review*.

A taxonomy of transmission channels

What makes monetary transmission a complex and interesting topic is the fact that there is not one, but many channels through which monetary policy operates. Figure 1 depicts schematically an eclectic view of monetary policy transmission, identifying the major channels that have been distinguished in the literature.[3] The process begins with the transmission of open market operations to market interest rates: either through the reserves market, or through the supply and demand for money more broadly. From there, transmission may proceed through one (or more) of the following channels.

Figure 1

Schematic view of monetary transmission



The *interest rate channel* is the primary mechanism at work in conventional macro models. The basic idea is straightforward: given some degree of price stickiness, an increase in the nominal interest rates (for example) translates into an increase in the real rate of interest and the user cost of capital. These changes lead in turn to a postponement of consumption, or a reduction of investment spending. This is precisely the mechanism embodied in conventional specifications of the “IS” curve - whether of the “old Keynesian” variety, or the forward-looking equations at the heart of the “new Keynesian” macro models developed by Rotemberg and Woodford (1997) and Clarida et al (1999), among others. But as Bernanke and Gertler (1995) pointed out, the macroeconomic response to policy-induced interest rate changes is considerably larger than that implied by conventional estimates of the interest elasticities of consumption and investment. This observation suggests that mechanisms other than the narrow interest rate channel may also be at work in the transmission of monetary policy.

[3] A similar description of the channels of monetary transmission appears in Mishkin (1995).

One such alternative path is the *wealth channel*, built on the life cycle model of consumption developed by Ando and Modigliani (1963), in which households' wealth is a key determinant of consumption spending. The connection to monetary policy comes via the link between interest rates and asset prices: a policy-induced interest rates increase reduces the value of long-lived assets (stocks, bonds and real estate), shrinking households' resources and leading to a fall in consumption.

Asset values also play an important role in the *broad credit channel* developed by Bernanke and Gertler (1989), but in a manner distinct from that of the wealth channel. In the broad credit channel, asset prices are especially important, in that they determine the value of the collateral that firms and consumers may present when obtaining a loan. In "frictionless" credit markets, a fall in the value of borrowers' collateral will not affect investment decisions; but in the presence of information or agency costs, declining collateral values will increase the premium borrowers must pay for external finance, which will in turn reduce consumption and investment. Thus, the impact of policy-induced changes in interest rates may be magnified through this "financial accelerator" effect.

Like the broad credit channel, the *narrow credit* or *bank lending channel* relies on credit market frictions, but in this version banks play a more central role. This idea goes back at least to Roosa (1951), and was restated in an influential paper by Bernanke and Blinder (1988). The essential insight is that because banks rely on reservable demand deposits as an important source of funds, contractionary monetary policy, by reducing the aggregate volume of bank reserves, will reduce the availability of bank loans. And because a significant subset of firms and households rely heavily or exclusively on bank financing, a reduction in loan supply will depress aggregate spending.

The *exchange rate channel* is an important element in conventional open economy macroeconomic models, although it is often neglected in the closed economy models typically applied to the United States. The chain of transmission here runs from interest rates to the exchange rate via the uncovered interest rate parity (UIP) condition relating interest rate differentials to expected exchange rate movements. Thus, an increase in the domestic interest rate, relative to foreign rates, would lead to a stronger currency and a reduction in net exports and a reduction in the overall level of aggregate demand.

Finally, there is also what might be described as a *monetarist* channel - "monetarist" in the sense that it focuses on the direct effect of changes in the relative quantities of assets, rather than interest rates.[4] The logic is that because various assets are imperfect substitutes in investors' portfolios, changes in the composition of outstanding assets brought about by monetary policy will lead to relative price changes, which in turn can have real effects. In this view, interest rates play no special role, other than as one of many relative asset prices. Although this mechanism is not a part of the current generation of "new Keynesian" macro models, it is central to discussions of the likely effects of policy when, as in the case of Japan, there is a binding zero lower bound on nominal interest rates (see eg McCallum (2000)).

