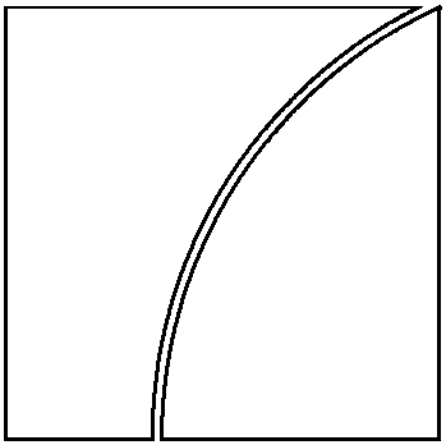
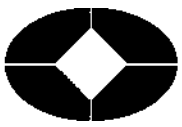
Basel Committee
on Banking Supervision

Working Paper No. 18



The transmission channels between the financial and real sectors: a critical survey of the literature

February 2011



BANK FOR INTERNATIONAL SETTLEMENTS

The Working Papers of the Basel Committee on Banking Supervision contain analysis carried out by experts of the Basel Committee or its working groups. They may also reflect work carried out by one or more member institutions or by its Secretariat. The subjects of the Working Papers are of topical interest to supervisors and are technical in character. The views expressed in the Working Papers are those of their authors and do not represent the official views of the Basel Committee, its member institutions or the BIS.

Copies of publications are available from:

Bank for International Settlements
Communications
CH-4002 Basel, Switzerland

E-mail: publications@bis.org
Fax: +41 61 280 9100 and +41 61 280 8100

ISSN: 1561-8854

Contents

Research Task Force Working Group on the Transmission Channels between the Financial and Real Sectors of the Basel Committee on Banking Supervision

Co-Chairs:
Ms Antonella Foglia, Bank of Italy, Rome
Ms Diana Hancock, Board of Governors of the Federal Reserve System, Washington, DC

Mr Piergiorgio Alessandri	Bank of England, London
Ms Tamiko Bayliss	Financial Services Authority, London
Mr Frederic Boissay	European Central Bank, Frankfurt
Mr Ian Christensen	Bank of Canada, Ottawa
Mr Jérôme Coffinet	French Prudential Supervisory Authority, Paris
Mr Chris D'Souza	Bank of Canada, Ottawa
Ms Rochelle Mary Edge	Board of Governors of the Federal Reserve System, Washington, DC
Mr Frank Heid*	Deutsche Bundesbank, Frankfurt
Mr Takashi Isogai*	Bank of Japan, Tokyo
Mr Gabriel Jimenez	Bank of Spain, Madrid
Ms Terhi Jokipii	Swiss National Bank, Zurich
Mr Jonathan D Jones	Office of Thrift Supervision, Washington, DC
Mr Jan I Kakes	The Netherlands Bank, Amsterdam
Mr Thomas Kick	Deutsche Bundesbank, Frankfurt
Mr Matthew Osborne	Financial Services Authority, London
Mr Vladimir Pillonca	Financial Services Authority, London
Mr Cyril Pouvelle	Bank of France, Paris
Ms Anna Rendina	Bank of Italy, Rome
Mr Douglas Robertson	Office of the Comptroller of the Currency, Washington, DC
Ms Katherine Samolyk	Federal Deposit Insurance Corporation, Washington, DC
Mr Miguel Segoviano	Comisión Nacional Bancaria y de Valores, Mexico City
Mr Hovick Shahnazarian	Sveriges Riksbank, Stockholm
Mr Haakon Solheim	Central Bank of Norway, Oslo
Mr Bent Vale	Central Bank of Norway, Oslo
Ms Natalja von Westernhagen*	Deutsche Bundesbank, Frankfurt
Mr Pierre-Francois Weber	Bank of France, Paris
Ms Raquel Lago	Secretariat of the Basel Committee on Banking Supervision, Bank for International Settlements, Basel

* Former member of the working group who prepared valuable inputs into the review before leaving the working group.

Executive summary

Understanding the transmission channels that exist between the financial and real sectors of the economy is critically important when assessing financial stability. Robust financial systems are viewed as those that do not adversely induce the propagation and amplification of disturbances that affect the financial system and those that are capable of withstanding shocks and limiting disruptions in the allocation of saving to profitable investment opportunities. In fact, most definitions of financial stability and the "macroprudential approach" to financial supervision recently advocated by many financial stability bodies, such as the G20 and the Financial Stability Board, emphasise the macroeconomic consequences of disruptions to the functioning of the financial system.

In response to the importance of this topic, the Basel Committee on Banking Supervision established a working group under its Research Task Force to study the transmission channels between the financial and the real sectors (the RTF-TC group). More specifically, this working group has been mandated to critically review the existing literature and then to undertake original research. This paper presents the working group's first output: a review of the literature on the transmission channels between the financial and the real sectors, as well as the working group's observations as to aspects of the transmission channels that remain inadequately addressed by the existing literature. Research undertaken as part of the work program of the group – and their implications for financial stability policy and macroprudential supervision – will constitute the second and main output of the group.

The working group has identified three transmission channels to exist between the financial and the real sector: (i) the borrower balance sheet channel; (ii) the bank balance sheet channel; and (iii) the liquidity channel. The first two channels are often referred to as the financial accelerator channel; the third channel emphasises the liquidity position of banks' balance sheets, whose interest has been fairly recent – in part, spurred on by the current crisis.

The *borrower balance sheet channel* – which applies to both firms and households – stems from the inability of lenders to (i) assess fully borrowers' risks and solvency, (ii) monitor fully their investments, and/or (iii) enforce fully their repayment of debt. There are two mechanisms for the functioning of this channel. First, borrowers face an "external finance premium", which refers to a positive wedge between the costs of externally and internally raised funds. This wedge typically depends inversely on borrowers' creditworthiness, which in turn is tied to borrowers' net worth or equity. Any shock that affects the borrowers' net worth will affect their cost of financing, which will then affect the volume of expenditures that borrowers ultimately desire to undertake and thereby aggregate demand. For example, fluctuations in asset prices – a financial shock – also affect borrower net worth, which means that the external financial premium also transmits financial shocks to the real economy. Second, lenders are unable to enforce fully their repayment of debt, which leads lenders to require collateral for borrowing. Any financial shock leading to a fall in the value of borrowers' assets, which are used as collateral, will tighten the collateral constraint, which in turn lowers production and spending and depresses asset prices farther.

The empirical literature has extensively studied how real economic variables affect households and firms' balance sheets and net worth, thus providing evidence on the sources of the shocks affecting the borrowers' balance sheet channel. If borrowers' net worth is affected by shocks to aggregate demand and the real economy, the presence of the external finance premium serves to propagate shocks to the real economy and amplify business-cycle fluctuations – hence the channel's name, the financial accelerator.

In particular, the literature surveyed deals predominantly with how macroeconomic conditions affect borrower defaults and delinquencies, although this is more from the perspective of how

these variables in turn go on to affect bank balance sheets, thus providing evidence also on the sources of the shocks affecting the banks' balance sheet channels (see below). Another part of the literature focuses directly on the linkages between the real economy and measures of bank performance (at the regional or local level). The main conclusion of this stream of literature is that macroeconomic conditions either affect borrower defaults and delinquencies, which in turn influence the strength of bank balance sheets, or directly affect measures of banks' performance. In addition to aggregate shocks, idiosyncratic shocks and regional/local conditions appear to be important.

The empirical literature that provides direct evidence on the existence of the borrower balance sheet channel focuses on the good forecasting properties of default-risk indicators, such as corporate credit spreads, on the future state of economic activity. Because corporate credit spreads likely reflect the quality and net-worth position of corporate balance sheets and thereby disruptions in credit supply, these results do provide some support on the presence of the firm balance sheet channel. However, although the forecasting success of these analyses is notable, there is substantial variation in the forecasting performance of spreads across differently measured spreads, across time and across different classes of firms. Moreover, many successful forecasting relationships prove to be unstable. One issue with this class of models is that they do not distinguish between the multiple possible causes for observed empirical relationships. Importantly, in addition to the interpretation of corporate credit spreads based on credit supply conditions, it is also possible that current corporate credit spreads reflect future expected default probabilities, which depend on the future economic conditions and could therefore be the reason for the real activity forecasting ability of corporate credit spreads. All in all, it is difficult to employ spreads without controlling for supply and demand characteristics.

According to the *bank balance sheet channel*, adverse shocks to financial institutions' balance sheets can entail sharp contractions in credit and result in such shocks having magnified effects on economic activity. Two conditions are necessary for such amplified effects to occur: the inability of banks to fully insulate their supply of lending in response to such shocks and borrowers to be highly dependent on banks for credit.

The bank balance sheet channel is sometimes divided into two separate components. The first component is the traditional bank lending channel, where shocks affecting banks' balance sheets have effects on the cost and availability of credit which go beyond the traditional effect through interest rates. The second component is the bank capital channel, where a reduction in bank capital increases the cost of funds faced by banks and, in turn, the cost of funds faced by borrowers; a further reason why bank capital can affect lending stems from regulatory capital requirements, since they place an upper bound on bank assets and thereby on bank lending. Risk-based capital requirements have the potential to further exacerbate the effects of bank capital on lending: worsening economic conditions deteriorate the actual bank capital ratio not only via the effect of loan losses on bank capital but in addition risk-weighted assets also may increase. Bank capital is shown to affect lending even when the regulatory constraint is not momentarily binding, which implies that shocks to bank profits, such as loan defaults, can have a persistent impact on lending.

The early empirical literature on the traditional bank lending channel was characterised by a lively debate which ultimately did not reach a consensus, but more recent research has focussed more on differences between banks in their balance sheet structure (and their ability to insulate their lending following shocks) and what these differences imply for the strength of the bank lending channel. The general result of this literature for the United States is that it is through small banks that the bank lending channel is transmitted, since large banks are likely to be able to raise nondeposit funding more easily than small banks and thereby better insulate their supply of lending. It is still an open issue, however, whether the bank lending channel is in practice relevant for economic activity.

Empirical results support the existence of the bank capital channel. That is, banks do appear to adjust their balance sheets in response to exogenous changes in their capitalisation. Moreover, banks with relatively weak capital positions experience weak loan growth relative to their better capitalised peers. The empirical literature also finds support for the hypothesis that risk-based capital requirements amplify business cycles. That said, studies have assessed the likely quantitative effect of Basel II purely by using simulations, under the assumption that loan portfolios are time-invariant, not taking into account that banks in practice adapt their portfolio to the business cycle or to any new regulation.

Developments and innovations in financial markets in recent years are likely to have altered the bank balance sheet channel. The developments that the literature emphasises are the intensification of securitisation, the increased use of market funding and the emergence of a so-called "risk taking channel" (ie banks' risk tolerance is influenced by monetary policy that is too expansive). The liquidity composition of bank balance sheets, asset size and bank capitalisation are other balance sheet characteristics that studies have emphasised as influencing the strength of the bank lending channel.

In light of these recent developments, a third theoretical channel highlights the importance of a *liquidity channel* as a determinant of banks' ability to extend credit and in turn to affect real economic variables, either in influencing the strength of the traditional bank lending channel or in creating additional transmission channels. In this literature, high leverage ratios, large maturity mismatches in banks' balance sheets and mark to market accounting are critical elements in the propagation of funding liquidity shocks to bank lending and the real economy. In light of the current crisis, the literature has also emphasised the interrelation of funding liquidity and market liquidity. The empirical literature provides evidence that financial intermediaries' net worth is highly sensitive to fluctuations in asset prices and that financial intermediaries – notably investment banks – adjust their balance sheets actively in such a way that leverage is high during booms and low during busts (ie leverage is procyclical). Moreover, the growth in investment banks (broker-dealer) balance sheets helps to explain future real activity especially for components of GDP that are sensitive to the supply of credit.

Finally, the transmission channels between the financial and the real sectors have been recently analysed in a dynamic stochastic general equilibrium (DSGE) framework, that in principle constitute a complete, internally-consistent representation of the economy which captures all fundamental interactions between households, firms and policy makers. Models of the like which include financial frictions, bank capital or both borrower and bank balance sheet channels features have been recently introduced by a number of authors; nonetheless there is not yet a comprehensive framework that simultaneously includes all the most relevant features for practitioners and supervisors.

On the basis of these findings, the group has identified the following gaps in the literature:

- On the topic of the refinement of macro stress testing models, the most important deficiency of existing models is their lack of any feedback effects. Macro stress testing models consider the effects of real conditions on bank balance sheets but rarely account for the fact that such bank balance sheet developments themselves have macroeconomic effects, which typically reinforce the effects of the initial macro shock.
- On the topic of how conditions in the real economy affect conditions in the financial sector, a notable gap is the focus of this literature on borrower default and delinquency outcomes with limited consideration of borrower balance sheet positions more generally. Borrower balance sheet positions (even without defaults and delinquencies) are relevant to the perceived creditworthiness of borrowers, which in turn influences borrowers' access to credit and their terms on credit, which in turn affects their borrowing and ultimately economic activity.

- On the issue of the development of models which capture the interaction between conditions in the financial sector and the real economy, a key gap – common also to macro stress testing models – is the limited attention paid to nonlinearities and structural instabilities. Another gap that is relevant primarily to DSGE models that consider interactions between the financial and real sector is the relatively stylised treatment of banks. While the seminal papers in the literature provide useful techniques for including financial intermediation in DSGE models, their characterisation of banking activities does not capture what are the most important concerns of practitioners (such as bank capital constraints and the mismatch of asset and liability maturities).
- On the question of the influence of bank capital on lending, an important gap – highlighted by recent events – is the extent to which private versus government capital injections have different implications for lending and economic activity. Several countries over the current crisis have implemented policies to inject capital into the banking sector and so examining whether injecting capital publicly is completely analogous to private capital injections would be of clear value to policymakers. A related topic concerns the need for analytical foundations of the effect of regulations on the system as a whole. For example, there has been little work done on the private incentives that emerge from banking regulations. Yet, "capital arbitrage" has been shown to be one important root of the crisis. In addition, it is very important to understand the incentive that financial regulation creates in the current context of regulation overhaul.
- On the issue of how bank and borrower balance sheet positions influence bank-level variables relevant to economic activity, an issue that has been overlooked is that of the *separate* influences of borrower and lender balance sheet conditions in propagating macroeconomic and financial disturbances to the real economy. This results for the most part from the fact that borrower and bank balance sheets, which are both influenced by macroeconomic conditions, typically deteriorate or improve at the same time and ultimately, the only variables that researchers observe are the resulting lending volumes or lending rates (or spreads).
- On the question of how cross-country financial transmission channels influence international business-cycle co-movement, an important gap is the fact that most analysis is undertaken on a reduced-form basis, which provides limited information on the precise channels in operation.
- On the influence of financial sector variables on the transmission of monetary policy, a key gap is the question of how lending affects real activity. Another gap that has opened up as a result of the recent crisis is on the implications of securitisation for the bank lending channel. Essentially all of the research to date on this topic was undertaken prior to the crisis and so a critical question is how these results hold up in the current environment. The RTF-TC workplan can also provide further advancements on the relationship between the stance of the monetary policy and banks' risk attitude (the so-called risk-taking channel).

The transmission channels between the financial and real sectors: a critical survey of the literature

I. Outline of the literature survey

This literature survey is organised as follows. Section II discusses the possible transmission channels that the current literature has identified to exist (in theory) between the real and financial sectors. Section III reviews the evidence on how real economic variables affect financial variables. More specifically, the discussion in this section considers existing research on how real macroeconomic variables affect households' and nonfinancial and financial firms' balance sheets, including the literature on macro stress testing models, a specific class of models that study this particular issue for banks' balance sheets. Section IV reviews the evidence on how financial variables affect real economic variables via the balance sheet positions of households, and nonfinancial and financial firms. This section also considers implications of the financial-to-real sector channels for the international transmission of business cycles. Section V considers most of the channels reviewed in section II in a general equilibrium context. Research in this literature allows for the possibility of feedback effects between the real and financial sectors in the context of theoretically-rigorous models (which are required to distinguish between the two directions through which real and financial transmission channels operate). Finally, Section VI presents the working group's observations as to areas of the transmission channels that remain inadequately addressed by the existing literature and that would benefit from further study. An appendix at the end of the paper describes the wide range of methodological techniques and models that the literature that this paper reviews has used to study these channels. These approaches include single- and multi-equation approaches, time-series, cross-sectional and panel data approaches, modelling approaches with differing degrees of theoretical structure, as well as macro stress testing models, simulation tools that help policy makers to assess system-wide (and individual institutions' also) financial soundness under alternative economic scenarios.

II. Real and financial transmission channels: the theory

This literature review considers transmission channels between the real and financial sectors that (potentially) operate in both directions. Specifically, conditions in the real economy affect financial conditions – in particular households' and (financial and nonfinancial) firms' balance sheets – and the conditions of households' and firms' balance sheets in turn affect real economic activity. The theoretical literature on the linkages that runs from the real to the financial sector is for the most part standard macroeconomic theory. Specifically, weaker macroeconomic conditions reduce the revenues and profits of businesses (including banks) and the incomes of households, which results in households' and businesses' net worth increasing more slowly or in some cases decreasing. This implication of weaker economic activity is fairly unequivocal and indeed Jacobson et al (2005), in one of the papers discussed later in the review, note how the notion of macroeconomic conditions affecting balance sheets would be considered by most economists to be "trivially true". An additional implication of reduced business revenues and household profits is that it increases borrower default probabilities, which in turn has implications for bank losses and thereby bank balance sheets.

The theoretical literature on the linkage that runs from the financial to the real sector represents the lion's share of the literature on real and financial sector transmission channels. Before discussing these financial- to-real sector transmission channels, however, it

is worth clarifying what the RTF-TC working group considers to represent such channels. As such, interactions that exist between financial variables (such as interest rates) and real variables (such as consumption or investment), which arise purely from the intertemporal aspect of households' and firms' spending decisions – rather than as a result of any financial friction – do not, in the working group's view, constitute a financial and real sector transmission channel. For example, the permanent income model of consumption notes the relevance of the discounted value of a household's stream of future income in determining its current consumption. Because the appropriate discount factor for future income is the real interest rate, this results in the real interest rate, a nominally financial variable, influencing consumption. Similarly, in the neoclassical investment model, interest rates affect spending decisions because they represent the relevant variable for discounting future flows of capital rental income and/or depreciation allowances. It is important to note, however, that although these financial variables influence real activity in standard macro models of consumption and investment, there is no more than a trivial role for the financial sector. Indeed, the financial sector in these models serves only to transfer income across time; and it performs this role perfectly, without facing any of the financial frictions that in practice exist in the intermediation of credit.

In studying the real and financial sector transmission channels, the RTF-TC working group's interests lie in understanding how informational asymmetries, incomplete markets, agency costs and costly contract enforcement, in conjunction with the financial sector's attempts to overcome these problems, influence the interactions between key financial and real sector decision variables that are absent from a standard, full-information, neoclassical model. This paper reviews the existing literature that deals with these financial and real sector interactions.

According to the group, three channels have been identified by the theoretical literature to account for the transmission of shocks originating in the financial sector to the real economy and the amplification and retransmission, via the financial sector, of shocks originating in the real economy. The three channels, which broadly relate to the overall asset and liability position of either banks or their borrowers, are: (i) the borrower balance sheet channel; (ii) the bank balance sheet channel; and (iii) the liquidity channel. The first two channels – which are often referred to as the financial accelerator (see Bernanke and Gertler (1995)) – challenge the Modigliani-Miller view of the irrelevance of financing for a firm's (or for a bank's) investment decision.[1] The borrower balance sheet channel and aspects of the bank balance sheet channel emphasise the influence of the net-worth or equity position of the borrower or bank on the credit conditions these agents face. Both balance sheet channels can arise as a result of capital-market frictions – such as information asymmetries, problems in contract enforcement and agency costs – while a specific bank balance sheet channel can also arise for banks as a result of regulatory requirements on bank capital. The third channel emphasises the liquidity position of balance sheets and highlights the rigidities that can be present (either in all circumstances or at times of extreme stress) in altering balance sheet variables. These rigidities in turn then affect real economic variables. Interest in this channel has been fairly recent – in part, spurred on by the current crisis – and to date has been addressed for the most part in the context of banks.

[1] It is well-known that the Modigliani and Miller capital structure irrelevance theorem holds only under several restrictive assumptions that do not hold in reality. These assumptions are: (i) a firm's total cash flows to its debt and equity holders are not affected by its capital structure; (ii) there are no transactions costs; and (iii) no arbitrage opportunities exist in the economy. See, for example, Grinblatt and Titman (2002) for further discussion.

A. The borrower balance sheet channel

The borrower balance sheet channel – which applies to both firms and households – stems from the inability of lenders (i) to assess fully borrowers' risks and solvency, (ii) to monitor fully their investments, and/or (iii) to enforce fully their repayment of debt. This leads lenders to require collateral for borrowing, which means that a borrower's equity position influences their access to credit.

There are two broad classes of borrower balance sheet models. In the first class of models – associated with Bernanke and Gertler (1989) and Carlstrom and Fuerst (1997) – borrowers face an "external finance premium", which refers to a positive wedge between the costs of externally and internally raised funds. This wedge typically depends inversely on borrowers' creditworthiness, which in turn is tied to borrowers' net worth. The external finance premium arises from the fact that borrowers have an incentive to take on greater amounts of risk than are in lenders' interest, and lenders have limited means to restrict the amounts of risk that borrowers take on. Involving borrower net worth in the financing of a project is, however, one way to align more closely the risk-taking incentives of borrowers and lenders since doing so means that borrowers, along with lenders, will face similar losses should a project fail. Thus, the greater the net worth of the borrower, the lower is the premium required by the lender.[2] This means that any shock that affects net worth (such as a financial shock or a shock to aggregate demand that weakens firm profits and household income and in turn net worth) will affect the borrower's cost of financing, which (via standard user-cost or interest rate channels) will then affect the volume of expenditures that borrowers ultimately desire to undertake and thereby aggregate demand. Net worth is affected by shocks to aggregate demand and the real economy, which means that the presence and the properties of the external finance premium serve to propagate shocks to the real economy and amplify business-cycle fluctuations – hence the channel's name, the financial accelerator. In addition, financial sector shocks, such as fluctuations in asset prices also affect borrower net worth, which means that the external financial premium also transmits financial shocks to the real economy.

The second class of borrower balance sheet or financial accelerator model is associated with the work of Kiyotaki and Moore (1997). In this model, assets play a dual role in the economy, in that they are used to produce goods and services and to provide collateral for loans. The need for collateral in these models arises from the fact that lenders cannot force borrowers to repay their debts unless the latter are secured. These problems of debt-contract implementation create interactions between credit limits and asset prices through both a static, within-period multiplier and a dynamic, inter-temporal multiplier. Any financial shock leading to a fall in asset prices will tighten the collateral constraint, which in turn lowers production and spending and depresses asset prices farther. Note also that because reduced production and spending stemming from shocks to the real sector also depress asset prices, shocks to the real economy can also be propagated via this mechanism.

Borrower collateral also plays a key role in Holmström and Tirole's (1997) financial accelerator model, which allows for both intermediated credit (offered by banks) and non-intermediated credit (offered by investors). In this model, non-intermediated credit is less

[2] It is interesting to note that demanding greater equity or collateral as part of a loan has not always been viewed as a way to induce less risk-taking behaviour by borrowers. For example, Stiglitz and Weiss (1981) show how imperfect information and moral-hazard and adverse-selection effects result in interest rates being unable to clear the lending market such that credit rationing occurs. Importantly, they also show that increased collateral requirements do not overcome these problems, because higher levels of equity can reflect more risky past behaviour. In addition, increased collateral requirements as a share of a project's financing may also mean that only small, perhaps less profitable, projects obtain financing.

costly for borrowers, because it does not involve any monitoring, although it requires that greater collateral be offered by borrowers. If borrowers have insufficient collateral to obtain non-intermediated credit from investors, they must obtain credit from banks. This lending requires costly monitoring, which up to some point banks recoup by charging a higher cost of funds to borrowers. However, banks also have limited capital, which places a limit on their ability to monitor, so that borrowers with very low collateral are unable to obtain any type of credit. Adverse shocks to borrower collateral, which Holmström and Tirole call a *collateral squeeze*, produce higher funding costs along with some borrowers failing to obtain credit, where the effects are most severe for poorly capitalised borrowers. Both of these effects restrain expenditure and result in lower aggregate demand.

B. The bank balance sheet channel

The bank balance sheet channel can be divided into two separate components: the traditional bank lending channel and the bank capital channel. Both channels recognise that adverse shocks to financial institutions' balance sheets – which may arise from changes in monetary and regulatory policy or bank capital losses – can entail sharp contractions in credit and result in such shocks having magnified effects on economic activity. One condition necessary for such amplified effects to occur is for some borrowers to be highly dependent on banks for credit. This dependence implies that if the supply of bank loans is severely disrupted, these borrowers – while not completely cut-off from credit – face sizable difficulties and costs in finding and forming relationships with new lenders, and this results in these borrowers having to curtail their expenditures. Another condition that causes adverse bank balance sheet shocks to have amplified effects on economic activity is the inability of banks to fully insulate their supply of lending in response to such shocks.

In the traditional *bank-lending channel framework*, monetary policy shocks have effects on the cost and availability of credit which go beyond the traditional effect through interest rates. In particular, when the latter of the two above conditions is met, both sides of banks' balance sheets contract in response to a negative monetary shock. On the liability side, a monetary policy tightening decreases money supply and money demand, which is the standard effect of monetary policy. On the asset side, it entails a change in the asset composition, leading to a stronger decline in credit supply, which is the lending channel (Bernanke and Blinder (1988)). Moreover, through the condition of high dependence on banks for credit, borrowers must reduce their real spending after a tightening in credit conditions by banks. This analysis can also be applied to other types of shocks such as bank capital losses.

Recent developments in financial markets, most notably the emergence of private securitisation markets, have raised the question of whether the dramatic growth in securitisation has diminished the importance of the bank lending channel. For example, Nwogugu (2007) considers the interactions between capital reserve requirements and securitisation and shows that from a theoretical perspective the latter undermines the ability of the central bank's reserve requirements to limit the expansion of credit by commercial banks.

The models discussed above assume that banks hold no capital and are entirely funded by external liabilities. Furthermore, there is no endogenous credit risk in these models (all loans are paid back), and so there is no room to analyse regulatory policy. Other models analyse why changes in banks' capital levels, which can arise for a number of reasons, influence the volume of loans that banks can extend, *the bank capital channel*. In Holmström and Tirole's (1997) financial accelerator model, all bank lending is financed by capital, which provides the incentive for banks to monitor borrowers, and thereby overcome the moral-hazard problems present in borrowers' investment decisions. Consequently, a capital crunch will result in banks providing less credit to borrowers, where (as was also the case with an adverse shock

to borrower collateral) the effects are most severe for poorly capitalised borrowers. Reduced credit restrains expenditure and results in lower aggregate demand.[3]

Another reason, noted by Stein (1998), as to why bank capital can affect lending is directly analogous to the financial accelerator model discussed in the previous section, albeit for banks rather than households or firms. Specifically, the cost and availability of nondeposit funds for any given bank will depend on the perceived creditworthiness of the institution, which, like the borrower balance sheet model, is tied to bank capital. Intuitively, better capitalised banks are perceived to have stronger incentives to carefully underwrite and monitor loans and as a result are able to attract nondeposit funding at a lower cost. This implies that an external finance premium that depends negatively on bank capital is present for banks' non-insured financing. Since the external finance premium paid by banks is in turn reflected in the cost and availability of funds to bank-dependent borrowers a reduction in bank capital increases the cost of funds faced by banks and the cost of funds faced by borrowers and thereby constrains economic activity.

As discussed by van den Heuvel (2002), a further reason why bank capital can affect lending stems from regulatory requirements. That is, due to regulatory capital requirements a bank's holding of capital places an upper bound on bank assets and thereby bank lending. Importantly, there are two conditions required for the bank capital channel to operate. First, banks should have no excess capital that can be used to buffer against shocks that deplete bank capital. And, second, the capital market is imperfect in that it is costly for a bank to raise capital.

Any shock – financial or real – that adversely affects bank capital will reduce banks' ability to extend credit, which in turn will restrain the volume of expenditures that the banks' borrowers can ultimately undertake. Shocks to aggregate demand, as well as conditions in real estate markets, may influence loan losses and, if not buffered by profits, can affect bank capital. In addition, changes in interest rates as well as changes to the slope of the yield curve, because they affect real activity and bank profits, can also affect bank capital. Van den Heuvel (2002) highlights the cushioning effect that above regulatory levels of bank capital have on this channel. In particular, he develops a dynamic model of bank asset and liability management in which interest rate shocks have a more delayed and amplified effect on lending by banks with depleted capital relative to banks that are well capitalised. That said bank capital is shown to affect lending even when the regulatory constraint is not momentarily binding, which implies that shocks to bank profits, such as loan defaults, can have a persistent impact on lending. Note also that financial sector shocks such as fluctuations in asset prices also affect banks' capital, which means that the bank capital channel also transmits financial shocks to the real economy.

Basel II capital requirements have the potential to further exacerbate the effects of bank capital on lending and this has been a major source of concern in discussions on the impact of the revised regulatory framework for capital adequacy. As Lowe (2002), Borio et al (2001), Altman and Saunders (2001), and Goodhart et al (2004) all note, not only do worsening economic conditions deteriorate the actual bank capital ratio via the effect of loan losses on bank capital but in addition risk-weighted assets also rise. This is because in downturns, credit risk, as measured by the borrower's probability of default (PD), loss-given-default (LGD) and exposure at default (EAD), typically increases thereby also increasing capital

[3] Note that a third type of capital shock – specifically, a reduction in the capital invested by investors, also called a *saving squeeze* – can occur in Holmström and Tirole's model. This type of capital shock also reduces lending and expenditure. As with the other capital shocks in the model, the effects of a saving squeeze are most severe for poorly capitalised borrowers.

requirements, which under the Basel II framework are more closely tied to risk than under a "flat-rate" capital requirements framework, such as Basel I. Banks would therefore face much higher capital needs, while finding it more difficult to increase their capital because their profits and hence their capacity to build up reserves diminishes. Faced with these difficulties in raising new equity, banks would likely then de-lever their assets and reduce certain types of their assets – such as lending – which have higher risk weights. This would imply a reduction in the amount of credit extended to firms and households, which could in turn worsen the initial economic downturn. Conversely, during an economic upturn, banks holding excess capital would face much lower capital needs, expand credit further and fuel a credit-led boom. At present, this literature is largely empirical or simulation-based, although Jacques (2008) presents a theoretical model that produces procyclical capital outcomes.

C. The liquidity channel[4]

The ongoing financial crisis has highlighted the importance of liquidity as an influence on banks' ability to extend credit and thereby on economic activity. In some cases, liquidity conditions merely influence the strength of existing real and financial sector transmission channels.[5] In other cases, however, liquidity considerations create additional real and financial sector transmission channels. This point has long been established, although the recent crisis has lead to an increased focus on these types of channels. High leverage ratios and large maturity mismatches in banks' balance sheets are a critical element in the propagation of funding liquidity shocks to bank lending and the real economy. Indeed these features of bank balance sheets and the adverse asset price spirals that they can engender were noted as early as Fisher (1933), who described the strong links between distressed asset sales and banks' health. The basic mechanism is that given a liquidity or solvency shock, banks start to sell assets, which creates excess supply in asset markets and lowers asset prices. Falling asset prices in turn imply further asset sales (so as to meet resulting margin calls), which in turn means that a downward spiral in asset prices and balance sheet health sets in.[6] Diamond and Dybvig (1983), in their seminal work on bank runs, also noted this mechanism while, more recently, Diamond and Rajan (2005) stress the interaction and reinforcing effects of banks' liquidity shortages and solvency problems. Noting that because banks finance illiquid assets with short-term debt, Diamond and Rajan explain how aggregate liquidity shortages can emerge, such that if depositors (or liability holders more generally) unexpectedly demand payments (or are unwilling to roll over debt), banks can be forced to prematurely foreclose otherwise profitable loans.[7] This can result in banks' facing sizable losses that will restrain future lending and at the extreme can drive contagious bank failures.

---

[4] Some of the material presented in this section and in Section V. D is drawn directly from a critical survey of existing research on liquidity risk prepared by a former RTF subgroup chaired by I van Lelyveld.

[5] For example, Kashyap and Stein (2000) introduce the liquidity structure of banks' balance sheets into the framework of the bank lending channel of monetary policy transmission and showed that the impact of monetary policy on lending is stronger for banks with less liquid assets as well as for small banks defined according to asset size.

[6] See Shim and von Peter (2007) for an excellent survey on asset market feedbacks and distressed selling and Amihud et al (2005) for an overview of the literature on the interaction between liquidity and asset prices.

[7] Krishnamurthy (2009) notes how new or unfamiliar financial products combined with Knightian uncertainty can serve as a trigger for such liquidity shocks. Specifically, large shocks to unfamiliar financial products lead agents to withdraw from such markets and cause a loss of funding liquidity to financial institutions. See also Gorton (2008).

In light of the current crisis, the literature (influenced by Brunnermeier and Pedersen (2009)) has made the distinction between two types of liquidity: funding liquidity and market liquidity. Funding liquidity refers to the liability side of banks' balance sheets and can be defined as an institution's ability to get funding immediately, through asset sales or new borrowing, in order to meet payment obligations on debt at maturity. On the other hand, market liquidity refers to the asset side of banks' balance sheets and defines the ease with which an asset can be traded. In Diamond and Rajan (2009), the presence of both funding and market liquidity can result in the anticipation of funding liquidity shortages inducing even healthy (ie liquidity ample) banks to refrain from lending. This occurs because the expectation of distressed banks being forced to sell (somewhat illiquid) assets in the future at fire-sale prices drives healthy banks to hoard liquid funds so as to allow them to take advantage of future investment opportunities. This mechanism appears to have been at work during the last financial market crisis.

The presence of both funding and market illiquidity is an important feature of Brunnermeier and Pedersen (2009). These authors develop a formal model that links the market liquidity of a security and the funding liquidity of traders. The providers of market liquidity are traders – specifically, market makers, banks' proprietary traders and hedge funds – that act as intermediaries by buying and selling securities. In practice, the funding of traders impacts market liquidity and is itself also impacted by market liquidity, because traders are subject to funding constraints on their trading. In the model, funding liquidity risk is the risk of a binding funding constraint, which stems from the requirement that a trader must be able to finance all of his or her security positions at any point in time. While there are some differences in the definition of capital across the three major types of traders, the basic funding constraint is that total capital use must be smaller than the available net capital available plus available debt funding. When dealer capital is abundant, market liquidity is at its highest level and insensitive to marginal changes in capital and margins.[8] In contrast, when funding liquidity is scarce, traders become hesitant to acquire positions, especially capital-intensive positions that require high margins. As a result, market liquidity is lower. Moreover, low future market liquidity can increase the risk of financing trades, thus increasing margins. There are multiple competitive equilibriums in Brunnermeier and Pedersen's model under the (necessary and sufficient) condition that decreased market liquidity leads to either higher margin requirements or losses on dealers' existing positions. In the "liquid" equilibrium, markets are liquid, which leads to favourable margin requirements for dealers, which consequently helps dealers make markets liquid. In the "illiquid" equilibrium, markets are illiquid, resulting in larger margin requirements (or dealer losses), thereby restricting dealers from providing market liquidity. Once in this equilibrium, market liquidity becomes very sensitive to shocks due to two amplification mechanisms, so-called "liquidity spirals": the margin spiral and the loss spiral.[9]

During crises, decreases in market liquidity and funding liquidity are mutually reinforcing and produce either margin spirals or loss spirals. Margin spirals occur in the following way. A decrease in funding compels a dealer to provide less market liquidity. If margins increase as market liquidity decreases, the initial decline in funding tightens the dealers' funding constraint further, which in turn forces them to diminish their trading and so on, leading to a margin spiral. Loss spirals (asset price spillovers) occur along similar lines. The model

[8] Margins can be covered either by using risk-free assets (cash) or by posting risky assets whose market value is reduced by a haircut.

[9] For fragility problems to arise (ie market illiquidity jumps discontinuously), either the margin must be sufficiently increasing in market illiquidity to destabilize the system, or the dealer's initial position in the security must be sufficiently large (ie correlated with the initial customers' demand shock).

explains the empirically documented features that market liquidity (i) can suddenly dry up (ie is fragile); (ii) has commonality (is correlated) across securities; (iii) is related to volatility; (iv) experiences flight to liquidity events; and (v) co-moves with the market.

Cifuentes et al (2005) show that mark to market accounting may turn out to be a channel for contagion and systemic risk. They analyse mark to market accounting in a model with regulatory solvency requirements and internal risk controls of banks. When a shock in the market reduces the market value of banks' assets, banks may be forced to sell parts of their assets in order to satisfy regulatory solvency requirements and/or internal risk limits. This causes market prices, and hence the market values of banks' assets, to decrease further when markets cannot perfectly absorb asset sales.[10] The authors show that regulatory minimum liquidity requirements can mitigate this mechanism and hence also systemic risk. (See also Allen and Carletti (2008), who show that mark to market accounting may turn out to be a channel for contagion and systemic risk.)

Wagner (2006, 2008) explores the implication of a lack of market liquidity in times of stress. On the one hand, a lack of market liquidity implies that asset sales to meet liquidity demands lower asset prices even further, which can lead to the failure of other institutions. On the other hand, low market liquidity increases the cost of failure for individual firms, the more so, the larger the number of banks that fail. Hence, a bank's returns, as well as the negative externalities arising when it fails, will depend on the entire return distribution of the other banks' portfolios. An optimal regulatory regime has to take this into account and banks which are more correlated with each other should face higher capital and/or liquidity requirements.

At the margin, commercial and universal banks expand and contract their balance sheets by borrowing in the repo market and in unsecured money markets. Such expansion and contraction of balance sheets is primarily constrained by regulation and credit-rating considerations. For example, when the haircut on AAA-rated mortgages is 5%, an intermediary can obtain a leverage of 20:1. When haircuts increase to 20%, the intermediary is forced to unwind as leverage has to drop to 5:1. Adrian and Shin (2010) provide a micro foundation for the determination of total leverage. In a macro-setting, Kiyotaki and Moore (2008) provide a general equilibrium analysis of the value of assets as collateral.

The interlinkages between funding liquidity and market liquidity can become a crisis-propagation channel in the presence of incomplete markets and asymmetric information. This is because in the face of such interlinkages, the absence of a complete set of contingent securities (which implies that it is not possible to hedge against future liquidity outcomes) combined with information asymmetries about the solvency of the banks (which implies that it is not possible to distinguish whether a bank is illiquid or insolvent), may stimulate fears of counterparty credit risk. Allen and Gale (2000), Brusco and Castiglionesi (2007), and Strahan (2008) belong to this literature.

Another important topic concerning the liquidity channel is the relationship between the use of leverage by institutions and liquidity problems. Gromb and Vayanos (2008) model financial market liquidity as provided by financially constrained arbitrageurs. They show that arbitrageurs, who depend on external capital ("smart money") and undertake leveraged transactions, provide liquidity to the market and also cause liquidity dry-ups. Market liquidity increases with the level of arbitrage capital (that is, internal money), as well as external "smart money" that arbitrageurs can access frictionlessly. They show that liquidity dry-ups follow periods of low returns for arbitrageurs' risky investment opportunities and that liquidity

[10] The literature on the potential procyclical effects of Basel II often expresses a similar critique of risk-sensitive capital requirements. See, for example, Daníelsson at al (2001).

is correlated across markets. Their welfare analysis shows that arbitrageurs may fail to take socially optimal positions in their investments, thereby adversely affecting their ability to provide market liquidity. This liquidity channel arises from their failing to internalise the price effects of their investment decisions.

Acharya and Viswanathan (2008) propose a model that explains the deleveraging phenomenon observed in the current crisis in terms of the agency problem confronted by leveraged institutions. They consider a moral hazard setup wherein leveraged institutions have incentives to take on excessive risks and are thus rationed when they attempt to roll over their debt. Institutions can sell assets to alleviate rationing. Liquidated assets are purchased by non-rationed institutions but their borrowing capacity is also limited by the same principal-agent relationship. The market-clearing or liquidation price exhibits cash-in-the-market pricing. When a large number of firms are liquidating assets, the market price will be below the expected discounted cash flow and asset prices will thus depend on the entire distribution of leverage in the economy. The distribution of leverage and its form as rolled-over debt is derived endogenously, with each institution's choice of leverage affecting the difficulty of other institutions in rolling over their debt in the future. The model provides an agency-theoretic linkage between market liquidity and funding liquidity and formalises the deleveraging of financial institutions observed during crises. It also explains the role played by system-wide leverage in generating deep discounts in prices when adverse asset-quality shocks occur following a period of good times.

Adrian and Shin (2008) point out another new feature of the current economic crisis, namely, that securitisation increased the importance of broker-dealers in the credit supply chain. They note that the growth of leveraged financial intermediaries that mark to market synchronises responses and increases feedback effects on the real economy. Financial stress may make it difficult to raise equity, in which case reducing leverage becomes synonymous with asset disposal. Increases in interest rate shocks or declines in asset prices can instigate the deleveraging cycle. Adrian and Shin also argue that because their liabilities are short-term, broker-dealers give a better signal of marginal funding conditions than commercial banks. Their findings also suggest that changes in the balance sheets of security broker-dealers help explain future real activity, especially for housing investment and durable goods consumption that are sensitive to credit supply. They find that the presence of broker-dealers leads to a faster and larger drop in housing investment in response to a Fed funds target increase, but also a quicker recovery. With their results in mind, one of the implications of the disappearance or conversion of all five major independent investment banks in the autumn of 2008 is that it signalled the severity of the approaching real sector storm, but also that their absence from the market could lengthen the time to recovery.