Three measurement challenges

Having categorised the various channels of monetary transmission, it is a task for empirical research to assess the macroeconomic impact of each channel, and to look for changes in the channels' strength over time. Empirical work addressing these questions immediately comes up against a number of challenges, however.

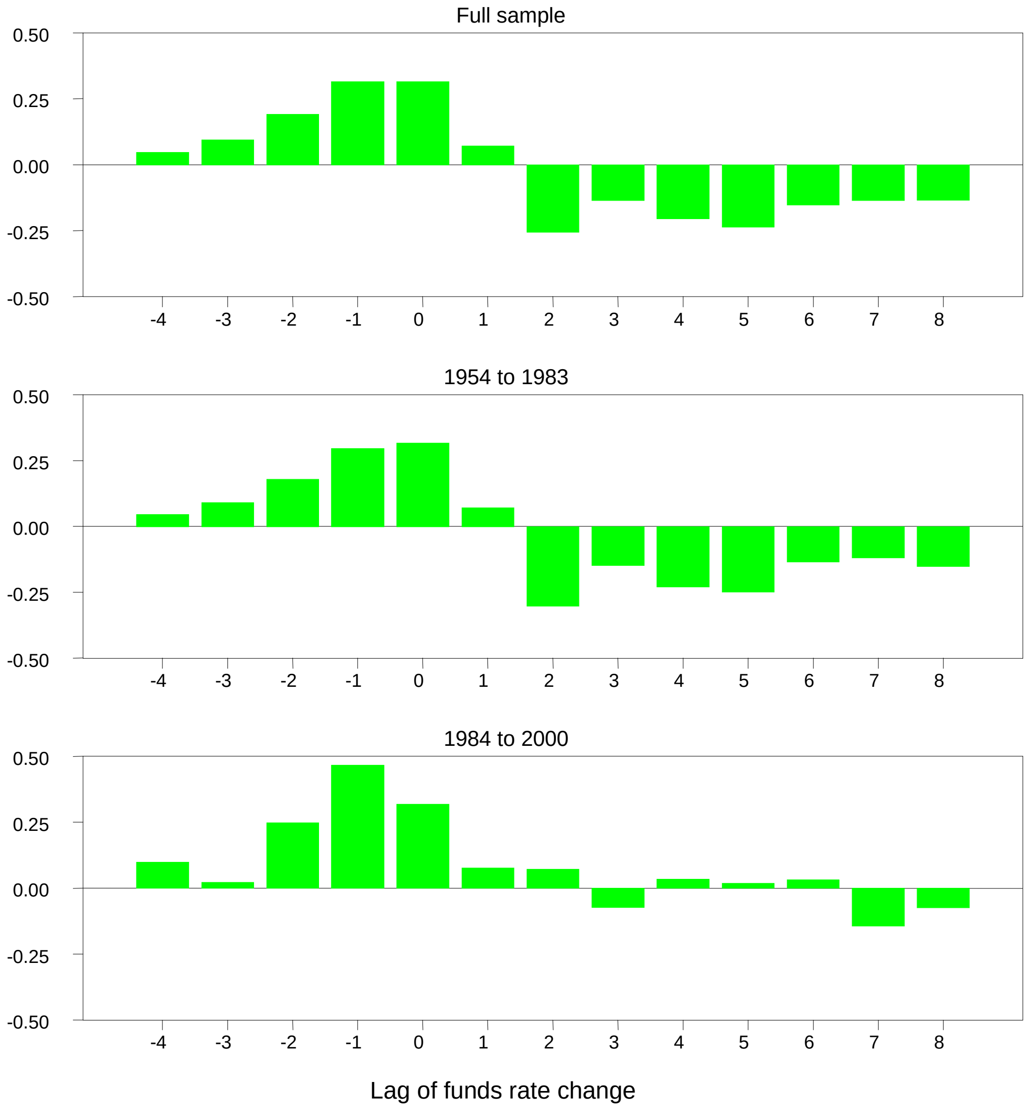
The first challenge is that of *simultaneity*. Typically, the Federal Reserve loosens policy when the economy weakens, and tightens when the economy strengthens; this endogenous response of policy to economic conditions is what makes it difficult to identify the effects of policy. This pattern is illustrated by the correlations plotted in the top panel of Figure 2: over the 1954-2000 period, the correlation between real GDP and current and future (ie negative lags of) funds rate changes is positive. This does not, of course, mean that interest rate increases are expansionary; rather it reflects

[4] Meltzer (1995) summarises this viewpoint. This monetarist channel is similar in spirit to, but considerably more sophisticated than, the earlier strand of monetarist thought based on the equation of exchange, $MV = PY$.

the tendency for the Fed to raise interest rates in response to unusually rapid real growth. The contractionary effect of higher rates is only apparent after a lag of two quarters, as shown by the negative correlation between GDP growth and funds rate changes lagged two quarters or more.

Figure 2

Correlations between real GDP growth and lagged funds rate changes



Even in this very simple view of the data, there is evidence that the link between policy and the economy has changed over time. Comparing the 1954-83 subsample (centre panel) to the 1984-2000 subsample (bottom panel), two differences are apparent. First, the correlation between output growth and subsequent funds rate changes is *stronger* in the later period than in the earlier period - evidence, perhaps, of more pre-emptive behaviour on the part of the Fed. And second, the correlation between funds rate changes and subsequent quarters' real GDP growth is *weaker* in the latter period - near zero, in fact - raising the provocative possibility that monetary policy has become ineffective. But an alternative explanation is that monetary policy has actually become *more* effective in dampening real economic fluctuations. (After all, if policy managed to completely eliminate any variation in the pace of economic activity, the correlation between the funds rate and real GDP growth would be zero.) Thus, the simultaneity problem creates a serious challenge for the interpretation of any changes in the observed relationship between monetary policy and the economy.

Economists have employed a variety of techniques to solve the simultaneity problem, but none of them is entirely satisfactory. Perhaps the most common approach, and one employed by several papers at the conference, is to use a vector autoregression (VAR) model to purge interest rate changes of systematic responses to economic activity, and focus instead on the response to exogenous monetary policy "shocks". Typically this is done by exploiting the presumed lag between policy and its effects on real activity, which is apparent in Figure 2. (Since financial markets respond immediately to policy, a non-recursive structure is more appropriate for modelling asset prices.) However, critics of the VAR approach find it implausible that the Federal Reserve behaves randomly, and argue that the "shocks" really represent either model specification errors, or changes in the overall policy regime.[5] In addition, the VARs' focus on shocks makes it hard to use them to analyse changes in the *systematic* element of monetary policy.[6] Nonetheless, the method remains popular because it offers a straightforward solution to the simultaneity problem, and appears to yield a reasonable characterisation of the economy's response to monetary policy.

Another way around the simultaneity problem is to use economic models with an explicit theoretical foundation, calibrated in such a way as to approximate the behaviour of the economy.[7] This approach, which was employed by two conference papers, is much more amenable to the analysis of the sorts of "what if" counterfactuals that come up in the context of investigating the transmission mechanism. Even these models, however, ultimately rely on estimates of economic parameters, and the simultaneity issue must be confronted at this stage. Hence, calibrated theory-based models are a useful complement to econometric models like VARs, but cannot altogether substitute for them.

Microeconomic approaches offer yet another way to circumvent the simultaneity problem, but these too are fraught with difficulties. Firm-level studies, for example, have been used to estimate the interest and cash flow sensitivities of investment spending, and thereby assess the strength of the interest rate and broad credit channels. By relying on cross-sectional or within-firm differences in the user cost of capital, they eliminate the macro-level simultaneity problem described above. But firms' financing decisions can affect the user cost, and this introduces a degree of micro-level endogeniety that can complicate the results' interpretation. The microeconomic approach has also been effectively deployed in assessing the bank lending channel, notably by Kashyap and Stein (2000). But here too micro-level endogeneity can be a problem, particularly when relationships with banks' other choice variables, like holdings of liquid assets, are involved. Furthermore, with any micro study, extrapolating from micro-level results to macro-level effects will inevitably depend on assumptions about how other firms or banks respond in equilibrium. Ultimately, these sorts of studies may therefore be more informative about the micro-level *distribution* of responses than they are on the overall macroeconomic impact.