III. Real to financial sector transmission channels

This section turns to the empirical evidence on financial and real sector transmission channels, beginning with how conditions in the real sector affect key variables in the financial sector. As noted in section II the models underlying the linkages that run from the real to the financial sector are for the most part standard macroeconomic theory. Specifically, weaker macroeconomic conditions reduce the revenues and profits of businesses (including banks) and the incomes of households, which results in households' and businesses' net worth increasing more slowly or in some cases decreasing. In addition, weaker business revenues and household incomes push up borrowers' default probabilities, which in turn weaken the position of banks' balance sheets. Both borrowers' and banks' balance sheet positions are important in considering the real and financial transmission channels. The strength of bank balance sheets is clearly important, because (as discussed in subsection II.B) banks' balance sheet health influences their ability to extend credit. Borrower balance sheet strength

is also important, for the following reasons. First, as discussed, borrowers' balance sheets influence delinquency and default rates, which in turn affects the strength of bank balance sheets. In addition, borrower balance sheet strength is a key determinant of the terms at which borrowers obtain credit and so it is also important for the study of financial and real sector transmission channels. This section, however, deals predominantly with how macroeconomic conditions affect borrower defaults and delinquencies, although this is more from the perspective of how these variables in turn go on to affect bank balance sheets (see subsection III.B). Research by Salas and Saurina (2002) suggests that borrowers feel the effect of slowing growth almost immediately, after which banks see an increase in problem loans.

Although the research presented in subsection III.B finds (perhaps unsurprisingly) that macroeconomic conditions affect borrower defaults and delinquencies, it is important to note that for real and financial transmission channels defaults and delinquencies are not the only relevant consideration when thinking about borrowers' financial condition. Borrowers' balance sheets can weaken (perhaps notably) before borrowers start to go delinquent or default on their loans, and this feature of financial conditions – which is critical to the terms that borrowers face – is not picked up in any of the papers reviewed. For the most part this reflects the fact that studying balance sheets developments requires balance sheet data, which are considerably more difficult to obtain (particularly for households and non-publicly traded firms, which are the borrowers typically more reliant on bank funding) to study than data on delinquencies and defaults. In reviewing the subsequent literature it is important to keep this point in mind, although the fact that the literature does find that delinquencies and defaults rise with weak macroeconomic conditions does suggest that borrower balance sheets are also deteriorating in these situations.

This section begins with a review of the literature that addresses this question in the context of the macro stress testing models (subsection III.A), before turning to consider the broader literature on the topic, first considering the effects of macroeconomic conditions on borrower defaults and delinquencies and bank balance sheets (subsection III.B, where, as discussed in the appendix, many of these models can also be used for stress testing purposes) before examining how the term structure of interest rates affects bank performance (subsection III.C). Reflecting the nature of research currently being undertaken in the yield curve literature, this latter topic is dealt with in a somewhat indirect way; specifically, by studying the relationship between the term structure and economic activity. That said we are very careful to draw from this appropriate and considered conclusions for the relationship between the yield curve and bank performance.

A. The evidence from macro stress testing models

A large amount of empirical work related to macro stress testing has examined the links between macroeconomic models and corporate sector credit quality, where credit quality is captured by variables such as probabilities of default or banks' loan loss provisions. Alves (2005) and Asberg-Sommar and Shahnazarian (2007) find cointegrating relationships between macro variables and Moody's KMV expected default frequencies (EDFs) and identify significant relationships between EDFs and short-term interest rates, GDP and inflation in cointegrated closed-economy VAR models. Aspachs et al (2006) use a VAR model which includes banking sector EDFs and macroeconomic data for seven industrialised countries and show that shocks to banks' default probabilities and equity values can impact GDP variables. Jacobson et al (2005) use a VAR approach to study the interactions between Swedish firms' balance sheets and the evolution of the Swedish economy and find that macroeconomic variables are important for explaining the time-varying default frequency in Sweden. Pesaran et al (2006) use a Global VAR (GVAR) model to generate conditional loss

distributions of a credit portfolio of a large number of firms in various regions of the world and related these to macro variables.

Credit risk models measuring credit quality at the individual bank level with static or dynamic panel data estimation are used at several central banks. Van den End et al (2006) present a macro stress testing model for the Dutch banking sector which maps multivariate scenarios to banks' credit and interest rate risks by deterministic and stochastic simulations. The model allows simulation of the initial effects of stress scenarios and distinguishes between PD and LGD. To some extent, cross-border risks are taken into account through a separate modelling of credit risk in domestic and foreign portfolios. Stochastic simulations allow for changing correlations between risk factors in stress situations and provide insight in banks' extreme losses.

Jakubík and Schmieder (2008) investigate both the corporate and the household sector for the Czech Republic and Germany. In their study, they show which macroeconomic variables are the most important for credit risk, compare country-specific differences and investigate the extent of the impact of the occurrence of unfavourable macroeconomic circumstances to the macro and micro (portfolio) level. The outcome of the credit risk modelling is used for macro stress testing purposes and translated into a Basel II-type micro stress test of a hypothetical credit portfolio. The study finds that the impact of the macroeconomic shocks is substantially higher in the Czech Republic than in Germany, both on the macro and micro level. For a stress test of medium severity, at the end of the first-year of the scenario, the increase in aggregate corporate default rates is more than 100% in the Czech Republic (compared with 40% in Germany) and the rise in Basel II internal ratings-based minimum capital requirements on the credit portfolio level is up to 60% in the Czech Republic (compared with roughly 30% in Germany). This confirms a finding made in previous studies that stress events have a more material effect in less developed economies.

Drehmann et al (2006) explore the impact of possible non-linearities on aggregate credit risk in a non-linear threshold VAR (TVAR) framework. By using aggregate data on corporate credit in the United Kingdom they investigate the non-linear transmission of macroeconomic shocks to aggregate corporate default probability. They find that non-linearities matter for the level and shape of impulse response functions of credit risk and that ignoring estimation uncertainty in stress tests can lead to a substantial underestimation of credit risk, particularly when considering large shocks. The results of the analysis confirm that large increases in interest rates are a key driver of credit risk and that large positive shocks to GDP tend to reduce risk significantly.

In their financial sector stress testing framework, Castren et al (2008) model the link between global macro-financial factors and firms' default probabilities (specifically, Moody's KMV EDFs) using a GVAR model. The GVAR model appears to be a useful tool for analysing the impact of a wide range of global macro-financial shock scenarios to euro area corporate sector credit quality. The empirical results show that median EDFs react most to shocks to GDP, exchange rates, oil prices and equity prices. Also, most sector level EDFs react rather similarly to the aggregate EDF, except for the technology-sector EDF, which is more sensitive to shocks than other sectors.

In the last few years, several sophisticated macroeconomic portfolio models, combining macro stress scenarios and credit risk at the portfolio level, have been developed at central banks and the International Monetary Fund (IMF). For example, Padilla and Segoviano (2006) present a macroeconomic stress testing approach to credit risk for Denmark that shows credit risk could materialise quickly if a boom-bust in real estate prices and credit occurs. The model consists of two components. The first part is a macro model in which firms' probabilities of default by industry are modelled – following Segoviano's (2006a) consistent PD methodology – as functions of macroeconomic and market risk factors with

limited number of observations. The second part is the bank portfolio model in which portfolio multivariate densities are recovered – following Segoviano's (2006b) consistent information multivariate density optimising methodology – that embed the variable structure (that depends on probabilities of loan default) of the linear and non-linear dependence between the loans that comprise the portfolio. This portfolio stress testing tool has also been implemented for the German banking system. Here the framework makes further improvements to the macro model; specifically, taking into account the heterogeneity between firms and linking the model to the macroeconometric forecasting and simulation tool NiGEM.[11]

A further refinement of the portfolio stress testing tool is the incorporation of the bank stability measures proposed by Goodhart and Segoviano (2009). They define the banking system as a portfolio of banks and infer the system's multivariate density from which stability measures are estimated. These measures take account of distress dependence among the banks in a system, thereby allowing the measurement of (i) common distress of the banks in a system, (ii) distress between specific banks, and (iii) distress in the system associated with a specific bank. Düllmann and Erdelmeier (2008) stress-test credit portfolios of 28 German banks based on a Merton-type, multi-factor credit risk model. The ad-hoc stress scenario assumes an economic downturn in the automobile industry, where the focus of the paper is on the major drivers of the stress impact on banks' credit portfolios. Although the percentage of loans in the automobile sector is relatively low for all banks in the sample, the expected loss conditional on the stress event increases substantially when accounting for inter-sector correlations. Gray et al (2008) have recently advanced the Merton model methodology to analyse (and manage) the financial risks of national economies. Specifically, their approach integrates the time pattern of the contingent claims analysis (CCA) balance sheet components, risk indicators and sensitivity parameters within a macroeconomic model – in which the sectors of an economy are viewed as interconnected portfolios of assets, liabilities and guarantees. The paper uses this framework to consider the implications of financial system risk for monetary policy.

Modelling feedback effects on the macro economy is complex and still in its early stage of development. A model framework which could overcome this problem is proposed by Jacobson et al (2005) in which they study the interactions between Swedish firms' balance sheets and the macroeconomy using a VAR approach. In their work, they confirm the relevance of macroeconomic variables for explaining time-varying default frequency in Sweden. Based on a similar model framework for financial institutions De Graeve et al (2008) establish an integrated micro-macro approach which considers not only the main sources of systematic risk, but also takes into account second round effects. This approach integrates a micro bank rating model measuring probability of distress directly on the bank level into a macroeconomic VAR-model to account for feedback. The results confirm the existence of a trade-off between monetary and financial stability, ie an unexpected tightening of monetary policy increases the probability of financial distress. Finally, Asberg-Sommar and Shahnazarian (2009) use a vector error correction model to study interdependencies between the aggregate EDF and the macroeconomic development. Asberg-Sommar and Shahnazarian point out that a reduced interest rate is usually expected to increase the inflation while increasing the growth rate in the economy. However, when expected defaults are included in the model, a reduced interest rate gives both lower inflation and higher growth. The reason for this is that a lower interest rate lowers EDF, a measure of the risk premium. Lower risk premium contributes to lower lending interest rates that firms and

[11] NiGEM is the National Institute of Economic and Social Research Global Econometric Model. This model is frequently used as the macroeconomic model component of macro stress-testing models.

consumers meet at the market and lower marginal cost of capital. This stimulates higher growth because corporate investments and households' consumption increases. At the same time, a decreased marginal cost of capital imposes a downward pressure on the product prices of firms in a monopolistic competition market and thereby the inflation.

B. The effects of real economic variables on balance sheets, delinquencies, defaults

Subsection III.B turns to the broader literature on real-to-financial sector transmission channels, where research is discussed that examines how real economic variables including employment, economic activity and asset markets affect household, firm and bank balance sheet positions.

Linkages between the real economy and bank performance (in particular through borrowers' default and credit risk)

In a comprehensive review of empirical studies that examine how the macroeconomy affects bank stability, Quagliariello (2008) concludes that, while it is clear that macroeconomic conditions play an important role in determining conditions in the banking industry, there is no specific list of macroeconomic variables that serves as reliable leading indicators that emerges from the literature. The studies suggest that low GDP growth, unsustainable lending growth and high interest rates are often associated with banking sector crises. Quagliariello also finds that banks exhibit procyclical behaviour with respect to lending and loan loss provisions, and that this behaviour tends to magnify economy-wide problems during recessions. Other evidence of a procyclical effect of banks' credit risk is found by Marcucci and Quagliariello (2009). Using data on Italian bank borrowers' default, they find that banks' riskiness increases during recessionary conditions; the relationship between borrower default and the business cycle is weaker in good times.

Laeven and Majnoni (2003) examine how loan loss provisions adjust to changes in GDP growth, bank earnings and loan growth. Using data from 45 countries, they find evidence that banks increase provisions when earnings increase, but provisions also increase when GDP growth falls. They conclude that banks may increase provisioning when earnings are strong, but they do not increase provisions enough when times are good so that they must further increase provisions during recessions, thereby reinforcing the business cycle. They subdivide their sample by geographic region and find that some regional differences emerge. Their results suggest that insufficient provisioning during good times is more pronounced in Asia and Japan relative to Europe, Latin America and the United States. The negative relationship between provisioning and GDP growth is strongest in the United States, though still significant in Japan and Asia.

A study of Swedish firms between 1990 and 1999 by Jacobson et al (2005) explore how macroeconomic conditions affect firm balance sheets. They find that measures of the output gap, short-term interest rates and the real exchange rate are important for explaining changes in the default risk of firms. Their results suggest that default risk is very highly correlated with credit losses of loans to non-financial firms. These credit losses will directly affect bank balance sheets and capital positions. They also determine that changes in housing prices contain significant predictive power for changes in the real economy. However, when they look for effects of aggregate shocks on firms' balance sheet ratios, they conclude that idiosyncratic risk is far more important than aggregate shocks in explaining balance sheet ratios.

The availability of disaggregated data on corporate defaults allows a more in-depth analysis of the relative influence of macroeconomic (systematic) factors relative to industry/local

(idiosyncratic) factors, an issue that is also discussed in the next subsection. Using data for, respectively, Italian and Spanish corporate defaults, Fiori et al (2009) and Jimenez and Mencia (2008) found that it is possible to distinguish more "cyclical" sectors, that are more dependent from systematic risk, from those more dependent on idiosyncratic risk; however, business interconnections such as supply chain links and trade credit significantly increases inter-sector correlation and, hence, the overall default risk of banks' loan portfolios, an effect that would be totally neglected in a pure macrostructure approach.

Pesaran et al (2006) examine the effects of macroeconomic variables on individual firm default probabilities in 25 countries. They develop a model of credit losses that is contingent on macroeconomic variables and can distinguish between losses stemming from systematic shocks and those due to firm specific shocks. Their model uses GDP, inflation, interest rates, exchange rates, equity prices and real money balances to model the firm's default probability. With this model they are able to evaluate how a macroeconomic shock in one region can affect a credit portfolio that is concentrated in another region. By examining a simulated credit portfolio, they find that shocks have an asymmetric and non-proportional effect on credit risk. A negative shock increases expected losses more than an equivalent positive shock reduces expected losses. They also find that shocks to real equity prices and oil prices have the most significant effect on implied credit losses.

On the consumer side, Gross and Souleles (2002) study the effect of local economic conditions on personal bankruptcy and credit card delinquency in the United States between 1995 and 1997. They find that changes in local unemployment rates and house prices have a significant effect on personal bankruptcies. They also find that bankruptcy probabilities seem to have increased over time, which the authors attribute to falling default costs: legal, social and financial. Unemployment rates and house prices do not affect credit card delinquency probabilities, but the absence of health insurance does affect credit card delinquency. This difference may reflect the ability of consumers to make adjustments to credit card spending in response to an anticipated layoff, but an individual's limited ability to cope with an unexpected health crisis.

Mishkin (1977) remains an important study of how household balance sheets behave during recessions. He studies the causes behind the dramatic shift in household balance sheets in the United States during the 1973 to 1975 recession. He finds that in the run-up to the recession, consumer balance sheets improved, real net worth increased and consumer expenditures were high. A sudden drop in security prices led to deterioration in the household balance sheet and real consumer spending subsequently fell. Mishkin finds that changes in net wealth have significant effects on consumption, and he suggests that increased debt or a drop in asset values increase the likelihood of financial distress that leads to decreased consumer demand for durables and housing. He finds that fluctuations in household balance sheets can account for one-third of the drop in real aggregate demand that occurred during the 1973 to 1975 recession.

Although Mishkin's study does not explore the direct effect of changes in household balance sheets on bank balance sheets, a study by Qi and Yang (2009) provides one such link. They study LGD for residential mortgages with high loan-to-value ratios and find that loss severity increases in distressed housing markets. Mortgage loss severity is significantly and positively related to the loan-to-value ratio at the time of default. Other important factors that can affect LGD are loan size, property type, owner-occupation status and the age of the loan.

After considering various macro-financial linkages, it is interesting to note some potential sources of initiating shocks. Examining high frequency data, Bartolini et al (2008) identify several macroeconomic variables that can move asset prices in the very short run. They find that interest rates (as measured by two- and ten-year Treasury yields) are sensitive to surprises in nonfarm payrolls, the GDP advance release and the Institute for Supply

Management's manufacturing report. Surprises in the consumer confidence index and the core consumer price index also cause significant same-day changes in interest rates, but to a lesser extent. The authors find that a 1% surprise increase in nonfarm payrolls triggers a 78 basis point increase in two-year Treasury yields and approximately a 60 basis point increase in ten-year Treasury yields. Surprising macroeconomic news has much less of an effect on equity prices and foreign exchange rates. Given the importance of interest rate changes for firm and household balance sheets, it is noteworthy that interest rates appear to be particularly sensitive to economic news.

Goodhart et al (2006) explore the effect of changes in GDP growth and asset prices on credit growth directly on the default probabilities of banks in 18 countries. They find evidence that property markets play an important role in bank profitability and vice versa. In particular, they establish that in roughly half of the countries they study changing asset prices (both aggregate and housing prices) have a positive and significant effect on bank credit and changing bank credit has a slightly weaker positive and significant effect on asset prices. They also show that an increase in real GDP has a positive and significant effect on bank credit and asset prices. Their results also suggest that deviations in bank lending and asset prices from their trend relationship with GDP improve the estimation of bank default probabilities.

Linkages between the real economy and bank performance: specific sectors

In addition to linkages between general macroeconomic conditions and the financial sector, several empirical studies focus on linkages between specific economic sectors and banks. This includes studies that look at linkages evident at the regional or local level as well as studies that look at the importance of specific economic sectors for bank performance – notably real estate markets, which tend to be local in nature. There is also a distinction between studies that examine historical relationships and studies that quantify the predictive power of economic variables for future bank performance; most notably in the types of models that bank supervisors use to conduct offsite monitoring of banking conditions, or to statistically forecast supervisors' ratings downgrades.

As Jacobson et al (2005) note, "Most economists would consider it trivially true that macroeconomic conditions influence the state of firms' balance sheets". In practice, as noted above, because banks vary so much in terms of their scale and exposures to particular industries or regions, it is challenging to quantify linkages between economic conditions and the idiosyncratic performance of specific institutions.

Linkages between the real economy and bank performance at the regional/local level

In a diverse economy comprised of distinct sectors or regional economies, economic shocks affecting the creditworthiness of banks need not be a national phenomenon. For the United States for example, the FDIC (1997) documented that the banking sector problems during the 1980s and early 1990s were very regional in nature; occurring mainly in regions experiencing severe economic distress.

From a research perspective, periods where economic conditions vary substantively across regions or industries represent opportunities to quantify linkages between economic conditions and bank performance at the local level. However, even during the US period of regional economic unevenness, researchers have tended to find that in explaining bank performance bank-specific characteristics explain larger shares of observed differences in the performance of specific institutions and regional economic variables contribute relatively little explanatory power in standard reduced-form models. For example, Jordon and Rosengren (2002) find that economic variables contribute relatively little explanatory power

when added to models using a bank's own financial ratios. Similarly, local economic data have not generally been found to markedly improve models intended to help bank supervisors identify particular institutions that will experience future problems. For example, Nuxoll et al (2003) find that even during the 1984 to 1995 period of regional economic unevenness, state economic variables contributed relatively little to out-of-sample forecasts of bank failures, nonperforming asset ratios and CAMEL downgrades related to excessive bank growth.

That said findings of low explanatory power should not lead policy makers to conclude that local economic conditions do not have important effects on the financial health of banks in the market where they operate. Rather, the evidence suggests that it is very difficult to determine the economic conditions that are relevant to specific institutions, which moreover seem to vary dramatically by institution characteristics, such as asset size, business strategies and geographic coverage. For example, a bank's financial size tends to be closely correlated with its geographic coverage. Consequently, the importance of particular regional measures of conditions and bank performance are likely to co-vary with bank size. Bank trading activities also vary with bank size, implying that the sensitivity of bank performance to interest rates is also likely to vary by bank size.

To more closely align a bank's market area with a particular measure of local economic data (such as county or state-level data) some studies have restricted their analysis of local economic linkages to smaller US "community banks", which are often defined as institutions having assets of $1 billion of less. For example, Meyer and Yeager (2001) examine the contribution of county-level data in explaining variation in the performance among rural banks between 2000 and 2007 but find that the county economic data are only weakly correlated with small rural bank performance. Other studies of this type tend to draw similar conclusions.

Furlong and Krainer (2007) note that a bank's exposure to economic conditions depends on its portfolio activity; that is, its overall level of lending and its specific loan exposures to particular industries or regions. They argue that specialisation in terms of business strategies can affect the sensitivity of even relatively small-localised banks to regional economic conditions. While their study does not examine linkages between bank profitability and specific local or national economic variables *per se*, Furlong and Krainer find notable differences in the correlations of bank-level profitability ratios to state-level averages, which they interpret as evidence of the idiosyncratic nature of the linkage between economic condition in a state and the performance of a particular bank.

Given the heterogeneity of banks even within a size group, it is not surprising that linkages between regional economic conditions and bank performance tend to be more evident at an aggregated level than for specific institutions. Several studies have examined state-level measure of bank performance prior to the relaxation of US interstate banking restrictions in the mid 1990s and found that disparities in regional economic conditions helped to explain the difference in state banking conditions during the 1980s and early 1990s (see Samolyk (1994), and Neely and Wheelock (1997)). More recently, Daly et al (2008) examine state-level nonperforming loan ratios, using geographic bank branch and deposit data to account for the contribution of multi-state banking organisations to state banking conditions. While they do not find that employment growth or changes in real estate prices are particularly useful for predicting changes in bank performance, they find that coincident indicators developed to track a state's gross output "have a statistically significant and economically important influence on state-level, aggregate bank performance".

Linkages between the real economy and bank performance via real estate conditions

The current global economic cycle underscores the importance of real estate conditions for banking sector conditions. As discussed often in real estate research (for example see Quigley (2002)), there are inherently local dimensions to real estate conditions that can be important for regional economic and financial cycles. Imperfect information, financing constraints and bankruptcy costs are particularly important to real estate markets for a number of reasons: First, real estate transactions tend to be highly leveraged; second, the production of new supply can substantially lag behind demand; and third, real estate related industries are important components of real economic activity in all local economies.

Real estate conditions have long been viewed as important for banking conditions (see Herring and Wachter (1999) for an example of this view). The regional US banking sector problems of the 1980s and 1990s have been related to expansions in asset-based lending as real estate values soared (such as farmland, commercial real estate in the oil-belt and later in New England and California) and subsequently fell. Similarly, Japan's real estate cycle and banking sector difficulties of the 1990s represents another stark example of real estate related banking sector problems.

Most existing studies of linkages between real estate conditions and bank performance have tended to examine linkage at the national level. For example, Gerlach et al (2003) examine linkages between real estate prices and nonperforming loan ratios of Hong Kong banks between 1995 and 2002, and find the expected negative relationship. However, somewhat surprisingly, they find that the size of a bank's real estate loan exposure appears to reduce the sensitivity to fluctuations in macroeconomic conditions. They interpret this finding as evidence that property prices may represent more of a measure of general economic conditions rather than an indicator that can be linked to the asset quality of specific institutions. It also may have reflected factors that reduce the risks associated with property lending for Hong Kong banks, such as limits on loan-to-value ratios for residential mortgage loans.

At the more disaggregate level, there are numerous studies that use loan level data on residential mortgage performance to examine linkages between housing conditions (interest rates and local housing price appreciation) and mortgage default or prepayment behaviour (for example, as predicted by options-pricing models of default). A widely cited paper, Deng et al (2000), uses proprietary data on fixed rate, single family, owner occupied home mortgages issued between 1976 and 1983 to jointly analyse prepayment and default decisions through early 1992. It estimates option values derived from loan-level data and metro area repeat sales price indices estimated for 30 metropolitan statistical areas (MSAs), which are included in competing hazard models that estimate the likelihood of mortgage default and prepayment over the life of a loan. The empirical results indicate that changes in the values of the options to prepay or default implied by local housing price movements are an important determinant of loan performance.

More recently, the availability of loan performance data on Alt-A and subprime (also called nonprime) residential mortgages sold into private loan securitisations prior to the collapse of that market has been used in a number of studies to examine the importance of local house price movements, borrower characteristics (mainly credit scores) and loan characteristics in explaining subprime borrower defaults in recent years. For example, Mayer et al (2008) examine factors that could explain increases in nonprime loan delinquencies and defaults through mid 2008. They conclude that while the underwriting of nonprime loans deteriorated during the mid 2000s, declining house prices represent a key factor driving performance problems for nonprime mortgages.

However, in spite of significant variation in local residential real estate condition in the United States (a fact documented by McCarthy and Peach (2004), and Himmelberg et al (2005)),

there has been relatively little research that has focused explicitly on studying direct linkages between local real estate conditions and the performance of specific institutions. One reason for this gap in the literature is that Call report data on the real estate loans held by US banks do not contain information about the geographic distribution of these loans and very limited information about loan characteristics (for example, lien status). In addition, prior to the current crisis, residential mortgage lending was not considered a particularly risky lending activity (as evidenced by it lower Basel I risk weight). As discussed by Deng et al (2000), although it was evident that home mortgage markets would weaken as local conditions deteriorated, default rates on home mortgage loans were not particularly high even through the 1980s and early 1990. Moreover, in an environment where lenders can securitise loans, the relationship between local real estate conditions and bank performance will be affected by the extent to which banks diversity their geographic concentration of their mortgage-related investments by purchasing MBS and RMBS, which since Fannie Mae and Freddie Mac would guarantee the mortgage would imply no credit risk to the bank.

There appears to be even less existing evidence on the effects of commercial real estate (CRE) conditions on the performance of CRE loans or on the banks that hold these loans. The lack of studies in this case appears to be driven by a lack of consistent data series on local commercial business real estate conditions.

Because of the importance of commercial real estate conditions for bank performance, researchers have studied bank performance during periods of real estate distress to identify bank characteristics associated with vulnerability to these types of conditions. During the late 1990s, the FDIC developed a real estate stress test model which related a bank's portfolio characteristics to its subsequent performance during the New England real estate crisis of the early 1990s. As described by Collier et al (2003), the model scored banks in terms of the balance sheet ratios that were linked with bank distress during that episode to derive CAMELS-type ratings. The estimated ratings were useful in identifying institutions that later had problems related to real estate stress in California during the late 1980s and early 1990s. The model also was also successful in identifying banks experiencing problems during more moderate real estate downturns in other parts of the country. Not surprisingly, construction lending was most critical risk factor in bank performance problems related to real estate stress.

C. The yield curve and bank performance

A well-known macroeconomic stylised fact is the yield curve's ability to predict future macroeconomic activity. Inverted yield curves predict recessions, steeply upward-sloping yield curves predict fast periods of growth, and flat yield curves predict periods of slow growth (see Estrella and Hardouvelis (1991), Harvey (1988, 1991) and Haubrich and Dombrosky (1996) for documentation of these facts).

There are two main reasons put forward for this strong predictive relationship, of which only one relates to the real-to-financial transmission channels. The first explanation, which is purely real in nature, is that the slope of the yield curve reflects expectations of the future path of monetary policy, which in turn reflects expectations of future inflation and economic activity.[12] The second explanation, which relates to real-to-financial transmission channels, is

[12] Specifically, an inverted yield curve indicates that markets expect interest rates to move down in the future – implying that they are likely also to be expecting lower future growth – while an upward sloping yield curve indicates that markets expect interest rates to rise in the future – implying that they are likely also to be expecting higher future growth. Consequently, the forecasting ability of the yield curve stems from the fact that it embodies market expectations about future growth prospects of the economy.

that the yield curve has a large influence on bank profits and thereby bank capital positions, which in turn (via the channels outlined in subsection II.B) influences future lending and economic activity. Although the first explanation is perhaps the more familiar one, the importance of the second explanation should not be underestimated. Arguably, one of the principal causes of the US savings and loan (S&L) crisis in the late 1980s and early 1990s was the sizable increase in short-term interest rates that occurred when the Federal Reserve switched from an interest rate target to a monetary base target in conducting monetary policy in October 1979. As a result, the Treasury yield curve became inverted, which caused savings and loans' short-term funding costs to exceed the returns on their mortgage portfolios, a large proportion of which were fixed-rate mortgages. The empirical literature on the topic that is reviewed below is non-structural in nature and so does not make any attempt to distinguish between these explanations. The reader must therefore be cautious to bear in mind both possible interpretations. Note also that the profitability explanation for the relationship between the yield curve and economic activity also relies on (i) interest rate risk not being fully hedged by banks and (ii) bank capital positions having an important effect on lending and activity. This is a topic that is discussed in subsection III.B above.

In recent years, the macro-dynamic approach to modelling the interaction between the term structure of interest rates and the real economy has grown dramatically in popularity, and indeed Diebold et al (2005) observe that macro-finance term structure modelling is in its infancy with many unresolved issues to explore involving the specification and implementation of these models (see Kim (2008) for a discussion of the many challenges). Ang and Piazzesi (2003) and Ang et al (2006) use a non-structural VAR approach to examine the joint behaviours of a no-arbitrage affine yield curve model and macroeconomic variables for the United States. The macroeconomic factors are measures of inflation and real activity that are generated using principal components and the yields are measured using zero coupon bond yields. Ang and Piazzesi (2003) find that output shocks have a significant impact on intermediate yields and curvature of the yield curve, while inflation surprises have large effects on the level of the entire yield curve. They also find that better interest rate forecasts are achieved when macro factors are added to the latent factors in the affine term structure model (see Moench (2008) for a recent example of a non-structural FAVAR approach).

Unlike Ang and Piazzesi (2003), who only allow for unidirectional dynamics from the macro factors to yields, Ang et al (2006) allow for bidirectional dynamics and find that interactions in both directions are important for yields and for the macroeconomy. In other non-structural work, Diebold et al (2006) provide a macroeconomic interpretation of the Nelson-Siegel yield curve representation by combining it with VAR dynamics for the US macroeconomy. They find the level factor is highly correlated with inflation and the slope factor is highly correlated with real activity, but the curvature factor is unrelated to the macro factors. In addition, they also find evidence that interactions in both directions are important.

In contrast to the reduced-form or non-structural work discussed above, Bekaert et al (2005), Hordahl et al (2006), and Rudebusch and Wu (2008) use New Keynesian structural VAR models to examine the relation between the term structure and macroeconomic dynamics. These papers use macro variables that obey a set of structural macro relations and append a term structure to a New Keynesian macro model. For example, Rudebusch and Wu (2008) obtain a good fit to US data with a model that combines an affine no-arbitrage dynamic term structure model and a small standard macro model, which consists of a monetary policy reaction function, an output Euler equation and an inflation equation. In this macro-finance model, the level factor reflects the market's views about the underlying or medium-term inflation target of the central bank, and the slope factor captures the cyclical response of the central bank. Shocks to the level factor have a feedback effect on the real economy through an ex ante real interest rate. Clearly, these models consider specifically the anticipated monetary policy explanation for the interaction between the yield curve and macroeconomic

conditions. An important challenge, therefore, for the alternative explanation based on bank profitability and capital is to develop a structural model that can deliver such a relationship as well.

Previous work, for the most part, has ignored the potential for non-linearity in the relation between the term spread and the real sector. Galvao (2006) uses a structural break TVAR (SBTVAR) to estimate and identify time-varying, non-linearity in a VAR that is used to predict the 2001 US recession. Using quarterly data on the spread between 10-year Treasury bonds and three-month Treasury bills and the growth rate in real output, Galvao finds evidence that the spread as a leading indicator anticipates correctly the timing of the recession.

IV. Financial-to-real sector transmission channels

This section reviews the empirical support for the financial to real sector transmission channels described in section II. In addition, subsection IV.C reviews the implications of the financial-to-real channels discussed for international transmission channels.

A. The borrower balance sheet channel

A sizable literature has documented the good forecasting properties of default-risk indicators, such as corporate credit spreads, on the future state of economic activity, which – because corporate credit spreads likely reflect the quality and net-worth position of corporate balance sheets and thereby disruptions in credit supply – does suggest some support for the presence of the firm balance sheet channel. Notably, Stock and Watson (2003) provide a detailed review of this literature.[13] In addition, Mody and Taylor (2004), in documenting the breakdown in the term spread as a predictor of real activity in the United States during the 1990s, provide long-horizon regression evidence that the high-yield spread predicts activity well. However, although the forecasting success of these analyses is notable, there is substantial variation in the forecasting performance of spreads across differently measured spreads (such as commercial paper to Treasury bill spreads and corporate bond to Treasury bond spreads for corporate bonds of different grades and maturities) and over time many successful forecasting relationships prove to be unstable. Of course, this may reflect financial market evolution, which results in changes in the information content of different financial market variables or it may also reflects this literature's tendency to rely on a single credit-spread index rather than on a range of measures.

One issue with reduced-form analyses of credit spreads on economic activity is that they do not distinguish between the multiple possible causes for observed empirical relationships. Importantly, in addition to the interpretation of corporate credit spreads based on credit supply conditions, it is also possible that current corporate credit spreads reflect future expected default probabilities, which depend on the future economic conditions and could therefore be the reason for the real activity forecasting ability of corporate credit spreads. Gilchrist et al (2009) address this issue using a structural (recursive) FAVAR model to re-

[13] Stock and Watson (2003) provide a comprehensive review of the literature on the role of asset prices in forecasting macroeconomic variables such as output and inflation. Because asset prices are forward-looking, they represent a class of potentially useful predictors, which includes interest rates, differences between interest rates (spreads), returns, and other measures related to the value of financial or tangible assets such as bonds, stocks, housing, gold, etc. In addition, asset prices and returns typically are observed in real time with minimal measurement error, which aids in producing more reliable forecasts.

examine the effects on real activity of disturbances in credit spreads measured on a broad array of individual firm credit spreads constructed from the secondary bond prices on outstanding senior unsecured debt issued by a large panel of US nonfinancial firms. Importantly, they are also able to include in the FAVAR equity prices for the nonfinancial firms that they consider, which – because equity prices (like credit spreads) are affected by future economic conditions but (unlike credit spreads) are not affected by credit supply disruptions – allows the authors to isolate the effect of credit supply shocks on economic activity. According to impulse response functions generated by the FAVAR, unexpected increases in bond spreads cause large and persistent contractions in economic activity. Shocks emanating from the corporate bond market are found to account for more than 20% of the forecast error variance in economic activity at the two- to four-year horizon. Overall, their results suggest that credit market shocks have contributed significantly to US economic fluctuations over the period 1990 to 2007.

It is worth noting that although most reduced-form analyses (at least for the United States) do tend to support the existence of the borrower balance sheet channel, some research does not find support for it. One recent example is Burgstaller (2006), who uses numerous proxies of external finance premiums and banking sector mark-ups to study whether they predict real activity in Austria using multivariate VAR models. The predictor variables studied include: net interest margin (banks); net interest spread (non-banks); Lerner index (NII, for banks and non-banks); corporate bond spread; bank finance premium; commercial credit spread; consumer spread; housing credit premium; term spread; real stock returns; economic sentiment; and interest income premium (non-banks). This study finds no evidence for financial accelerator mechanisms and countercyclical mark-ups in the banking sector representing significant channels for the propagation of aggregate shocks in Austria.

Although the effect of credit-market shocks on the macroeconomy is one aspect of the borrower balance sheet channel, another important aspect is the extent to which it propagates shocks to the real economy. One approach that the literature has used for considering this issue is to look at differences in how large and small firms respond to monetary policy shocks. The focus on different sized firms arises because information asymmetries differ notably across large and small firms and it is information asymmetries that ultimately give rise to the firm balance sheet channel. The *Quarterly Financial Report* (QFR) of US manufacturing firms was the key source for these studies since it contains information on all sized firms and not just those that are publicly traded.[14] This literature finds strong evidence for differential effects of monetary policy shocks on the activities of large and small firms. Gertler and Gilchrist (1993, 1994), for example, found that relative to large firms, small-firm sales accounted for a disproportionately larger decline following a monetary policy shock and also played a very prominent role in the economy's shedding of inventory stocks. While these results seemed to support the presence of a borrower balance sheet channel, they were subject to the criticism that financial information may not be the sole difference between firms of different sizes. Some of these critiques were addressed by Bernanke et al (1996) who attempted to account also for the fact that firm size might also reflect industry membership or bank dependence and found that earlier results in support of the firm balance sheet channel remained. For the most part, this topic was actively researched in the mid-1990s but has received less academic attention in recent years.

[14] As Gertler and Gilchrist explain the QFR reports quarterly time series on a set of real and financial variables for the manufacturing sector. Each aggregate time series is available in disaggregated form, by firm size class (with the measure of size gross nominal assets). There are eight size classes, ranging from under $5 million in gross assets to over $1 billion. The data are available from 1958Q4 to the present.

Gertler and Gilchrist (1994) consider nonlinearities in the effects of monetary policy (albeit in slow versus fast growth regimes), which is a prediction of financial accelerator models (see Bernanke and Gertler (1989), Azariadis and Smith (1998) and Blinder (1987)). More recently, nonlinear dynamics such as regime switching and asymmetric responses to shocks have been studied in a range of contexts, including the balance sheet channel.

Balke (2000) examines whether credit plays a role as a nonlinear propagator of shocks, using a structural (recursive) TVAR in which a regime change occurs if credit conditions cross a critical threshold. While linear VARs fail to capture nonlinear dynamics between the variables in the system, a TVAR is a relatively simple way to capture nonlinearity such as regime shifting and the asymmetry implied by theoretical models of credit and macroeconomic activity. In addition, the TVAR approach allows credit regimes to switch as a result of shocks to other variables besides credit, so that credit regimes are endogenous. The TVAR estimated in Balke (2000), which uses US quarterly data for GDP growth, GDP deflator inflation, the federal funds rate and three different measures of credit market conditions over the period 1960 to 1997, finds that credit shocks have a larger effect on output in the tight credit regime than is normally the case.

Using similar methods to Balke (2000), Atanasova (2003) uses a reduced-form TVAR to investigate the effects of monetary policy shocks – ie an aggregate demand shock – on UK economic activity in the credit constrained and unconstrained regimes. For the euro area, Calza and Sousa (2006) examine whether output and inflation respond asymmetrically to credit shocks using a structural (recursive) TVAR. They find evidence of threshold effects related to credit conditions in the economy. That is, the VAR model coefficients switch when credit conditions weaken beyond a certain point, which results in impulse response function no longer exhibiting symmetry over the lending cycle.[15] However, the results suggest that nonlinearities in the euro area arising from credit market imperfections may be less pronounced than in the United States, probably reflecting differences in the institutional features of the banking sectors between the United States and euro area.

Interestingly, the nonlinear results obtained by Balke and others using the TVAR methodology is also obtained by Levin et al (2004) using quite a different approach. Specifically, these authors employ a data set that includes balance sheet variables, measures of expected default and credit spreads on publicly-traded debt for about 900 US nonfinancial firms over the period 1997Q1 to 2003Q3 to estimate only the debt-contracting framework underlying the financial accelerator model of Bernanke et al (1999). In doing this, the authors find that a simple linear model cannot explain the magnitude of the increase in credit spreads that results when firm balance sheet positions deteriorate and default probabilities rise and that only an associated rise in bankruptcy costs can reconcile these changes. Worth noting also with these results is the fact that the firms considered are all large, suggesting that the borrower balance sheet channel still operates for large firms, even if its effects are stronger for small firms.

B. The bank balance sheet channel and the procyclicality of risk-based capital requirements

As noted in section II, the bank lending channel can be broken down into two separate components: the traditional bank lending channel and the bank capital channel. Associated

[15] Specifically, with asymmetric responses the effects of a loosening of monetary policy is no longer the exact opposite of a same-sized tightening. In addition, scaling up or down the size of a monetary policy shock no longer implies an equivalent (linear) transformation to the original responses.

with the bank capital channel in turn is the question of whether or the extent to which it is amplified by Basel II capital requirements. The literature on these aspects of the bank balance sheet channel is considered in this section.

The bank balance sheet channel

The early empirical literature on the traditional bank lending channel was characterised by a lively debate – which ultimately did not reach a consensus – between Kashyap et al (1993, 1996) who reported support for the channel and Oliner and Rudebusch (1995) who rejected it. The persistent problem in any empirical work considering the bank lending channel is that of distinguishing shifts in loan demand (which reflect aggregate demand considerations) from shifts in loan supply (which reflect the lending channel). Kashyap et al addressed the identification problem, by relying on the argument that shifts in loan demand that stem from aggregate demand shocks should affect all forms of finance similarly, while shifts in loan supply, which stem from bank balance sheet developments, should affect only bank lending. Consequently, Kashyap et al examine the bank lending channel by documenting differential movements following monetary policy shocks in aggregate bank loans and aggregate commercial paper volumes as measured by the US flow of funds accounts. Here, they find a larger decline in bank lending, thereby leading them to conclude that the lending channel was present. Oliner and Rudebusch, however, argued for the importance in accounting for firm size in such analysis given the extreme divergences in commercial paper usage across firms of different sizes and reported that when a Kashyap et al-type analysis was conducted separately for large firms and for small firms (using the QFR described above), the observed changes in bank and non-bank lending volumes were essentially the same, thereby suggesting the absence of any special bank lending effect. Oliner and Rudebusch argued that what accounted for Kashyap et al's finding was a general shift of credit towards larger firms, which because larger firms finance themselves with a greater proportion of commercial paper, resulted in their finding that commercial paper volumes declined less relative to bank lending. This debate concluded with a general agreement that the use of aggregate data to address the existence of the bank lending channel was somewhat problematic.

While Kashyap et al and Oliner and Rudebusch focussed on the differential reliance of firms of different sizes on bank credit, subsequent research has focussed more on differences between banks in their balance sheet structure (and their ability to insulate their lending following shocks) and what these differences imply for the strength of the bank lending channel. Kashyap and Stein (1995) noted that since large banks are likely to be able to raise nondeposit funding more easily than small banks and thereby better insulate their supply of lending, the bank lending channel should be reflected more strongly in the behaviour of small banks.[16] Their empirical analysis based on US Call report data found broadly similar responses for deposits at different sized banks but more sizable responses of lending and securities for small banks following a monetary policy shock, thus providing support for the presence of a bank lending channel albeit dependent on bank size.

Another way in which banks can insulate their lending supply following shocks to their balance sheet is by drawing down their stock of liquid securities. Consequently, the liquidity composition of bank balance sheets could also influence the strength of the bank lending channel. Kashyap and Stein (2000) examine this question using US Call report data and find that in line with the predictions of the bank lending channel monetary policy shocks have

[16] Indeed, a critique of the bank lending channel advanced by Romer and Romer (1990) was that banks could insulate their supply of lending by altering both their nondeposit funding and security holdings.

larger effects on the lending of banks with less liquid asset compositions. In addition, bank asset size continues to have an important influence on lending responses.