The second challenge to assessing the strength of any particular channel of monetary transmission comes from the concurrent operation of multiple channels. For example, because we typically observe a fall in both output *and* bank lending after a policy-induced increase in interest rates, it is hard to tell what share of the output decline to attribute to a decline in loan demand (resulting from the interest rate increase), and how much to the reduction in loan supply implied by the bank lending channel. An analogous problem confronts attempts to assess the strength of the wealth channel. A common, if not entirely satisfactory, solution to this problem is to compare policy's estimated effect to its impact with the channel in question econometrically "turned off". If the remaining equations are assumed unchanged by this intervention, then the difference between the two responses can be interpreted as a gauge of the channel's contribution.

Adding to these two challenges is the problem of isolating a change in the strength of the channels of monetary transmission. This challenge is particularly daunting for a number of the studies undertaken for the conference, thanks to the evolutionary nature of the changes under consideration. Changes in the use of securitisation, households' equity holdings and the financing of residential investment have all proceeded gradually, as has the consolidation in the financial services industry. Consequently their effects on the transmission mechanism, if any, will only become evident over relatively long periods of

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[5] Cochrane (1994) and Rudebusch (1998), among others, have made these points.

[6] Hard, but not impossible; see Boivin and Giannoni (forthcoming), Bernanke et al (1997) and Sims and Zha (1995).

[7] The most commonly used models for this purpose are those based on Rotemberg and Woodford (1997) and Clarida et al (1999).

time. Statistically detecting structural changes is generally easier when those changes are abrupt, as was the October 1979 shift in Fed operating procedures. Moreover, the fact that many of these gradual changes occurred concurrently makes it even harder to cleanly separate out their effects.

Survey and synthesis

Taken together, the papers presented at the conference documented significant changes in the linkages between the basic instrument of monetary policy - reserves - and macroeconomic outcomes. But these changes do *not* imply a change in the efficacy of policy. Reasons for these changes can be found at two stages: first in the linkages between reserves and interest rates (ie the top half of Figure 1), and second in the connection between interest rates and economic activity.

From reserves to interest rates

The epicentre of monetary policy in the United States is the reserves market: it is here that the overnight interest rate targeted by the Fed is determined, and open market operations have their impact. Krieger's contribution provided an overview of some of the changes that have taken place in this market in recent years, in particular the declining volume of reserve balances and the diminishing reliance on open market operations to effect rate changes. Reasons for the decline in reserve balances include the decline in required reserves, as well as the adoption of "sweep accounts" in the mid-1990s. The Bennett and Peristiani contribution showed that one side effect of these trends is that reserve requirements are no longer binding for many banks, and that this has weakened the link between the Fed funds rate and banks' desired reserve balances.

The implications of these changes for the link between open market operations and interest rates are documented empirically by Demiralp and Jordá. Their main finding is that prior to 1994, changes in the Fed funds target were accompanied by systematic patterns in open market operations. These patterns are no longer evident after 1994, yet the effective Fed funds rate seems to track its target more closely than in the past. Meanwhile, the timing of announced policy changes seems to have become a factor in the response of term interest rates. From this evidence, they conclude that "announcement effects" have taken on increased importance in recent years.

Observing these trends, one possible conjecture is that their continuation could eventually undermine altogether the Fed's leverage over interest rates. Woodford's and Goodfriend's contributions addressed this conjecture at a conceptual level. Both start with the observation that the effect of recent innovations to reserve management has been to decrease the demand for the level of reserves, and that this may eventually create some technical difficulties for Desk operations. Neither sees these innovations as a fundamental threat to the Fed's ability to influence interest rates, however, and both note that further erosion in reserve demand could easily be offset by changes to Desk operating procedures. Based on other central banks' experience, Woodford suggests that a "corridor" system with interest-bearing reserves and a lombard-style lending facility would effectively solve any foreseeable problems created by the further evaporation in reserve demand. Goodfriend's proposal also involves interest-bearing reserves, but differs from Woodford's in that it envisions an expansion in the level of reserves sufficient to satiate the market. The result would be a system that allowed for separate control over both the overnight interest rate and the quantity of bank reserves.

Interest rates and output

The volatility of real GDP has declined markedly since the mid-1980s, as documented by McConnell and Perez-Quiros (2000). Over roughly the same period, Boivin and Giannoni's conference paper showed that the economy's response to monetary policy also appears to have declined.[8] What was responsible for these changes? Are changes in the transmission mechanism responsible, or were they

[8] This decline in the response of output to monetary policy is also documented by Taylor (1995) using an estimated structural model of the economy.

brought about by a change in the conduct of monetary policy? Or perhaps the cause was some other structural change in the economy, such as an innovation in firms' management of inventories?

In thinking about this question, it is useful to recall the Frisch (1933) schema of *shocks* and *propagation*: a change in volatility may come about either because the size of the shocks has diminished, or because of weaker propagation. Monetary *transmission* can be thought of as encompassing the various ways in which monetary policy "shocks" are propagated through the economy. But monetary *policy* is more than just a source of shocks: the systematic response of policy to macroeconomic conditions also affects the propagation of monetary (and other) shocks. A more strongly countercyclical policy, for example, will attenuate shocks' impact on output.

The Boivin and Giannoni conference paper addressed this "shocks-versus-propagation" issue directly, using VAR analysis to assess the effects of the reduction in the size of monetary shocks, changes in monetary propagation and other changes in the economic environment. They found that the variance of monetary policy shocks *has* indeed declined sharply since the early 1980s, but this decline cannot account for the reduced volatility of output. Instead, changes in the systematic response of policy to macroeconomic conditions seem to account for most of the diminished response to shocks. The paper also considered - and dismissed - the view that changes elsewhere in the economy were responsible.

Monetary policy is not the *only* factor in the propagation of shocks, of course; other changes in the economic environment may be at work as well. The Kahn, McConnell and Perez-Quiros paper analysed the possible role of inventories, which have historically been a major contributor to macroeconomic volatility. The authors' hypothesis is that better inventory management, which has been made possible by improvements in information technology, has attenuated the propagation of demand shocks - including those from monetary policy - through inventories. Specifically, the technology has allowed firms to better anticipate sales fluctuations, so that production responds more quickly - but less sharply - to sales fluctuations. Using simulations of a small equilibrium model, the authors showed that such a change in inventory management can account for the observed behaviour of output and inventories, whereas a change in the monetary policy rule cannot.

Financial intermediation

A number of papers at the conference dealt with role of financial intermediation in the transmission of monetary policy: those by Lown and Morgan, Van den Heuvel, McCarthy and Peach, Estrella, and English. In the last 20 years, a number of significant regulatory and structural changes in the financial system have affected monetary policy transmission. Changes in regulation such as the repeal of Regulation Q in the early 1980s and the changes in structural of bank capital regulations during the 1980s and early 1990s dramatically altered the incentives and the ability of banks and other institutions to lend as policy changed. Moreover, the steady disintermediation of credit formation in the United States - both via direct borrowing in financial markets and via securitisation of financial institution assets - has increased competition in many lending markets, and thus increased the importance of the price of credit in the transmission mechanism. While most of the regulatory and structural changes have reduced the importance of outright credit rationing, their overall impact on the transmission mechanism remains an open question.