Bank capitalisation is another balance sheet characteristic that the literature has emphasised as influencing the strength of the bank lending channel, where as noted in section II this influence can stem from market forces as well as regulatory reasons. Kishan and Opiela (2000) study bank capitalisation and monetary policy by looking at lending by banks segregated into different asset-size and capital leverage ratio groups. Their analysis finds that small undercapitalised banks have the largest response of loans to monetary policy shocks but the smallest response of large-time deposits, indicating that small, poorly capitalised banks are unable to raise alternative funds to sustain lending levels when monetary policy contracts. Consistent with this result, van den Heuvel (2002) also finds that bank leverage at the state level amplifies the effect of monetary policy on state-level output.

The general result of this literature – specifically, that it is through small banks that the bank lending channel is transmitted – raises the question of whether, since small banks account for a modest fraction of overall bank lending, the bank-lending channel is in practice relevant for economic activity. On this question, there are two distinct views on which the literature has not appeared to have reached any consensus. In particular, while Hancock and Wilcox (1998) have noted that a dollar decline in small bank loans has a larger impact on economic activity than a dollar decline in large bank loans – a phenomenon that they call "high-powered loans", Ashcraft (2006) has more recently argued that economic activity has a fairly low elasticity with respect to lending such that the macroeconomic implications of the bank lending channel are small and of limited concern.

Analyses similar to that of Kashyap and Stein (1995, 2000) and Kishan and Opiela (2000) have been undertaken for Europe by a number of authors, including de Bondt (1998, 1999), Favero et al (1999) and Altunbas et al (2002), with the overall finding that support for the bank lending channel is less definitive in Europe than for the United States. For example, de Bondt's (1998) study based on individual bank balance sheet data over the period 1990 to 1995 finds that support on a country level for the existence of the bank lending channel can vary depending on the monetary policy proxy used.[17] Empirical support can also depend on the approach, as evident from the fact that, in de Bondt's (1999) study that uses aggregate data, the bank lending channel is found to be present, albeit in a different set of countries from those documented in his previous paper.[18] In addition, empirical support for the bank lending channel can vary by time period, as is the case with Favero et al's (1999) study that focuses on individual European bank's response to the monetary tightening in 1992 and ultimately finds no support for the channel. In between these extremes is the panel data study on banks in the EMU by Altunbas et al (2002), which finds that undercapitalised banks of any size tend to respond relatively more to changes in monetary policy.

The 1990–1992 capital crunch literature represents another way to assess the bank capital channel. This literature, although it does not look *per se* at the effect of monetary policy on bank loan growth for a given degree of capitalisation, deals with how banks adjust their balance sheets in response to exogenous changes to their capitalisation (such as

[17] Using changes in money market rates as the proxy for monetary policy, de Bondt found evidence of a bank lending channel in Germany, Belgium and the Netherlands, while in the rest of the countries he studied, specifically, France, Italy and the United Kingdom, he found no significant effect. That said, when a monetary conditions index was used instead to measure monetary policy stance, evidence for a lending channel also appeared present in Italy and France.

[18] Specifically, the bank lending channel is found to be present in Italy, German and France, but not in the United Kingdom, Belgium and the Netherlands.

unforeseen writedowns or the imposition of tighter regulatory standards) and sheds light on how bank capital affects – or more precisely acts as a constraint on – bank lending. Studies on the 1990–1992 capital crunch focus on whether the introduction of the Basel I capital regime caused a contraction in lending supply. In the United States, Berger and Udell (1994) failed to find evidence that Basel I contributed to a reduction in loan supply, whereas Hancock and Wilcox (1994) and Peek and Rosengren (1995) find that the new risk-weighted capital standards may have resulted in a substitution away from loans towards lower risk-weighted assets such as government securities. Brinkmann and Horvitz (1995) also find evidence that capital standards may have affected loan growth during the 1990–91 recession in the United States; specifically, they find that banks with relatively weak capital positions experienced weak loan growth relative to their better capitalised peers. In addition, when raising additional capital, these weaker institutions again experienced relatively weak loan growth, suggesting that less of the new capital supported new lending compared to the impact of new capital on loan growth at institutions with stronger capital positions. For Japan, Brana and Lahet (2009), Honda (2002) and Woo (2003) find evidence for a regulation-induced credit crunch in 1997. Outside of the United States and Japan, Wagster (1999) examines a cross-section of developed countries and found little evidence of a regulation-induced credit crunch except in Canada and the United Kingdom. However, as acknowledged in one review of this literature (Jackson et al (1999)), the studies all suffer from the limitation that they are unable to distinguish a reduction in lending due to regulatory capital constraints from the impact of market discipline on banks which fall below the market's perception of a sound level of capital.

Recent studies have attempted to distinguish between lending reductions due to regulatory capital constraints and reductions stemming from market forces, by using bank-specific capital requirements set by bank supervisors as a measure of regulatory capital constraints. Such a regime has been operated in the United Kingdom since the early 1990s and has provided the opportunity for researchers to examine the extent to which bank capital requirements are binding on banks. Ediz et al (1998) analysed UK bank data from the period 1989 to 1995 and found that banks whose risk-weighted capital ratio fell within a "regulatory pressure zone" of one standard deviation above the trigger (capturing the effect of firms with volatile capital ratios holding larger buffers above the regulatory minimum) tended to raise their capital ratios, consistent with the hypothesis that banks attempt to maintain a buffer of capital over regulatory minima. Further evidence in support of this hypothesis is provided by Alfon et al (2004), who combine a qualitative questionnaire of UK banks with an econometric analysis of supervisory data from 1998 to 2002 and conclude that the need to achieve a buffer over regulatory minima is a major motivation for banks when choosing their capital structure, suggesting that changes in capital requirements over time would indeed be binding for banks.

Bank lending rates – or more precisely the spread of bank lending rates over the cost of funds – are another dimension along which it is possible to consider the operation of the bank lending channel. The academic literature that analyses the role of banks in the broader economy has recently begun to analysing lending rates, although most research to date takes a more structural (that is, market-form), rather than business-cycle perspective. For example, Heffernan (2006) documents pricing based on a model of a monopolistic competition market in which lending rates in such a market are determined by a mark up on banks' marginal cost. Gambacorta (2004) analyses bank pricing in this class of models and considers the microeconomic and macroeconomic factors that are most important for this pricing behaviour. He finds that there are differences in the short term – that depend critically on funding structure – on how banks choose to pass on costs to lending rates, although in the long term the differences are almost negligible. Cottarelli et al (1995) discuss the relation between the financial structure and the determination of bank lending rates in Italy. More specifically, the paper provides an econometric measure of the degree of lending rate stickiness in Italy and compares it with the measures obtained for a sample of 30 industrial

and developing countries. It notes that the high degree of stickiness of bank lending rates observed in Italy in the past was related to constraints on competition within the banking and financial markets and it argues that this liberalisation should lead to a reduction of lending rate stickiness and to a faster transmission of monetary policy. Finally, Maudos Villarroya and Fernandez de Guevara (2004) show that the interest margin in the banking sector is dependent of the conditions of competition, interest rate risk, credit risk, the average cost and risk taking behaviour of the banks. Reduced competition is shown to increase the banks' interest margins. However, this effect on the lending rate is countered by lower average costs and credit risks. They also point out that the average costs are one of the main factors behind banks' pricing behaviour. Notably, they consider how factors affected by macroeconomic conditions – such as interest rate risk and credit risk – may affect the interest rate margin, suggesting evidence for some form of accelerator via bank lending rates.

Developments and innovations in financial markets in recent years are likely to have altered the bank lending channel. The developments that the literature emphasises are the intensification of securitisation, the increased use of market funding and the emergence of a so-called "risk taking channel". The working group views these developments to the bank channel rather than as additional channels themselves. However, because this literature is relatively new it is quite possible that going forward the consensus view may be that they represent additional transmission channels.

Securitisation provides an additional avenue along which banks can alter their balance sheets so as to moderate changes in lending volumes brought about by monetary policy. For example, the bundling of loans into tradable securities and their sale on secondary markets represents a source of liquidity for banks, in addition to increased nondeposit funding and the sale securities, which the previous literature emphasised. In addition, the removal of loans from bank balance sheets via the securitisation process can represent regulatory capital relief, which can then prevent or moderate a decline in lending. To date, the literature suggests that securitisation reduces the strength of the bank lending channel. Specifically, Loutskina and Stahan (2006) obtain this outcome for the United States using the securitisation of jumbo mortgages, while Altunbas et al (2009) using a dataset of European banks find that securitisation insulates banks' loan supply from the effects of monetary policy. Note, however, that these studies were both undertaken prior the current crisis, so their conclusions may not be relevant going forward.

Another form of financial innovation that could impact the bank lending channel is related to the increased use of market funding, such as certificates of deposit or covered bonds, rather than traditional retail deposits. Although some evidence suggests that these alternatives sources of funding were used primarily by large banks, which benefited from inter-company funding (Ashcraft (2006)), this development would nonetheless tend to weaken the traditional bank lending channel, which relies on bank deposits. That said the price at which market funding can be obtained by banks (that is, the external finance premium) is sensitive to the balance sheet position of banks. Thus to the extent that monetary policy affects economic conditions, which in turn feedback on bank profitability and thereby balance sheets, the lending channel could still remain operative albeit of a lesser strength.

Finally, in another strand of the literature, Borio and Zhu (2007) have emphasised that a monetary policy that is too expansive does not only influence credit supply but also banks' risk tolerance. At this stage, there is limited empirical evidence of a so-called "risk-taking channel" but the results of Jimenez et al (2008) for Spain and Ioannodou et al (2008) for Bolivia suggest that an endogenous response of risk taking to monetary policy stance likely modified (and certainly intensified) the bank lending channel in the recent years. Jimenez and Saurina (2006) also document a relationship between rapid credit growth and loan

losses, where rapid credit growth is tied to episodes of too expansive monetary policy which appears to result in more lenient lending terms.

The procyclicality of risk-based capital requirements

The mechanism described in subsection II.B, via which risk-based capital requirements amplify business cycles, requires two conditions to be met. First, capital requirements would need to increase in economic downturns and decline in upturns and second, credit supply would need to be inversely related to capital requirements. The following subsections survey the literature on these two conditions.

Evidence on the cyclicality of regulatory capital

There is general agreement in the academic literature that capital requirements under the new Basel II capital framework will be more cyclical than under Basel I.[19] For example, based on US data, Allen and Saunders (2003) document that increases in interest rates and decreases in asset prices both work to raise the corporate sector PDs and LGDs. More recently, Qi and Yang (2009) study LGDs for US residential mortgages with high loan-to-value ratios and find that loss severity increases in distressed housing markets and is significantly and positively related to the loan-to-value ratio at the time of default. For Sweden, Jacobson et al (2008) find that fluctuations in output also affect corporate defaults. As a result, the links between economic activity and credit risk have raised concerns about the cyclicality of risk-sensitive regulatory capital. Many studies have assessed quantitatively, that is by simulations, the likely magnitude of cyclicality of capital requirements under Basel II. Depending on the quantitative methodology used in estimating PDs (ie point-in-time or through-the-cycle), the sample period and portfolio composition, these simulation exercises show that the capital required under Basel II can be twice as high as under Basel I during a recession. Catarineu-Rabel et al (2003) estimate that Basel II would have increased banks' capital charges by about 15% in the United States during the credit crunch of the early 1990s, while Kashyap and Stein (2004), whose analysis uses a somewhat longer sample period (1998 to 2002), produce estimates of 30% to 45% of extra capital charges on average. Importantly, these authors draw attention to the potential heterogeneity of procyclicality results across banks. For example, Basel II is more likely to have the largest cyclical effects for banks using point-in-time rating systems or for banks that lend to relatively high-credit quality firms. This is because realistically the ratings of low credit-rating firms cannot get much lower (outside of default) and so there can never be more than a modest effect on capital charges as a result of downgrades for these firms.

The early studies listed above were all performed under the assumption that banks' loan portfolios are time-invariant – that is, based on a "passive simulated portfolio" – and as a result do not take into account the fact that banks in practice adapt their portfolio to the business cycle. For example, banks typically tend to tighten lending standards during recessions and loosen lending standards in expansions. Gordy and Howells (2004) show that if one controls for a "flight-to-quality" effect and uses an appropriate reinvestment rule in the simulations, then Basel II cyclical effects on capital requirements become significantly smaller than those previously found in the passive simulated portfolio literature.

---

[19] This review is limited to studies that considered the procyclicality of the (2006) Basel II capital framework. Since the crisis, new research has emerged on the need for procyclical capital and loan loss reserve buffers and indeed the Basel III framework includes a credit cycle-dependent component in the capital framework. Procyclicality studies related to the new Basel III framework are not referenced in this survey. For a discussion of this literature, with a more policy-oriented focus, see a recent paper by the Committee of European Banking Supervisors (see CEBS (2009), Annex 1).

Evidence on the effect of capital requirements and capital buffers on bank lending

The cyclicality of regulatory capital requirements is a necessary but not sufficient condition for Basel II to have procyclical effects on the macroeconomy. Indeed, in practice banks hold a significant amount of capital above their regulatory requirement (so-called "capital buffers"), which may serve to insulate their credit supply from changes in countercyclical capital requirements. There are several reasons for holding capital buffers. For example, they may be held (i) for efficiency reasons (see Berger et al (1995)), (ii) as a signal to the market (see Flannery and Sorescu (1996)), or (iii) to avoid the costs associated with having to issue fresh equity at short notice in case their Tier 1 capital ratio unexpectedly falls below the regulatory minimum (see Barrios and Blanco (2003), Heid (2005) and Repullo and Suarez (2008)). Ultimately, therefore, whether capital regulation influences bank lending depends on whether capital buffers are large enough to absorb adverse shocks to equity capital without distorting banks' lending activity. Capital buffers have been observationally large in the United States and EU countries, as documented by Flannery and Rangan (2007), who report Tier 1 capital ratios in the United States of above 10% on average in the 1990s – more than twice the regulatory minimum – with similar numbers found for Europe.[20]

For the Basel II framework to have procyclical effects, the question is, of course, whether such buffers are large enough to prevent increases in capital requirements having an effect on lending. Currently, the evidence suggests that regulatory capital does affect bank lending. On the other hand, however, Altunbas et al (2002) find that lending of low-capitalised banks suffers more from monetary policy tightening, although their results are not statistically significant for the major European countries. In addition, Gambacorta and Mistrulli (2004) find that capital buffers affect lending in Italy and provide evidence that credit supply is less sensitive to GDP shocks for well-capitalised banks than for banks with low capital buffers. Likewise, Hancock et al (1995) find similar results for the United States. In particular, when they estimate directly the responses of lending to capital shocks, they find that capital shocks caused banks to contract lending more and more quickly in the 1990s than they had in the 1980s.

The main shortcoming of the above empirical work is related to the lack of data under a risk-sensitive capital requirement regime. Most estimates of the sensitivities of bank lending to regulatory capital requirements and GDP are conducted over a sample period when Basel II was not yet implemented and are in fact based on simulation so that the validity of these results will depend to a significant extent on how banks' capital and lending behaviours actually adapt under the new regulatory capital regime.

In addition to simulation studies, other information on the question of whether the relationship between bank capital and credit supply will remain the same under Basel II as under Basel I can be drawn from theoretical studies. These existing theoretical analyses suggest (i) that the new regulation will significantly change both capital buffers and lending behaviours at the bank level; and (ii) that these changes are likely to mitigate, at least partially, the potential procyclical effects of risk-sensitive capital requirements on lending. For example, Heid (2005), Zhu (2007), and Repullo and Suarez (2008) argue that banks are likely to manage their capital more dynamically under Basel II. This is based on the plausible conjecture that banks – recognising that future adverse shocks to their earnings and the cyclical position of the economy may impair their capacity to lend in the future – will as precaution accumulate capital in excess of minimum regulatory capital in upturns. In other words, capital buffers should turn from countercyclical under Basel I to procyclical under Basel II, which should

[20] Note, however that under prompt corrective action – a features of US legislation – a bank needs much more than the regulatory minimum to be classified as "well-capitalised".

work to smooth the credit cycle. Jovikuolle and Vesala (2007) focus on the impact of the new regulation on banks' lending behaviour and lending standards. They find that banks are likely to raise their lending standards in upturns in order to reap all the benefits from relatively lower capital requirements on high-credit-quality firms. This means that one should expect lending standards to turn from countercyclical to procyclical under Basel II, which should work to limit excessive lending to risky businesses during economic expansions.

C. The international dimensions of the borrower and bank balance sheet channels

Cross-border ownership of assets, which has been increasing over time, combined with the channels just described, presents an additional means for the international transmission of macroeconomic shocks. Specifically, with cross-border ownership of assets, an adverse macroeconomic shock in a foreign country, by causing asset price declines and perhaps also loan defaults, can result in the balance sheets of households as well as financial and nonfinancial businesses in the home country being impacted in much the same way as they would had the shock originated domestically. This deterioration in balance sheet positions would then affect the macroeconomy in the same way as described theoretically in subsections II.A and II.B and empirically in subsections IV.A and IV.B. Potentially, this channel of international business cycle transmission could help to account for the well documented empirical fact that business cycles across countries co-move by more than just standard trade and capital flow channels would suggest.

The most widely used framework for the analysis of interdependence between business cycles of different countries with financial variables is that of the GVAR model, described in the methodological appendix. Dees and Vansteenkiste (2007) uses a GVAR model to analyse the transmission of US cyclical developments to 26 other countries/regions over the sample period 1979 to 2003. Although the principal focus of their study is the importance – relative to own country shocks – of US macroeconomic developments on other countries' economic conditions, the paper emphasises the importance of financial and consumer confidence shocks in explaining business cycle co-movement. Related work using the same GVAR methodology by Dees et al (2007), but focussing on the international linkages of the euro area, finds a very rapid transmission of financial shocks, which, moreover, often gets amplified as they are transmitted from the United States. The study also finds that equity and bond markets are far more synchronous than real output, inflation and interest rates, and that financial variables, through their ultimate effect on real variables represent an important source of international co-movement. Sgherri and Galesi (2009) also adopt the GVAR methodology in a model that includes cross-country financial flows and analyse regional financial spillovers across Europe following a historical slowdown in US equity prices. The results show that financial shocks are transmitted across countries relatively quickly, with asset prices being the main channel of transmission. Interestingly, however, while there is considerable co-movement in asset prices across countries, the effects on credit growth are found to be generally country-specific, suggesting equity markets are more synchronous than banking systems.

As is the case with any reduced-form analyses, it is not clear to which extent the across-country transmission of business-cycle fluctuations via financial variables reflects the real and financial sector transmission channels. For example, although the increased co-movement of output as a result of more synchronised movements in equity prices could represent an international transmission channel stemming from the effect of asset prices on balance sheets, it could equally represent the effect of household stock-market wealth on consumption (which as noted earlier, is not considered to be a real-financial linkage). A few papers consider the effects of weakening bank balance sheets on real variables, where the initial source of weakness stems from a shock originating in some other country. Peek and

Rosengren (2000) use the Japanese banking crisis and Japanese banks' commercial mortgage lending to US firms as a natural experiment to test how loan supply shocks that produce bank capital losses can affect real economic activity. Interestingly, they find that the retrenchment in Japanese lending as a result of large banking-sector losses had a substantial impact on US real estate activity, thereby suggesting that the bank lending channel can induce an international transmission channel when lending across national borders takes place. Kaminsky and Reinhart (2000) and Van Rijckeghem and Weder (2001) consider the Mexican, Thai and Russian financial crises to examine whether bank capital losses that stem from loan defaults in the crisis country and result in banks having to cut back their lending, thereby acting as a channel of contagion across countries. Both sets of authors find that contagion is more likely when countries share a common bank lender suggesting that reductions in the credit extended to firms in many countries (that result from bank capital losses) are a powerful international transmission channel.

D. The liquidity channel

There are several papers that provide empirical support for many of the testable implications of the model proposed by Brunnermeier and Pedersen (2009). Using a newly developed measure of funding liquidity, Drehmann and Nikolaou (2009) find strong empirical evidence that market liquidity is low when funding liquidity demands are high, and that this relationship only occurs in stressed conditions. Chordia et al (2000), Hasbrouck and Seppi (2001), and Huberman and Halka (2001) provide empirical support for market liquidity that is correlated across stocks. Acharya and Pedersen (2005) find evidence for flight to liquidity which refers to the fact that when aggregate market liquidity falls, it falls primarily for illiquid assets. Finally, Chordia et al (2005) show that increases in volatility lead to declines in the market liquidity of bonds and stocks.

Adrian and Shin (2008) provide evidence that financial intermediaries' net worth is highly sensitive to fluctuations in asset prices. This is due to the large leverage embedded in their balances sheets and to mark to market accounting. Moreover, they point out a strong positive relationship between changes in leverage and changes in balance sheet size when banks actively adjust their balance sheets to changes in net worth. In periods of high economic growth and asset price increases, banks' balance sheets strengthen; as they target a certain level of leverage, they tend to purchase more assets, which amplifies the upward trend in prices and strengthens balance sheets further. The reverse mechanism happens when the economy is in a downturn. As a result, leverage is procyclical and entails an amplification of the financial cycle. [21]

V. Real and financial sector transmission channels in general equilibrium

Section V considers most of the transmission channels described in section II in a general equilibrium framework, in the context of the (currently) most widely used class of general

[21] It should be noted, however, that the use of leverage has some drawbacks as a measure of liquidity risk of an individual bank. Breuer (2000) points out that the simple leverage ratio cannot take into account important off-balance sheet transactions such as derivatives and securities lending. Thus, as off-balance sheet transactions (such as special investment vehicles (SIVs)) are vulnerable to liquidity risk, the leverage ratio has its limitation as a measure of liquidity risk. Although Breuer proposed some methods for resolving this problem, they may be difficult to implement.

equilibrium models, the DSGE models (that are described in subsection A.III of the methodological appendix).[22] It is worth noting that for more than a decade, DSGE models, both in the real business cycle and New-Keynesian traditions, completely ignored financial markets and institutions and the information asymmetries, frictions and corresponding transmission channels they might entail. This reflected the then generally held view in this literature that financial variables were merely a reflection of the real economy, but did not play any additional role in affecting the outcomes of real variables.