Lown and Morgan directly examined the role of bank lending standards to businesses in the transmission mechanism, and provide new evidence on the relevance of the bank lending channel. Using a VAR approach, they find that lending standards have important predictive power for both loan volume and economic output. The link between monetary policy shocks and lending standards appears to be more tenuous, however. They found that innovations to the Fed funds rate are not particularly important in explaining lending standards, although when lending standards are added to the VAR model, they appear to "substitute" for monetary policy shocks in predicting real economic activity. The authors hypothesise that lending standards in part reflect "moral suasion" by policymakers to reduce credit formation at the same time as monetary policy tightening via open market operations. Episodes of moral suasion have become less common in recent years, however, raising the question of whether lending standards will continue to predict economic activity going forward; tentative results for the 1990s do, however, suggest that standards have retained their predictive power.

The disintermediation of credit formation via securitisation was examined by two papers at the conference. Estrella examined to what degree asset securitisation (and mortgage securitisation in particular) has affected the transmission mechanisms of monetary policy. Using an estimated structural "IS" equation, he found that the sensitivity of both real output and housing investment to the real Fed funds rate declined significantly as the degree of asset securitisation increased in the 1980s and 1990s. Because the sensitivity of mortgage interest rates to Fed funds changes has, if anything, increased, he suggests that securitisation has largely affected the "non-interest rate" transmission mechanisms such as the bank lending or credit channels of monetary policy.

McCarthy and Peach focused more directly on the housing market, using a structural model of housing investment to examine how regulatory changes and other innovations in housing finance have affected the transmission of policy shocks to housing investment. Like Estrella, they found that interest rates - as opposed to quantity constraints - have taken on a larger role since the dismantling of Regulation Q and the shift from thrift-based intermediation to a more market-oriented system of housing finance. Perhaps as a consequence of these changes, mortgage interest rates now respond more quickly to monetary policy than they did prior to 1986. Residential investment, on the other hand, responds more *slowly*, and now fluctuates more or less concurrently with the overall level of economic activity. An important implication is that the housing sector is no longer in the vanguard of monetary transmission.

The papers by Van den Heuvel and by English are more forward-looking in their outlook. They focused on two factors, bank capital requirements and consolidation in the financial services industry, which may well have significant effects on the transmission mechanism, but which have received little attention from researchers to date. English discussed how the inexorable trend towards consolidation in the financial industry might affect both the implementation and the transmission of monetary policy. He focused in particular on the ways in which consolidation might undermine central banks' ability to implement monetary policy, and how the size and timing of policy's effects may change as the financial system becomes increasingly dominated by a small number of very large institutions. At least thus far, however, these concerns appear to be largely unwarranted: a recent collaborative study by the G10 central banks, summarised by English, suggests that financial consolidation has thus far had minimal effects on the implementation of policy and the transmission of policy changes through the financial system.

Van den Heuvel examined the role of bank capital and capital requirements in the transmission mechanism, and proposes a "bank capital" channel of monetary policy. This channel is related to the bank lending channel described above, in that it involves policy-induced changes in bank loan supply. Instead of viewing bank reserves as the relevant binding constraint, however, it emphasises the role of banks' capital structure in shaping the response of policy-induced interest rate changes. Because poorly capitalised banks are less likely to lend than well capitalised institutions, the macroeconomic impact of policy's effects through the bank capital channel will depend on both the distribution and the level of bank capital ratios when the policy change occurs. Bank capital requirements may therefore interact with monetary policy in subtle and hard-to-predict ways. Moreover, to the extent that it affects their exposure to interest rate risk, the maturity distribution of banks' assets will also affect the transmission of policy.

On the role of asset prices

Two papers at the conference dealt with the transmission of monetary policy through asset prices. The Lettau, Ludvigson and Steindel contribution scrutinised the empirical basis for the wealth channel in the United States. Using a structural VAR model, they estimated the response to Fed funds rate shocks, and to assess the strength of the channel they compared the estimated impact to the impact assuming no response of asset prices. Overall, they concluded that the wealth channel is relatively weak - smaller than what typically comes out of experiments with conventional large-scale structural models. In fact, their evidence suggests that the wealth channel is slightly weaker now than it was in the 1960s and 1970s, despite the growing importance of equities in households' portfolios. The reason for this may lie in the transitory nature of asset values' response to funds rate shocks, and the fact that consumption responds strongly only to more permanent changes in wealth. The findings suggest that rather than a causal link from monetary policy to consumption by way of asset prices, the apparent relationship between the three variables may reflect instead the simultaneous response of asset values and monetary policy to common, underlying inflation pressures.

The contribution by Aoki, Proudman and Vlieghe also analysed the role of wealth in monetary transmission, but in the context of the broad credit channel rather than the wealth channel. Specifically, they used a variant of the financial accelerator model developed by Bernanke et al (1999), calibrated to UK data, to assess the impact of monetary policy on the real economy through its effect on housing prices. Their model indicates that policy-induced changes in house prices have in fact played a significant role in the transmission of monetary policy in the United Kingdom. They also found that recent financial innovations, such as easier refinancing terms and increased consumer access to unsecured credit, may have altered the transmission mechanism via housing prices. Easier access to housing collateral in particular has increased the sensitivity of consumption to house prices and policy shocks, while better access to credit cards has weakened the link. Overall, they conclude that monetary policy shocks now have smaller effects on housing investment and housing prices in the United Kingdom, but slightly larger effects on consumption.

Conclusions and open questions

A number of broad policy conclusions can be drawn from the papers presented at the conference. The first is that monetary policy's effects appear to be somewhat weaker than in past decades. Financial innovation is one possible cause of this change, but not the only one: others are improved inventory management and the conduct of monetary policy itself. The second is that thanks to financial innovation and institutional changes in housing finance, the housing sector is no longer on the leading edge of the transmission mechanism. However, judging from the evidence for the United Kingdom, the role of housing assets on households' balance sheets warrants further study. Finally, it appears that neither financial consolidation nor shrinking reserve volume appears to be a major factor affecting monetary transmission - at least not yet.

Some loose ends and lacunae remain, however. First, while monetary policy seems to have retained its effectiveness, the economy's sensitivity to interest rates remains an open question. A comparison of the Estrella and Boivin-Giannoni papers illustrates this issue. Both find that the response of real activity to interest rates has diminished: Estrella using a "structural" IS equation, and Boivin and Giannoni in the context of a monetary VAR. Estrella attributes this to a change in intermediation brought about by securitisation, and as Kahn, McConnell and Perez-Quiros suggest, improved inventory management may also have played a role. Yet as Boivin and Giannoni show, it may be that the diminished response results not from less sensitivity to interest rates per se, but instead as a result of the endogenous reaction of monetary policy. We thus come back to the simultaneity question: how is it possible to isolate the effect of interest rates on economic conditions when interest rates are themselves a function of economic conditions?

Second, given the decline in the relative importance of banking, the corresponding growth in securitised lending described in Estrella's paper, and the changes in housing finance documented by McCarthy and Peach, the durability of the predictive content of bank lending standards resists easy explanation. Similarly, the weak apparent link between lending standards and monetary policy remains something of a puzzle, perhaps reflecting the endogenous response of policy to credit conditions.

Third, the absence of attention to an open economy channel running through the exchange rate is an important lacuna. There are two reasons for this. The first is that despite the growth of trade in recent years, the external sector has remained a relatively small part of the US economy. (Exports and imports currently represent 10% and 14% of nominal GDP, respectively, a modest increase from 9% and 10% shares two decades ago.) And the second is that a firm connection between economic fundamentals and short-run exchange rate movements continues to elude researchers, frustrating efforts to pin down the exchange rate channel empirically.[9]

Clearly, the evolution of the monetary transmission mechanism will remain, as always, an important and fruitful area for future research.

[9] See, for example, Flood and Rose (1995, 1999) and Kuttner and Posen (2001).

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