The first models with macro-financial linkages in the DSGE tradition were developed within the financial accelerator framework described in subsection II.A. These models – of which the initial ones were either calibrated or estimated on US data – show that the existence of informational frictions in credit markets has significant implications for the macroeconomy. For example, the financial accelerator model of Bernanke et al (1999) yields an impact of the monetary policy shock on output (investment) that is 50% (100%) larger relative to an identical but frictionless model. The financial accelerator of Carlstrom and Fuerst (1997) generates somewhat different results, albeit still finding credit frictions to be important; specifically, the initial response of output to most shocks is dampened by the presence of a financial accelerator although the response of output is more persistent. In Iacoviello's (2005) implementation of the Kiyotaki and Moore (1997) financial accelerator model, the effect that credit frictions have is asymmetric; that is, the effects of demand shocks are amplified but the effects of supply shocks are dampened. Although these models all have borrowing and lending, none explicitly considered financial institutions.

DSGE models with a stylised banking sector have been developed by Goodfriend and McCallum (2007), Christiano et al (2008), and Curdia and Woodford (2009). Goodfriend and McCallum's model builds on the financial accelerator framework, but they introduce into the model perfectly competitive banks. These are funded by household and interbank deposits and generate a variety of loans using a production function that employs "monitoring effort" and collateral. The model features a standard financial accelerator effect, but also a "banking attenuator" effect; that is, an expansionary shock increases households' demand for bank deposits, which increases banks' demand for collateral and the cost (and price) of issuing loans. This model is calibrated to US data. Shocks originating within the banking sector appear to have significant macroeconomic implications. The authors find that, after a 1% decline in the value of banks' collateral, the policy rate should fall by 5% in order to stabilise output and inflation; a standard Taylor-rule response, on the other hand, leads to a recession where both inflation and employment fall by about 2%.

Christiano et al develop a very large and richly-specified DSGE model that includes financial frictions (specifically borrower balance sheet effects). This model is then used to analyse the slowdown in economic activity that occurred in 2001. The model is estimated on both US and euro area data and time series for the model shocks are retrieved from the estimation procedure. These shocks suggest that the slowdowns in both the US and euro area were mainly driven by a combination of demand shocks and shocks to the business sector, whereas "banking shocks" affecting either the supply or demand of credit played only a minor role. Another interesting finding from this research is that, since interest rates are less volatile in the euro area, the European Central Bank was able to achieve the same degree of output stabilisation than the Federal Reserve with smaller changes in policy rates.

Curdia and Woodford extend the basic (three-equation) New-Keynesian model to allow for credit flows and credit distortions; specifically, a time-varying wedge between the saving and

[22] Note that we do not discuss the liquidity channel because this channel remains an area that has not yet been considered in the DSGE framework.

borrowing rates faced by households. The paper then considers the implications of these extensions for optimal policy, with particular focus on the questions of how the federal funds operating target should be adjusted for changes in credit spreads and whether monetary policy should respond to variations in credit. On the first question, the authors find that a standard Taylor rule can be improved upon by responding to credit spreads, although the size of the response is quite sensitive to the precise shock underlying the increase in the spread. On the second question, they find no benefit from policy responding to credit because credit is too persistent to be useful in guiding policy. Ultimately, the model of Curdia and Woodford is extremely stylised, such that any model results should be verified on more richly specified models before guiding policy decisions.

While the above models provide many useful techniques for including financial intermediation in DSGE models, on balance, their characterisation of banking does not capture what are likely the most important concerns of practitioners. Indeed, while they do include intermediated lending per se, they do not capture the features of banks that were emphasised by the bank lending-channel described in subsection II.B.

Models with bank capital – more similar to those described in subsection II.B – have been introduced into the general equilibrium framework by a number of authors, including van den Heuvel (2008), who introduced bank capital into a deterministic general equilibrium model, and Chen (2001), Meh and Moran (2004), and Aikman and Paustian (2008), who include bank capital in a DSGE model. In van den Heuvel (2008), banks are funded by (fully insured) deposits and equity, and face a regulatory constraint by which bank equity must be greater than a given, fixed fraction of total assets. Regulatory requirements are the only reason banks hold equity in this setup. The constraint generates a trade-off for households' welfare: it prevents banks from taking on too much risk (which they are tempted to do under full deposit insurance), but at the same time it hinders their liquidity provision function. The model, which is calibrated to US data, is ultimately used to study the welfare consequences of different capital requirement ratios (although it appears likely that the model could also be used to study business-cycle dynamics). This analysis suggests – somewhat untimely – that the capital requirement is too high.

The models with bank capital that have been developed by Chen (2001), Meh and Moran (2004) and Aikman and Paustian (2008) have no regulatory constraints, but in the spirit of Stein (1998), which was discussed in subsection II.B, banks need to hold capital to attract depositors. The need to hold capital by banks is exactly analogous to the need to hold capital by firms in the borrower balance sheet model – specifically, a badly capitalised bank is perceived as riskier because it has weaker incentives to monitor its loans, so it faces a market-based, countercyclical capital requirement. And, indeed, these models include both borrower and bank balance sheet channels. Chen shows qualitatively that the interaction between cyclical capital ratios and collateral constraints can amplify and prolong negative productivity shocks, but nonetheless suggests that a countercyclical regulatory requirement would not be effective in smoothing the cycle. Meh and Moran (2004) find that frictions (and hence capital buffers) reduce the impact of a monetary policy shock on output and investment by around 0.5%, while making the shock more persistent – a result analogous to that of Carlstrom and Fuerst (1997), discussed at the start of this section. Aikman and Paustian calibrate their model to UK data, finding that the existence of frictions amplifies the impact and persistence of the response of output to both monetary policy and technological shocks (the response increased by about 50% in the former case and 20% in the latter). Shocks to bank capital generate mild but prolonged contractions; specifically, if the capital-asset ratio falls from 10% to 7.5%, output declines by a maximum of 0.6%, recovering in about two years. The authors find that an aggressive inflation targeting is optimal irrespectively of the underlying financial frictions.

The models described above all assume that banks are identical and abstract from (endogenous) credit risk. Goodhart et al (2005, 2006) argue that these limitations make them unusable from a financial stability perspective. As an alternative, these authors propose a stylised two-period general equilibrium model with heterogeneous banks and incomplete markets. The model generates endogenous markets for interbank loans and bank equity. Goodhart et al (2005) calibrate a simplified version of the model to a set of UK banks and perform a set of static stress tests, including a monetary policy expansion and a "regulatory" shock that increases the cost of defaults. A 3% monetary expansion lowers the interbank rate by 0.8%; lending and deposit rates also fall, and output grows by 0.05%. Policy simulations indicate that regulation has a strong influence on banks' risk-taking behaviour; if the penalty for violating capital requirements increases (such as harsher prompt corrective action responses), banks reduce their exposures and both credit and output decline.

Since the behaviour of households in Goodhart et al's model is represented by reduced-form equations, the model is actually only a "partially-micro-founded general equilibrium model" and in addition, due to the lack of dynamics, the model is silent on feedbacks and second-round effects. De Walque et al (2008) embed a simplified version of Goodhart et al (2005) into a full, inter-temporal DSGE setting with representative lenders (households) and borrowers (perfectly competitive firms). Banks are split into "merchant banks" (which borrow in the interbank market and lend to firms) and "deposit banks" (which receive deposits and lend in the interbank market). The model is calibrated to data for Luxembourg. The presence of endogenous, procyclical recovery rates generates a further "acceleration" effect, but this appears quantitatively small; specifically, in the case of a productivity shock, the additional output response generated by this mechanism is only about 0.1%. The authors also compare a Basel I regulatory framework to a Basel II framework where capital requirements are based on endogenous risk weights. The latter reduces "financial instability" (measured by volatility in banks' recovery rates) but at the cost of higher macro (output) volatility.

VI. Gaps identified in the literature

On the topic of the refinement of macro stress testing models (which was discussed in subsection III.A of this survey) the literature review has highlighted several deficiencies in the existing class of models. Some of the deficiencies identified by the review – such as the relatively limited attention paid to maturity mismatch, liquidity concerns, nonlinearities and structural instabilities – are not unique to macro stress testing models and represent significant shortcomings for other classes of models used to study real and financial transmission channels. The discussion of these deficiencies is therefore deferred until later when the shortcomings of these other classes of models are discussed. Other deficiencies, however, are more specific to macro stress testing models and here the most important is the lack of any feedback effects. That is, macro stress testing models consider the effects of real conditions on bank balance sheets but rarely account for the fact that such bank balance sheet developments themselves have macroeconomic effects, which usually reinforce the effects of the initial macro shock. Moreover, in cases where stress test models do include feedback, this is done in very simplistic and cursory ways.[23]

On the issue of how conditions in the real economy affect conditions in the financial sector (which was discussed mainly in subsection III.B of this survey) a notable gap is the

[23] Some studies that have tried to include feedback effects include Hoggarth, Sorensen and Zicchino (2001) and Kida (2008).

primary focus of this literature on borrower default and delinquency outcomes with very limited consideration of borrower balance sheets more generally. Clearly households' and firms' balance sheets can deteriorate in ways that are relevant to how their creditworthiness is perceived by lenders even without defaults or delinquencies on loans. Because borrowers' perceived creditworthiness influences their access to credit (and the terms they face on credit), the effect of real economic conditions on creditworthiness is an important transmission channel, which is missed in studies which focus only on defaults and delinquencies. Research that looks at how real economic conditions affect the general strength of borrower balance sheets – rather than just borrower defaults and delinquencies – is therefore an area that would benefit from future study.

There are relatively few studies that focus on the interaction of international capital flows with stress tests of the domestic financial sector. Hidden currency mismatches coupled with exchange rate depreciation may translate into a sharp deterioration in the capacity of borrowers to service their loan. These losses for credit risk will deteriorate banks' solvency and liquidity, even if they have a balanced foreign currency position. This, in turn, will likely translate into a credit contraction affecting aggregate demand.[24] In addition, further research would also be beneficial to understand the impact of cross-border capital flows on the various credit channels. Capital flows can have important multiplier effects through transmission channels that can raise financial stability concerns especially in small, open economies. Recent history suggests that large international capital flows and reversals are often linked to asset price inflations and deflations which in turn have important implications for bank and consumer balance sheets, especially in the context of small open economies.

On the issue of the development of models which capture the interaction between conditions in the financial sector and the real economy (which was discussed in subsections IV.A and IV.B and section V of the survey) a key gap that the literature review has highlighted is the limited attention paid to nonlinearities and structural instabilities. These deficiencies are common to all classes of models employed to study real and financial linkages, such as reduced-form and structural VAR models, micro-founded DSGE models, as indeed they are also to macro stress testing models, which were mentioned earlier. To be sure, some research on VAR models – specifically, the TVAR models discussed in subsection IV.A – does allow for nonlinearities but it is not clear that this modelling strategy, which entails a single threshold at which model parameters switch values – is necessarily the closest representation of nonlinearities present in the economy. Nonetheless, this research provides empirical evidence for nonlinearities in the transmission channels between the real and financial sectors and suggests that transmission channels do likely operate differently during normal and crisis episodes, thereby highlighting the need for further study of nonlinearity issues. Structural instabilities have received less investigation but are nonetheless of equal importance in a rapidly innovating financial environment.

An important gap highlighted by the review of the existing literature on DSGE models that considers interactions between the financial sector and the real economy is the relatively stylised treatment of banks. As discussed in section V, while the seminal papers in the literature provide useful techniques for including financial intermediation in DSGE models, for the most part their characterisation of banking does not capture what are likely the most important concerns of practitioners. More recently, some DSGE models have begun to consider the role of bank capital. One issue, however, which the existing DSGE model literature has not yet considered is that of maturity mismatch and the liquidity concerns of bank – a gap also identified in the macro stress testing literature.

[24] See for example, Aguirre et al (2010).

The review of the existing literature on the influence of bank capital on lending – combined with recent events – has also highlighted as an important gap the issue of the extent to which private versus government capital injections have different implications for lending and economic activity. Several countries over the current crisis have implemented policies to inject capital into the banking sector and so examining whether injecting capital publicly is completely analogous to private capital injections would be of clear value to policy makers. A related topic concerns the need for analytical foundations of the effect of regulations on the system as a whole. For example, there has been little work done on the private incentives that emerge from banking regulations. Yet, "capital arbitrage" has been shown to be one important root of the crisis. In addition, it is very important to understand the incentive that financial regulation creates in the current context of regulation overhaul.

Finally, it is worth noting that the literature primarily focuses on how real shocks are transmitted to and propagated within the financial sector and less on how shocks originating in the financial sector can be transmitted to have real macroeconomic effects. While it is possible that the channels that operate to transmit shocks originating in the financial sector to the real economy are no different to those that transmit back to the real sector shocks that originated there but have since spilled over to the financial sector, it is also possible that they are different and this issue has not been addressed by the literature.

On the issue of how bank and borrower balance sheet positions influence bank-level variables relevant to economic activity (which was discussed in subsections IV.A and IV.B of the survey) the literature review has highlighted the following gap. Because borrower and bank balance sheets are both influenced by general macroeconomic conditions they typically deteriorate or improve at the same time and because ultimately, the only variables that researchers observe are the resulting lending volumes or lending rates, it is difficult to distinguish between the relative influences of borrower and lender balance sheet conditions in propagating macroeconomic and financial disturbances to the real economy. There appears to be only one published paper that attempts to make this distinction – specifically Hubbard et al (2002) – and indeed given this issue's very light treatment in the literature, the group chose to leave raising it to here.

On the question of how cross-country financial transmission channels influence international business-cycle co-movement (which was discussed in subsection IV.C of the survey) the literature review highlights as a notable gap the fact that most analysis is done on a reduced-form basis and provides limited information on the precise channels in operation.

On the influence of financial sector variables on the transmission of monetary policy (which was discussed along with other subject areas in subsection IV.B of the survey) the literature review has identified that a key gap in our knowledge is on the influence of lending on real economic activity. Specifically, while there is a sizable body of research on the question of how bank balance sheet positions influence lending, there is significantly less research on the question of how lending affects real activity, which moreover is a topic of some debate. More research on this linkage would be useful since it is the final step in tying bank balance sheet positions to economic activity. Another gap in the literature that has opened up as a result of the recent crisis is on the implications of securitisation for the bank lending channel. Essentially all of the research to date on this topic – which has found that securitisation weakens the bank lending channel – was undertaken prior to the crisis and so a key question is how these results hold up in the current environment.

Appendix

The methodologies for studying real and financial sector transmission channels

The empirical literature that studies the transmission channels between the real and financial sectors uses a wide range of methodological techniques. In this section, an overview of the techniques and models that are used in sections III, IV and V is provided to examine the theoretical real/financial transmission channels discussed previously in section II.

A.I. Reduced-form time-series models

This section begins with a discussion of the methodological techniques that primarily use a reduced-form approach to modelling the interaction between the financial sector (bank and non-bank) and the real economy. In contrast to the structural macroeconomic approach, which – as will be discussed in the next section – explicitly involves modelling the structure of the real economy in order to achieve theoretical consistency, the reduced-form (or non-structural) approach stresses the importance of empirical consistency and uses primarily empirical-based modelling (see Pagan (2003)).

A notable portion of the empirical work that studies financial and real sector transmission channels uses some variation of vector autoregression or VAR models. Sims (1980) developed VARs to address several key criticisms (including, spurious *a priori* identification restrictions and the Lucas critique) of the large, structural simultaneous equation macroeconometric models that were widely used in the 1960s and 1970s. A VAR is an *n*-equation, *n*-variable linear model in which each variable is explained by its own lagged values, plus current and past values of the remaining *n-1* variables.[25]

Stock and Watson (2001) discuss the three basic types of VARs: (i) reduced-form; (ii) recursive; and (iii) structural. A reduced-form VAR specifies each variable as a function of its own past values, the past values of all other variables being considered and a serially uncorrelated error term. Because the different variables are typically correlated with each other in macroeconomic applications, the error terms in the reduced-form model will be correlated across equations. A recursive VAR addresses this problem and constructs the error terms in each regression equation to be uncorrelated with the error in the preceding equations by including some contemporaneous values of the variables as regressors. Importantly, recursive VAR results depend on the recursive ordering of the variables (known as a Wold causal chain).

A structural VAR (SVAR) uses economic theory to specify the contemporaneous links among the variables (that is, identifying assumptions) that allow correlations to be interpreted causally. The identifying assumptions can involve the entire VAR or just a single equation. It should be noted that many of the structural VAR models that are presented in this literature review are in fact recursive VARs, in which economic theory is used to order the variables.

[25] One reason for the popularity of the VAR approach is that the Wold theorem ensures that any time-series vector has a VAR representation under mild regularity conditions.

Stock and Watson (2001) observe that the distinction between recursive and structural VARs is often murky in the empirical literature, since it is tempting for researchers to develop "economic theories" that conveniently lead to a particular recursive ordering of the variables in a structural VAR.

In addition to reduced-form, recursive and structural VARs, there are several variants of VAR models that are used in the literature. These other models include factor-augmented VARs; non-linear threshold VARs; and global VARs. Factor-augmented VARs (FAVARs) are VAR models in which one or more of the model variables is a principal components' series or factor drawn from a large set of data that reflect a similar macroeconomic or financial variable or concept (such as economic activity, inflation, or credit spreads). These models make use of recent developments in factor analysis for large data sets using diffusion indexes due to Stock and Watson (2002). TVARs represent a relatively simple way to incorporate nonlinear dynamics, regime shifts and asymmetries that linear VAR models are unable to capture. Specifically TVARs allow the models dynamic structure – that is, its coefficient and covariance matrix – to vary endogenously according to the evolution of the models threshold variable (which for the literature considered is generally a variable reflecting credit conditions). Global VAR (GVARs) models are a particular type of VAR model that represents the world economy and is designed to model economic and financial interrelationships at national and international levels. Individual country/region specific vector error-correcting models are estimated, where the domestic variables are related to corresponding foreign variables that are constructed to match the international trade pattern of the country being studied.[26] The individual country models are linked in a consistent manner so that the GVAR model is then solved for the world as a whole.

Finally, Vector Error Correction Models (VECMs) represent another type of VAR model that includes an error correction term. Error correction models can be used to test for long-run equilibrium relationships between time series. As noted by Granger (1986), this particular econometric framework is ideal for analysing relationships between variables that economic theory suggests should not deviate too far from each other in the long run. The choice of a VECM can be justified by its ability to detect common trends or cointegration between series as well as allowing for feedback effects between the dependent variable and explanatory variables.[27]

It should be noted that, while there are other kinds of analyses that examine the impact of the financial sector on macroeconomic conditions, such as single-equation forecasting models and dynamic factor analysis (eg Stock and Watson (2002), Stock and Watson (2003), and Bordo and Haubrich (2008)), the discussion here focuses on VAR-related approaches since these seem to be the most popular. Also, because the boundary between reduced-form and structural VAR models can be murky, both types of models are discussed. Finally, some of the empirical work (typically, single-equation analysis) only allows for unidirectional effects,

---

[26] Vector error-correcting models specify the short-run dynamics of each variable in a system, and in a framework that ties the dynamics to long-run equilibrium relationships suggested by economic theory. For example, economic theory suggests that economic activity across regions in a given country should converge. If this convergence hypothesis holds, then long-run relationships between employment across regions, for example, might be observed.

[27] Estimates of the coefficients may be improved if the existence of common trends in series is taken into account. Including shared trends becomes even more important when the model is estimated on high frequency data. A principal feature of cointegrated variables is that their time paths are influenced to the extent that any of these deviate from their long-run equilibrium relationship. Moreover, the short-run dynamics is influenced by the deviation from the long-run relationship.

while other work (typically, systems-of-equations approaches) allows for bidirectional effects or feedback effects between the financial and real sectors.

A.II. Micro-founded, DSGE models

Dynamic stochastic general equilibrium (DSGE) models typically take the form of complex, non-linear systems of equations. These models have two distinguishing features. First, they are micro-founded; that is, theoretically rigorous and built from first principles. That is, the behaviour of all macroeconomic variables is explicitly derived from basic assumptions involving the rational and forward-looking optimising behaviour of individual economic agents. Second, given their theoretical rigor, they constitute a complete, internally-consistent representation of the economy, which captures fundamental interactions between households, firms and policy makers. These features of DSGE models set them apart from most of the alternative models described in this survey. In addition, the DSGE literature has converged on a synthesis of nominal rigidity or price stickiness and to a class of models typically referred to as New Keynesian models.

Dynamic stochastic general equilibrium (DSGE) models represent the state of the art in macroeconomic modelling. Most of today's DSGE models adopt the general structure of the real business cycle approach introduced by Kydland and Prescott (1982), in that a key feature of these models is an impulse-response structure built around optimising agents in a general equilibrium setting. The ways that DSGE models account for the business cycle, however, differ from that used in the seminal work of Kydland and Prescott, which was in the real business cycle literature rather than the New Keynesian tradition. Finally, in order to keep the DSGE models manageable, strong simplifying assumptions are made. For example, heterogeneity across households and firms is typically ignored or is treated in a highly stylised way for reasons of tractability. Moreover, the modelling of the financial sector is missing or rudimentary. New Keynesian versions of DSGE models and VAR models incorporate market imperfections as a key feature in their construction (see, for example, Gray and Malone (2008)). More specifically, these models rigorously introduce imperfections and rigidities in the goods market, the labour market and the market for financial assets.

First-generation DSGE models were typically calibrated rather than estimated with a particular emphasis on using parameter estimates obtained from the applied microeconomic literature. That being said, widely varying degrees of effort could be put into calibrating parameter values, which potentially could be chosen on the basis of intuition or judgment rather than rigorous statistical procedures. Over the last 10 years, though, various estimation procedures have been developed, ranging from classical methods to more sophisticated Bayesian techniques (such as Markov chain Monte Carlo (MCMC) methods and the expectations-maximisation (EM) algorithm), which allow analysts to combine and integrate available data with prior (judgmental) views on the structure of the economy. These advances have significantly enhanced the policy relevance and usefulness of DSGE models, and they have bridged the gap between the DSGE models and reduced-form VAR macroeconometric models (discussed in subsection A.III). For example, it is possible to use a DGSE model to derive theoretically-consistent priors for a VAR and/or use a VAR to validate a DSGE model. Moreover, due to recent advances in numerical estimation methods and computing power, non-linear DGSE models can be estimated directly without resorting to linear approximations, which can improve the fit of the model and generate more

interesting model dynamics that make these models more suitable for financial stability analysis and stress testing.[28]

A.III. Cross-sectional and panel-data models

Cross-sectional data models are those that study a given set of individuals, firms, countries, or regions at the same point of time. As such, cross-sectional analysis compares differences between cross-sectional units without regard to differences in time. On the other hand, panel-data models are those that study a given sample of cross-sectional units over time.[29] As noted by Hsiao (2005), panel data sets provide important advantages over standard cross-sectional or time-series data sets. First, they provide a large number of observations, thereby increasing the degrees of freedom and improving the efficiency of econometric estimates. Second, they allow researchers to study economic issues that cannot be examined using cross-sectional or time-series data separately. For example, by using panel data sets, researchers are able to observe and assess how changes in variables of interest affect the same set of cross-sectional units over time. As a result, panel-data analysis generally allows the researcher to differentiate between individual-specific variations and general effects.

The principal difficulty in using panel data is that the researcher has to confront the important trade-off between panel breadth (number of cross-sectional units) and panel length (number of time periods). Because of data collection challenges, broad panel data might be available only for short time periods. Similarly, panel data sets with a long time series might be narrow in terms of the number of agents (ie individuals or firms or financial institutions). A relatively narrow panel data set then leaves open questions regarding the applicability of the results more generally. Due to regular, consistent and inclusive data collection for banking regulatory purposes, banking studies are often ideally suited for using panel data sets. For example, Salas and Saurina (2002) use a panel data set to distinguish how macroeconomic and other factors affect credit risk at two types of Spanish financial institutions. Panel data allows them to differentiate the role of credit policies with respect to credit risk at Spanish commercial banks and Spanish savings banks.

A.IV. Macro stress testing models

Macro stress testing refers to a range of quantitative techniques and models that are used by central banks and supervisory agencies to assess financial system-wide vulnerabilities to exceptional but plausible macroeconomic shocks. For many central banks and supervisors, the practice of macro stress testing was introduced as part of the Financial Sector Assessment Programs (FSAPs) conducted by the IMF and World Bank. As such, macro stress tests provide valuable information on the potential losses that a financial system might experience under severe real sector shocks, thereby helping policy makers to assess the

[28] See Canova (2007) for a technical discussion of the structure of DSGE models and the ways in which they are solved.

[29] A balanced panel data set consists of the same set of cross-sectional units being observed in each of the time periods. In contrast, in an unbalanced panel data set, some of the cross-sectional units are not observed in each time period.

financial soundness of the system.[30] In addition, it allows bank supervisors to identify the institutions whose current condition poses risks under alternative economic scenarios.

Before discussing the types of models used to conduct macro stress test exercises, it is instructive to consider the stages over which a macro stress text is conducted. As Sorge (2004) describes, the stages of a stress test are: (i) defining the scope of the analysis in terms of the relevant set of institutions and portfolios; (ii) designing and calibrating the macroeconomic stress scenario; (iii) quantifying the direct impact of the simulated macroeconomic stress scenario on the balance sheet of the financial sector (either by focusing on forecasting single financial soundness indicators under stress or by integrating the analysis of different types of risks, such as market and credit risks, into a single estimate of the aggregate loss distribution that could arise under the simulated stress scenario); (iv) evaluating the overall risk-bearing capacity of the financial system based on the stress test results; and (v) allowing for potential feedback effects both within the financial system and from the financial sector to the real economy, although feedback effects are often absent or modelled in rudimentary fashion. The focus of most macro stress tests currently is on credit risk at banking institutions, which reflects several considerations. First, banks are the core institutions in most financial systems and for most banks credit risk is the most important source of risk. Second, stress testing for credit risk is an important part of the Basel II framework.[31]

In its review of macro stress testing approaches to credit risk, Foglia (2009) found that central banks and supervisors apply a suite of modelling approached according to the state of the process. The first stage involves measuring the stress scenario's effects on macroeconomic conditions using a set of models, including structural macroeconometric models, a variety of VAR models (such as GVAR models) and vector error correction models, or pure statistical approaches (such as multivariate t-copula models).[32] In the second stage, a credit risk satellite model is estimated using either loan performance data (such as non-performing loans, loan loss provisions or historical default rates) or micro-level data related to the default risk of the household and/or corporate sector. The satellite or auxiliary model is used to link a measure of credit risk to the variables from the macroeconomic model and maps the external macro shocks into a bank's asset quality

---

30 See Foglia (2009) for a survey of the macro stress testing approaches used by central banks and supervisory agencies to assess credit risk for the financial sector.

31 Stress testing requirements of Basel II include the IRB-cyclicality tests and the forward-looking stress tests for the Internal Capital Adequacy Assessment Process (or ICAAP).

32 As noted in Foglia (2009), many stress testing approaches are built upon structural macroeconomic models – such as the National Institute Global Econometric Model (NiGEM) – to project the development of key macroeconomic indicators (such as GDP, interest rates, and house prices) under a certain stress scenario. Structural models impose consistency across predicted values in the stress scenario, and they allow for endogenous policy reactions to the initial shock. There are, however, also concerns that go along with the structural approach such as the modelling of policy responses, the time horizon, which variables are assumed fixed and which are shocked as well as with the inability of linear models to capture relationships between macroeconomic variables that may become non-linear during times of stress. VAR or VECM models can be used to stress a set of macroeconomic variables jointly and to project the stress scenario's combined impact on this set of variables. While VAR models are flexible in producing a set of mutually consistent shocks, they do not incorporate much economic structure. In its Systemic Risk Monitor (SRM), the Oesterreichische Nationalbank (OeNB) has developed a pure statistical approach to scenario design in which macroeconomic and financial variables are modelled through a multivariate t-copula. This approach takes into account that the marginal distributions can be different from the multivariate distribution that characterizes the joint behaviour of the variables, and it allows the model's dependence structure to increase under stress scenarios. The drawback of such a "purely" statistical approach is that the transmission mechanism within the model is not easy to interpret and, therefore, this model is not well suited for policy analysis.

shocks.[33] Finally, the last stage involves estimating the impact of the asset quality shocks on a bank's balance sheet (such as earnings or capital).

[33] Foglia (2009) also points out that both the structural econometric and the VAR approaches typically do not include a measure of credit risk. Hence, they require satellite (or auxiliary) models to map macroeconomic variables into indicators that can be used to transmit the macroeconomic scenario into banks' balance sheets, ie mapping external shocks onto banks' asset quality shocks. The credit risk satellite model can be based on data for individual banks and even on data for individual borrowers. In, for example, credit-quality regression models loan performance measures (like non-performing loans ratios) are typically related to set of macroeconomic and financial variables affecting credit risk (like economic growth, interest rates, exchange rates etc) A limitation of traditional stress testing is that the satellite model treats the macroeconomic variables as exogenous and ignores the feedback effects from a situation of distress in the banking system to the macro economy.

References

Acharya, V V and L H Pedersen (2005): "Asset pricing with liquidity risk", *Journal of Financial Economics*, vol 77, no 2, pp 375–410.

Acharya, V V and S Viswanathan (2008): *Moral hazard, collateral and liquidity, CEPR Discussion Papers 6630*, Centre for Economic Policy Research.

Adrian, T and H S Shin (2008): "Liquidity and financial contagion", *Banque de France Financial Stability Review*, no 11, pp 1–8.

——— (2010): "Liquidity and leverage", *Journal of Financial Intermediation*, vol 19, no 3, pp 418–37.

Aguirre, H et al (2010): "Foreign currency mismatches in banking systems: Potential vulnerabilities and policy implications", Banco Central de la República Argentina, mimeo.

Aikman, D and M Paustian (2006): *Bank capital, asset prices and monetary policy*, Bank of England working paper no 305.

Alfon, I, I Argimon and P Bascuñana-Ambrós (2004): *What determines how much capital is held by UK banks and building societies*, Financial Services Authority Occasional Paper 22.

Allen, F and E Carletti (2008): "Mark-to-market accounting and liquidity pricing", *Journal of Accounting and Economics*, vol 45, pp 358–78.

Allen, F and D Gale (2000): "Financial contagion", *Journal of Political Economy*, vol 108, no 1, pp 1–33.

Allen, L and A Saunders (2003): "A survey of cyclical effects in credit risk measurement models", *BIS Working Papers*, no 126, Basel.

Altman, E I and A Saunders (2001): "An analysis and critique of the BIS proposal on capital adequacy and ratings", *Journal of Banking and Finance*, vol 25, no 1, pp 25–46.

Altunbas, Y, O Fazylov and P Molyneux (2002): "Evidence on the bank-lending channel in Europe", *Journal of Banking and Finance*, vol 26, no 11, pp 2093–110.

Altunbas, Y, L Gambacorta and D Marques-Ibanez (2009): "Securitisation and the bank lending channel", *European Economic Review*, vol 53, no 8, pp 996–1009.

Alves, I (2005): "Sectoral fragility: factors and dynamics", *Investigating the relationship between the financial and real economy*, BIS Paper, no 22, Basel, pp 450–80.

Amihud, Y, H Mendelson and L H Pedersen (2005): "Liquidity and asset prices", *Foundations and trends in finance*, vol 1, pp 1–96.

Ang, A and M Piazzesi (2003): "A no-arbitrage vector autoregression of term structure dynamics with macroeconomic and latent variables", *Journal of Monetary Economics*, vol 50, no 4, pp 745–87.

Ang, A, M Piazzesi and M Wei (2006): "What does the yield curve tell us about GDP growth?", *Journal of Econometrics*, vol 131, no 1–2, pp 359–403.

Ashcraft, A B (2006): "New evidence on the lending channel", *Journal of Money, Credit, and Banking*, vol 38, no 3, pp 751–75.

Aspachs, O, C A E Goodhart, D P Tsomocos and L Zicchino (2007): “Towards a measure of financial fragility”, *Annals of finance*, vol 3, no 1, pp 37–74.

Atanasova, C (2003): “Credit market imperfections and business cycle dynamics: a nonlinear approach”, *Studies in nonlinear dynamics and econometrics*, vol 7, no 4, pp 1–20.

Azariadis, C and B Smith (1998): “Financial intermediation and regime switching in business cycles”, *American Economic Review*, vol 88, no 3, pp 516–36.

Balke, N S (2000): “Credit and economic activity: credit regimes and nonlinear propagation of shocks”, *Review of Economics and Statistics*, vol 82, no 2, pp 344–9.

Bardsen, G, K-G Lindquist and D P Tsomocos (2006): “Evaluation of macroeconomic models for financial stability analysis”, Norges Bank Working Paper 2006/01.

Barrios, V E and J M Blanco (2003): “The effectiveness of bank capital adequacy regulation: a theoretical and empirical approach”, *Journal of Banking and Finance*, vol 27, no 10, pp 1935–58.

Bartolini, L, L Goldberg and A Sacarny (2008): “How economic news moves markets”, *Current Issues in Economics and Finance*, vol 14, no 6, pp 1–7.

Bekaert, G, S Cho and A Moreno (2005): “New-Keynesian macroeconomics and the term structure”, *NBER Working Papers*, no 11340, National Bureau of Economic Research.

Berger, A N and G F Udell (1994): “Did risk-based capital allocate bank credit and cause a ‘credit crunch’ in the United States?”, *Journal of Money, Credit and Banking*, vol 26, no 3, pp 585–628.

Berger, A N, R J Herring, and G P Szego (1995): “The role of capital in financial institutions”, *Journal of Banking and Finance*, vol 19, no 3–4, pp 393–430.

Bernanke, B S and A S Blinder (1988): “Credit, money, and aggregate demand”, *American Economic Review*, vol 78, no 2, pp 435–9.

Bernanke, B S and M Gertler (1989): “Agency costs, net worth, and business fluctuations”, *American Economic Review*, vol 79, no 1, pp 14–31.

——— (1995): “Inside the black box: the credit channel of monetary policy transmission”, *Journal of Economic Perspectives*, vol 9, no 4, pp 27–48.

Bernanke, B S, M Gertler and S Gilchrist (1996): “The financial accelerator and the flight to quality”, *Review of Economics and Statistics*, vol 78, no 1, pp 1–15.

——— (1999): “The financial accelerator in a quantitative business cycle framework”, in J B Taylor and M Woodford (eds), *Handbook of macroeconomics,* vol 1C, *Handbooks in Economics*, vol 15, Amsterdam, New York and Oxford, pp 1341–93.

Blinder, A S (1987): “Credit rationing and effective supply failures”, *Economic Journal*, June 1987, pp 327–52.

Bordo, M D and J G Haubrich (2008): “The yield curve as a predictor of growth: long-run evidence, 1875–1997”, *Review of Economics and Statistics*, vol 90, no 1, pp 182–5.

Borio, C E V and M Drehmann (2009): “Towards an operational framework for financial stability: ‘fuzzy’ measurement and its consequences”, *BIS Working Papers*, no 284, Basel.

Borio, C E V, C Furfine and P W Lowe (2001): "Procyclicality of the financial system and financial stability: issues and policy options", in *Marrying the macro and microprudential dimensions of financial stability, BIS Papers*, no 1, Basel, pp 1–57.

Borio, C E V and H Zhu (2009): "Capital regulation, risk-taking and monetary policy: a missing link in the transmission mechanism?" *BIS Working Papers*, no 268, Basel.

Brana, S and D Lahet (2009): "Capital requirement and financial crisis: the case of Japan and the 1997 Asian crisis", *Japan and the World Economy*, vol 21, no 1, pp 97–104.

Breuer, P (2005): "Measuring off-balance sheet leverage", *IMF Working Papers*, no 00/202.

Brinkmann, E J and P M Horvitz (1995): "Risk-based capital standards and the credit crunch", *Journal of Money, Credit, and Banking*, vol 27, no 3, pp 848–63.

Brunnermeier, M K (2009): "Symposium: early stages of the credit crunch: deciphering the liquidity and credit crunch 2007–2008", *Journal of Economic Perspectives*, vol 23, no 1, pp 77–100.

Brunnermeier, M K and L H Pedersen (2007): "Market liquidity and funding liquidity", *NBER Working Papers*, no 12939.

Brusco, S and F Castiglionesi (2007): "Liquidity coinsurance, moral hazard, and financial contagion", *Journal of Finance*, vol 62, no 5, pp 2275–302.

Burgstaller, J (2006): *Financial predictors of real activity and the propagation of aggregate shocks*, Johannes Kepler University of Linz, Department of Economics, working paper no 0616.

Calza, A and J Sousa (2006): "Output and inflation responses to credit shocks: are there threshold effects in the euro area", *Studies in Nonlinear Dynamics and Econometrics*, vol 10, no 2.

Canova, F (2007): *Methods for Applied Macroeconomic Research*.

Carlstrom, C T and T S Fuerst (1997): "Agency costs, net worth, and business fluctuations: a computable general equilibrium analysis", *American Economic Review*, vol 87, no 5, pp 893–910.

Castren, O, S Dees and F Zaher (2008): "Global macro-financial shocks and expected default frequencies in the euro area", *European Central Bank Working Paper Series*, no 875.

Catarineu-Rabell, E, P Jackson and D P Tsomocos (2005): "Procyclicality and the new Basel Accord – bank's choice of loan rating system", *Economic Theory*, vol 26, no 3, pp 537–57.

CEBS (2009): "Position paper on a countercyclical capital buffer", July.

Chen, N-K (2001): "Bank net worth, asset prices and economic activity", *Journal of Monetary Economics*, vol 48, no 2, pp 415–36.

Chordia, T, R Roll and A Subrahmanyam (2000): "Commonality in liquidity", *Journal of Financial Economics*, vol 56, no 1, pp 3–28.

Chordia, T, A Sarkar, and A Subrahmanyam (2005): "An empirical analysis of stock and bond market liquidity", *Review of Financial Studies*, vol 18, no 1, pp 85–129.

Christiano, L, R Motto and M Rostagno (2008): “Shocks, structures or monetary policies? The euro area and US after 2001”, *Journal of Economic Dynamics and Control*, vol 32, no 8, pp 2476–506.

Cifuentes, R, G Ferrucci and H S Shin (2005): “Liquidity risk and contagion”, *Journal of the European Economic Association*, vol 3, no 2–3, pp 556–66.

Collier, C, S Forbush and D A Nuxoll (2003): “Evaluating the vulnerability of banks and thrifts to a real estate crisis”, *FDIC Banking Review*, vol 15, no 4, pp 19–36.

Cottarelli, C, G Ferri and A Generale (1995): “Bank lending rates and financial structure in Italy: a case study”, *International Monetary Fund Working Paper*, no 95/38.

Cúrdia, V and M Woodford (2009): “Credit frictions and optimal monetary policy”, *BIS Working Papers*, no 278, Basel.

Daly, M, J Krainer and J A Lopez (2003): “Does regional economic performance affect bank health? New analysis of an old question”, *Federal Reserve Bank of San Francisco Working Papers Series,* no 2004-01.

Daníelsson, J, P Embrechts, C A E Goodhart, C Keating, F Muennich, O Renault and H S Shin (2001): “An academic response to Basel 2”, *LSE FMG Special Paper*, no 130.

Davis, E and H Zhu (2005): “Commercial property prices and bank performance”, *BIS Working Paper*, no 175, Basel.

Dees, S, F Di Mauro, M H Pesaran and L V Smith (2007): “Exploring the international linkages of the euro area: a global VAR analysis”, *Journal of Applied Econometrics*, vol 22, no 1, pp 1–38.

Dees, S and I Vansteenkiste (2007): “The transmission of US cyclical developments to the rest of the world”, *European Central Bank Working Paper Series*, no 798.

De Graeve, F, T Kick and M Koetter (2008): “Monetary policy and financial (in)stability: an integrated micro–macro approach”, *Journal of Financial Stability*, vol 4, no 3, pp 205–31.

De Greef, I and R De Haas (2000): “Housing prices, bank lending, and monetary policy”, *De Nederlandsche Bank Research Series Supervision Paper*, no 31.

Deng, S and E Elyasiani (2008): “Geographic diversification, bank holding company value, and risk”, *Journal of Money, Credit, and Banking*, vol 40, no 6, pp 1217–38.

Deng, Y, J M Quigley and R Van Order (2000): “Mortgage terminations, heterogeneity, and the exercise of mortgage options”, *Econometrica*, vol 68, no 2, pp 275–308.

De Bondt, G J (1998): “Credit channels in Europe: bank-level panel data analyses”, *De Nederlandsche Bank Research Memorandum WO&E*, no 567.

——— (1999): “Credit channels in Europe: cross-country investigation”, *De Nederlandsche Bank Research Memorandum WO&E*, no 569, February.

De Walque, G, O Pierrard and A Rouabah (2009): “Financial (in)stability, supervision and liquidity injections: a dynamic general equilibrium approach”, *CEPR Discussion Papers,* no 7202.

Diamond, D W and P H Dybvig (1983): “Bank runs, deposit insurance, and liquidity”, *Journal of Political Economy*, vol 91, no 3, pp 401–19.

Diamond, D W and R G Rajan (2005): “Liquidity shortages and banking crises”, Journal of Finance, vol 60, no 2, pp 615–47.

——— (2009): “The credit crisis: conjectures about causes and remedies”, *American Economic Review*, vol 99, no 2, pp 606–10.

Diebold, F X, M Piazzesi and G D Rudebusch (2005): “Modeling bond yields in finance and macroeconomics”, *American Economic Review*, vol 95, no 2, pp 415–20.

Diebold, F X, G D Rudebusch and S B Aruoba (2006): “The macroeconomy and the yield curve: a dynamic latent factor approach”, *Journal of Econometrics*, vol 131, no 1–2, pp 309–38.

Drehmann, M, A Patton and S Sorensen (2006): *Corporate defaults and large macroeconomic shocks*, Bank of England, mimeo.

Drehmann, M and K Nikolaou (2009): “Funding liquidity risk: definition and measurement”, *European Central Bank Working Paper Series*, no 1024.

Düllmann, K and M Erdelmeier (2009): “Stress testing German banks in a downturn in the automobile industry”, *Deutsche Bundesbank Discussion Paper, Series 2: Banking and Financial Studies*, no 02/2009.

Ediz, T, I Michael and W Perraudin (1998): “The impact of capital requirements on U.K. bank behaviour”, *Federal Reserve Bank of New York Economic Policy Review*, vol 4, no 3, pp 15–22.

Estrella, A and G Hardouvelis (1991): “The term structure as a predictor of real economic activity”, *Journal of Finance*, vol 46, pp 555–76.

Favero, C A, F Giavazzi and L Flabbi (1999): “The transmission mechanism of monetary policy in Europe: evidence from banks’ balance sheets”, *NBER Working Paper*, no 7231.

Federal Deposit Insurance Corporation (1997), *History of the eighties – lessons for the future*, vol 1, December.

Fiori, R, A Foglia and S Iannotti (2009): “Beyond macroeconomic risk: the role of contagion in the Italian corporate default correlation”, *Bocconi University CAREFIN Working Paper*, no 2.

Fisher, I (1933): “The debt-deflation theory of great depressions”, *Econometrica*, vol 1, no 4, pp 337–57.

Flannery, M J and S M Sorescu (1996): “Evidence of bank market discipline in subordinated debenture yields: 1983–1991”, *Journal of Finance*, vol 51, no 4, pp 1347–77.

Flannery, M J and K P Rangan (2008): “What caused the bank capital build-up of the 1990s?”, *Review of Finance*, vol 12, no 2, pp 391–430.

Foglia, A (2009): “Stress testing credit risk: a survey of authorities’ approaches”, *The International Journal of Central Banking*, vol.5, no 3, September.

Furlong, F and J Krainer (2007): "Regional economic conditions and the variability of rates of return in commercial banking", *Federal Reserve Bank of San Francisco Working Paper Series*, no 2007-21.

Galvao, A B C (2006): "Structural break threshold VARs for predicting US recessions using the Spread", *Journal of Applied Econometrics*, vol 21, no 4, pp 463–87.

Gambacorta, L (2004): "How do banks set interest rates?", *NBER Working Paper*, no 10295.

Gambacorta, L and P E Mistrulli (2004): "Does bank capital affect lending behavior?", *Journal of Financial Intermediation*, vol 13, no 4, pp 436–57.

Gerlach, S, W Peng and C Shu (2005): "Macroeconomic conditions and banking performance in Hong Kong SAR: a panel data study", in *Investigating the relationship between the financial and real economy, BIS Papers*, no 22, Basel, pp 481–97.

Gertler, M and S Gilchrist (1993): "The role of credit market imperfections in the monetary transmission mechanism: arguments and evidence", *Scandinavian Journal of Economics*, vol 95, no 1, pp 43–64.

——— (1994): "Monetary policy, business cycles, and the behavior of small manufacturing firms", *Quarterly Journal of Economics*, vol 109, no 2, pp 309–40.

Gilchrist, S, V Yankov and E Zakrajšek (2009): "Credit market shocks and economic fluctuations: evidence from corporate bond and stock markets", *Journal of Monetary Economics*, vol 56, no 4, pp 471–93.

Goodfriend, M and B T McCallum (2007): "Banking and interest rates in monetary policy analysis: a quantitative exploration", *Journal of Monetary Economics*, vol 54, no 5, pp 1480–1507.

Goodhart, C A E, B Hofmann and M Segoviano (2004): "Bank regulation and macroeconomic fluctuations", *Oxford Review of Economic Policy*, vol 20, no 4, pp 591–615.

——— (2006): "Default, credit growth, and asset prices", *IMF Working Paper*, no 06/223.

Goodhart, C A E, P Sunirand and D P Tsomocos (2005): "A risk assessment model for banks", *Annals of Finance*, vol 1, no 2, pp 197–224.

——— (2006): "A model to analyse financial fragility", *Economic Theory*, vol 27, no 1, pp 107–42.

Gordy, M B and B Howells (2006): "Procyclicality in Basel II: can we treat the disease without killing the patient?", *Journal of Financial Intermediation*, vol 15, no 3, pp 395–417.

Gorton, G (2008): "The Panic of 2007", *NBER Working Papers*, no 14358.

Gray, D F, R C Merton and Z Bodie (2006): "A new framework for analyzing and managing macrofinancial risks of an economy", *NBER Working Papers*, no 12637.

Gray, D F and S W Malone (2008): *Macrofinancial risk analysis,* John Wiley & Sons.

Grinblatt, M and S Titman (2002): *Financial Markets & Corporate Strategy*, McGraw-Hill.

Gromb, D and D Vayanos (2008): "Leverage and liquidity dry-ups: a framework and policy implications", mimeo.

Gross, D B and N S Souleles (2002): “An empirical analysis of personal bankruptcy and delinquency”, *Review of Financial Studies*, vol 15, no 1, pp 319–47.

Hancock, D and J A Wilcox (1994): “Bank capital and the credit crunch: the roles of risk-weighted and unweighted capital regulations”, *American Real Estate and Urban Economics Association Journal*, vol 22, no 1, pp 59–94.

——— (1998): “The ‘credit crunch’ and the availability of credit to small businesses”, *Journal of Banking and Finance*, vol 22, pp 983–1014.

Hancock, D, A J Laing and J A Wilcox (1995): “Bank capital shocks: dynamic effects on securities, loans, and capital”, *Journal of Banking and Finance*, vol 19, no 3–4, pp 661–77.

Harvey, C R (1988): “The real term structure and consumption growth”, *Journal of Financial Economics*, vol 22, pp 305–33.

——— (1991): “The term structure and world economic growth”, *The Journal of Fixed Income*, vol 1, pp 7–19.

Hasbrouck, J and D J Seppi (2001): “Common factors in prices, order flows, and liquidity”, *Journal of Financial Economics*, vol 59, no 3, pp 383–411.

Haubrich, J G and A M Dombrosky (1996): “Predicting real growth using the yield curve”, *Federal Reserve Bank of Cleveland Economic Review*, vol 32, pp 26–35.

Heid, F (2005): “Cyclical implications of minimum capital requirements”, *Deutsche Bundesbank Discussion Paper, Series 2: Banking and Financial Studies*, no 06/2005.

Heffernan, A S (2002): “How do UK financial institutions really price their banking products?” *Journal of Banking and Finance*, vol 26, pp 1997–2016.

Herring, R J and S M Wachter (1999): “Real estate booms and banking busts: an international perspective”, *Group of Thirty Occasional Papers*, no 58, Washington, DC.

Hilbers, P L C, Q Lei and L Zacho (2001): “Real estate market developments and financial sector soundness”, *IMF Working Paper*, no 01/129.

Himmelberg, C, C Mayer and T Sinai (2005): “Assessing high house prices: bubbles, fundamentals and misperceptions”, *Journal of Economic Perspectives*, vol 19, no 4, pp 67–92.

Hoggarth, G, S Sorensen and L Zicchino (2005): “Stress tests of UK banks using a VAR approach”, Working Paper no 282, Bank of England.

Holmström, B and J Tirole (1997): “Financial intermediation, loanable funds, and the real sector”, *Quarterly Journal of Economics*, vol 112, no 3, pp 663–91.

——— (1998): “Private and public supply of liquidity”, *Journal of Political Economy*, vol 106, no 1, pp 1–40.

Honda, Y (2002): “The effects of the Basle Accord on bank credit: the case of Japan”, *Applied Economics*, vol 34, no 10, pp 1233–39.

Hordahl, P, O Tristani and D Vestin (2006): “A joint econometric model of macroeconomic and term-structure dynamics”, *Journal of Econometrics*, vol 131, no 1–2, pp 405–44.

Hsiao, C (2005): “Why panel data?”, *IEPR Working Paper*, no 05.33.

Huberman, G and D Halka (2001): “Systematic liquidity”, *Journal of Financial Research*, vol 24, no 2, pp 161–78.

Iacoviello, M (2005): “House prices, borrowing constraints, and monetary policy in the business cycle”, *American Economic Review*, vol 95, no 3, pp 739–64.

Ioannodou, V P, S Ongena and J-L Peydro (2008): *Monetary policy and subprime lending: a tall tale of low Federal Funds rates, hazardous loans, and reduced loan spreads,* Tilburg University, mimeo.

Jackson, P, C Furfine, H Groeneveld, D Hancock, D Jones, W Perraudin, L Radecki and M Yoneyama (1999): “Capital requirements and bank behaviour: the impact of the Basle Accord”, *Basle Committee on Banking Supervision Working Papers*, no 1.

Jacobson, T, R Kindell, J Lindé and K Roszbach (2008): “Firm default and aggregate fluctuations”, *Sveriges Riksbank Working Paper Series*, no 226.

Jacobson, T, J Linde and K Roszbach (2005): “Exploring interactions between real activity and the financial stance”, *Journal of Financial Stability*, vol 1, no 3, pp 308–41.

Jacques, K T (2008): “Capital shocks, bank asset allocation, and the revised Basel Accord”, *Review of Financial Economics*, vol 17, no 2, pp 79–91.

Jakubík, P and C Schmieder (2008): “Stress testing credit risk: is the Czech Republic different from Germany?”, *Czech National Bank Working Paper Series*, no 9.

Jimenez G and J Mencia (2007): “Modelling the distribution of credit losses with observable and latent factors”, *Journal of Empirical Finance*, vol 16, pp 235–53.

Jimenez G, S Ongena, J-L Peydro and J Saurina (2008): “Hazardous times for monetary policy: what do twenty-three million bank loans say about the effects of monetary policy on credit risk-taking?”, *Banco de Espana Working Paper*, no 0833.

Jimenez G and J Saurina (2006): “Credit cycles, credit risk, and prudential regulation”, *International Journal of Central Banking*, vol 2, no 2, pp 65–98.

Joint Working Group of the Financial Stability Forum and the Committee on the Global Financial System (2009): “The role of valuation and leverage in procyclicality”, *CGFS Papers*, no 34.

Jokivuolle, E and T Vesala (2007): “Portfolio effects and efficiency of lending under Basel II”, *Bank of Finland Research Discussion Papers*, no 13.

Jordan, J S and E S Rosengren (2002): *Economic cycles and bank health*, Federal Reserve Bank of Boston, mimeo.

Kaminsky, G L and C M Reinhart (2000): “On crises, contagion, and confusion”, *Journal of International Economics*, vol 51, no 1, pp 145–68.

Kashyap, A K and J C Stein (1995): “The impact of monetary policy on bank balance sheets”, *Carnegie-Rochester Conference Series on Public Policy*, vol 42, pp 151–95.

——— (2004): “Cyclical implications of the Basel II capital standards”, *Federal Reserve Bank of Chicago Economic Perspectives*, vol 28, no 1, pp 18–31.

Kashyap, A K, J C Stein and D W Wilcox (1993): “Monetary policy and credit conditions: evidence from the composition of external finance”, *American Economic Review*, vol 83, no 1, pp 78–98.

——— (1996): “Monetary policy and credit conditions: evidence from the composition of external finance: reply”, *American Economic Review*, vol 86, no 1, pp 310–14.

Kashyap, A K, R G Rajan and J C Stein (2008): “Rethinking capital regulation”, in Federal Reserve of Kansas City (ed), *Maintaining stability in a changing financial system*, pp 431–71.

Kashyap, A K and J C Stein (2000): “What do a million observations on banks say about the transmission of monetary policy?”, *American Economic Review*, vol 90, no 3, pp 407–28.

Kida, M (2008): “A macro stress testing model with feedback effects”, Discussion Paper Series 2008/08, Reserve Bank of New Zealand.

Kim, D (2008): “Challenges in macro-finance modeling”, *Board of Governors of the Federal Reserve System Finance and Economics Discussion Series*, no 2008-06.

Kishan, R P and T P Opiela (2000): “Bank size, bank capital, and the bank lending channel”, *Journal of Money, Credit, and Banking*, vol 32, no 1, pp 121–41.

Kiyotaki, N and J Moore (1997): “Credit cycles”, *Journal of Political Economy*, vol 105, no 2, pp 211–48.

Krishnamurthy, A (2009): “Amplification mechanisms in liquidity crises”, *NBER Working Paper*, no 15040.

Kydland, F E and E C Prescott (1982): “Time to build and aggregate fluctuations”, *Econometrica*, vol 50, No 6, pp 1345–70.

Laeven, L and G Majnoni (2003): “Loan loss provisioning and economic slowdowns: too much, too late?”, *Journal of Financial Intermediation*, vol 12, no 2, pp 178–97.

Levin, A T, F M Natalucci and E Zakrajsek (2004): “The magnitude and cyclical behavior of financial market frictions”, *Board of Governors of the Federal Reserve System Finance and Economics Discussion Series*, no 2004-70.

Lowe, P W (2002): “Credit risk measurement and procyclicality”, *BIS Working Paper*, no 116, Basel.

Marcucci, J and M Quagliariello (2008): “Is bank portfolio riskiness procyclical? Evidence from Italy using a vector autoregression”, *Journal of International Financial Markets, Institutions and Money*, vol 18, no 1, pp 46–63.

Mayer, C J, K M Pence and S M Sherlund (2008): “The rise in mortgage defaults”, *Board of Governors of the Federal Reserve System Finance and Economics Discussion Series*, no 2008-59.

Maudos Villarroya, J and J Fernandez de Guevara (2004): “Factors explaining the interest margin in the banking sectors of the European Union”, *Journal of Banking and Finance*, vol 28, pp 2259–81.

McCarthy, J and R W Peach (2004): “Are home prices the next ‘bubble’?”, *Federal Reserve Bank of New York Economic Policy Review*, vol 10, no 3, pp 1–17.

Meh, C and K Moran (2004): "The role of bank capital in the propagation of shocks", *Bank of Canada Working Papers*, no 2004-6.

Meyer, A P and T J Yeager (2001): "Are small rural banks vulnerable to local economic downturns?", *Federal Reserve Bank of St Louis Review*, vol 83, no 2, pp 25–39.

Mishkin, F S (1977), "What depressed the consumer? The household balance sheet and the 1973–75 recession", *Brookings Papers on Economic Activity*, vol 1977; no 1, pp 123–64.

Mody, A and M P Taylor (2003): "The high yield spread as a predictor of real economic activity: evidence of a financial accelerator for the United States", *International Monetary Fund Staff Papers*, vol 50, pp 373–402.

Moench, E (2008): "Forecasting the yield curve in a data-rich environment: a no-arbitrage factor-augmented VAR approach", *Journal of Econometrics*, vol 146, no 1, pp 26–43.

Neely, M C and D C Wheelock (1997): "Why does bank performance vary across states?", *Federal Reserve Bank of St Louis Review*, vol 79, no 2, pp 27–40.

Nuxoll, D A, J O'Keefe and K Samolyk (2003): "Do local economic data improve off-site bank-monitoring models?", *FDIC Banking Review*, vol 15, no 2, pp 39–53.

Nwogugu, M (2007): "Some issues in disintermediation and securitization", *Applied Mathematics and Computation*, vol 186, no 2, pp 1031–9.

Oliner, S D and G D Rudebusch (1995): "Is there a bank lending channel for monetary policy?", *Federal Reserve Bank of San Francisco Economic Review*, no 2, pp 3–20.

Padilla, P and M Segoviano (2006): "Portfolio credit risk and macroeconomic shocks: applications to stress testing under data-restricted environments", *IMF Working Paper*, no 06/283.

Pagan, A (2003): "Report on modelling and forecasting at the Bank of England", *Bank of England Quarterly Bulletin*, spring, pp 1–29.

Peek, J and E S Rosengren (1995): "The capital crunch: neither a borrower nor a lender be", *Journal of Money, Credit, and Banking*, vol 27, no 3, pp 625–38.

——— (2000): "Collateral damage: effects of the Japanese bank crisis on real activity in the United States", *American Economic Review*, vol 90, no 1, pp 30–45.

Pesaran, M H, T Schuermann, B-J Treutler and S M Weiner (2006): "Macroeconomic dynamics and credit risk: a global perspective", *Journal of Money, Credit, and Banking*, vol 38, no 5, pp 1211–61.

Quagliariello, M (2008), "Does macroeconomy affect bank stability? A review of the empirical evidence", *Journal of Banking Regulation*, vol 9, no 2, pp 102–15.

Qi, M and X Yang (2009): "Loss given default of high loan-to-value residential mortgages", *Journal of Banking and Finance*, vol 33, no 5, pp 788–99.

Quigley, J M (2002): "Transactions costs and housing markets", in A O'Sullivan and K Gibb (eds), *Housing Economics and Public Policy*, Blackwell Publishing, pp 56–64.

Repullo, R and J Suarez (2008): "The procyclical effects of Basel II", *CEPR Discussion Papers*, no 6862, London.

Rochet, J-C and J Tirole (1996): “Interbank lending and systemic risk”, *Journal of Money, Credit, and Banking*, vol 28, no 4, pp 733–62.

Romer, C D and D H Romer (1990): “New evidence on the monetary transmission mechanism”, *Brookings Papers on Economic Activity*, Vol 1990, no 1, pp 149–98.

Rudebusch, G D and T Wu (2008): “A macro-finance model of the term structure, monetary policy and the economy”, *Economic Journal*, vol 118, no 530, pp 906–26.

Salas, V and J Saurina (2002): “Credit risk in two institutional regimes: spanish commercial and savings banks”, *Journal of Financial Services Research*, vol 22, no 3, pp 203–24.

Samolyk, K A (1994): “U.S. banking sector trends: assessing disparities in industry performance”, *Federal Reserve Bank of Cleveland Economic Review*, vol 30, no 2, pp 2–17.

Segoviano, M (2006): “Conditional Probability of Default Methodology”, Financial Markets Group Discussion Paper 558. London School of Economics.

——— (2007): “Portfolio credit risk and macroeconomic shocks: applications to stress testing under data-restricted environments”, *IMF Working Papers*, no 06/283.

Segoviano, M A and C Goodhart (2009): “Banking stability measures”, *IMF Working Papers,* no 09/4.

Sgherri, S and A Galesi (2009): “Regional financial spillovers across Europe: a global VAR analysis”, *IMF Working Papers*, no 09/23.

Shahnazarian, H and P Asberg-Sommar (2008): “Macroeconomic impact on expected default frequency”, *Sveriges Riksbank Working Paper Series*, no 219.

Shim, I and G von Peter (2007): “Distress selling and asset market feedback”, *Financial Markets*, vol 16, pp 243–91.

Sims, C A (1980): “Macroeconomics and reality”, *Econometrica*, vol 48, no 1, pp 1–48.

Sorge, M (2004): “Stress-testing financial systems: an overview of current methodologies”, *BIS Working Paper*, no 165.

Stein, J C (1998): “An adverse-selection model of bank asset and liability management with implications for the transmission of monetary policy”, *RAND Journal of Economics*, vol 29, no 3, pp 466–86.

Stiglitz, J E and A Weiss (1981): “Credit rationing in markets with imperfect information”, *American Economic Review*, vol 71, no 3, pp 393–410.

Stock, J H and M W Watson (2001): “Vector autoregressions”, *Journal of Economic Perspectives*, vol 15, no 4, pp 101–15.

——— (2002): “Macroeconomic forecasting using diffusion indexes”, *Journal of Business and Economic Statistics*, vol 20, no 2, pp 147–62.

——— (2003): “Forecasting output and inflation: the role of asset prices”, *Journal of Economic Literature*, vol 41, no 3, pp 788–829.

Strahan, P (2008): “Liquidity production in 21st century banking”, *NBER Working Papers*, no 13798.

Van den End, J W, M Hoeberichts and M Tabbae (2006): “Modelling scenario analysis and macro stress-testing”, *DNB Working Papers*, no 119.

Van den Heuvel, S J (2002): “Does bank capital matter for monetary transmission?”, *Federal Reserve Bank of New York Economic Policy Review*, vol 8, no 1, pp 259–65.

——— (2008): “The welfare cost of bank capital requirements”, *Journal of Monetary Economics*, vol 55, no 2, pp 298–320.

Van Lelyveld, I, F R Liedorp and M Pröpper (2009): “Stress testing linkages between banks in the Netherlands”, in M Quagliariello (ed), *Stress testing the banking system: methodologies and applications,* Cambridge University Press.

Van Rijckeghem, C and B Weder (2001): “Sources of contagion: is it finance or trade?”, *Journal of International Economics*, vol 54, no 2, pp 293–308.

Wagner, W (2006): “Diversification at financial institutions and systemic crises”, *Tilburg University Center for Economic Research Discussion Paper*, no 71.

——— (2008): “The homogenization of the financial system and financial crises”, *Journal of Financial Intermediation*, vol 17, pp 330–56.

Woo, D (2003): “In search of ‘capital crunch’: supply factors behind the credit slowdown in Japan”, *Journal of Money, Credit, and Banking*, vol 35, no 6, pp 1019–38.

Wagster, J D (1999): “The Basle Accord of 1988 and the international credit crunch of 1989–1992”, *Journal of Financial Services Research*, vol 15, no 2, pp 123–43.

Zhu, H (2008): “Capital regulation and banks’ financial decisions”, *International Journal of Central Banking*, vol 4, no 1, pp 165–211.