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

Christian Upper and Thomas Werner,[1]
Deutsche Bundesbank

1. Motivation

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

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

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

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

---

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

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

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

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

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

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

2. Spot-futures pricing relation and obstacles to arbitrage

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

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

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

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

3. The German bond market as a “safe haven”

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

---

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

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

Table 1

Chronology

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

Source: BIS (1999).

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

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

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

4. Market microstructure and data

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

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

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

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

---

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

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

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

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

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

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

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

Table 2

Summary statistics

(2 January to 7 December 1998)

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

[1] Roll (1984) statistic.

5. Market activity and liquidity

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

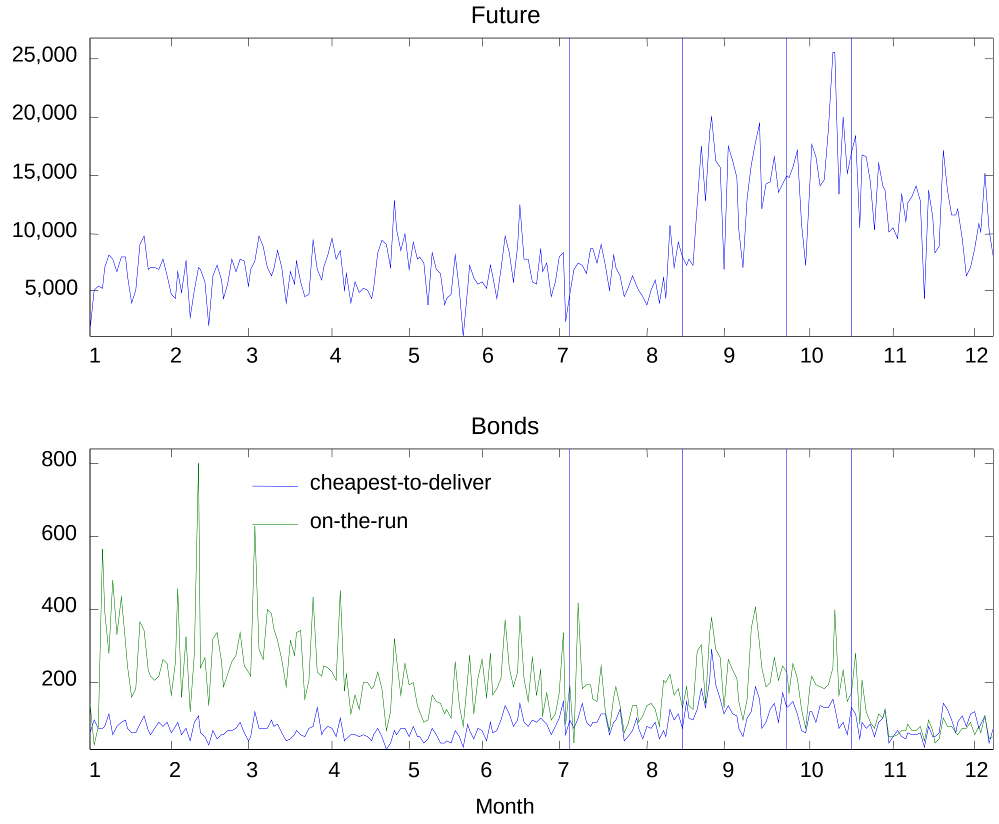
[10] On 28 October 1998, a new Bundesanleihe was issued which is not contained in our data set. Hence our data cover only the second most recent issue during the last two months of the sample period.

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

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

Figure 1

Number of transactions per trading day



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

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

Figure 2

Daily turnover (DM billions)

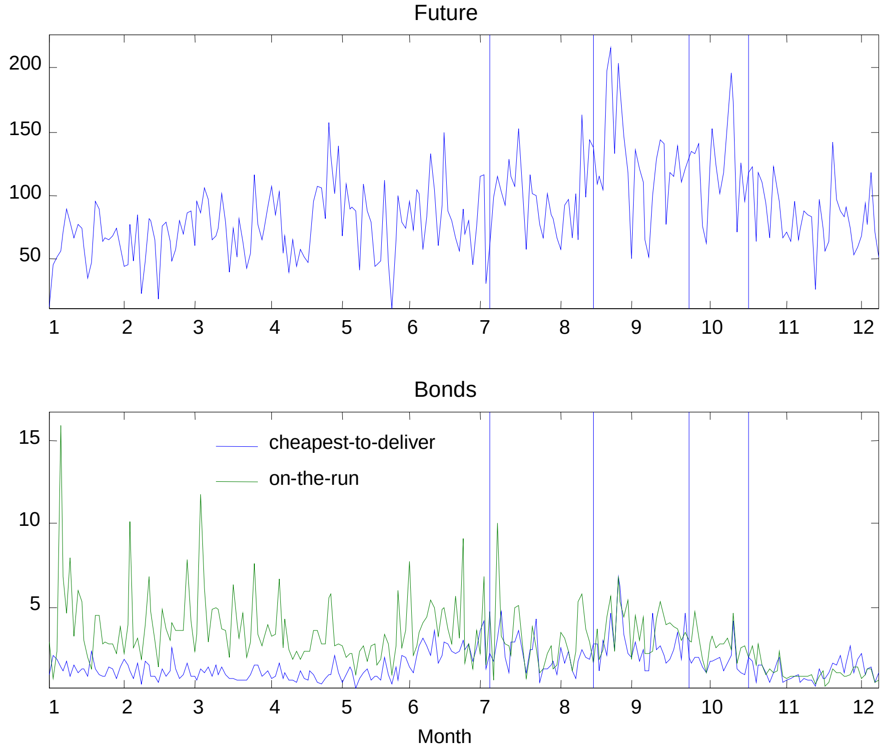


Figure 3

Average trade size (DM millions)

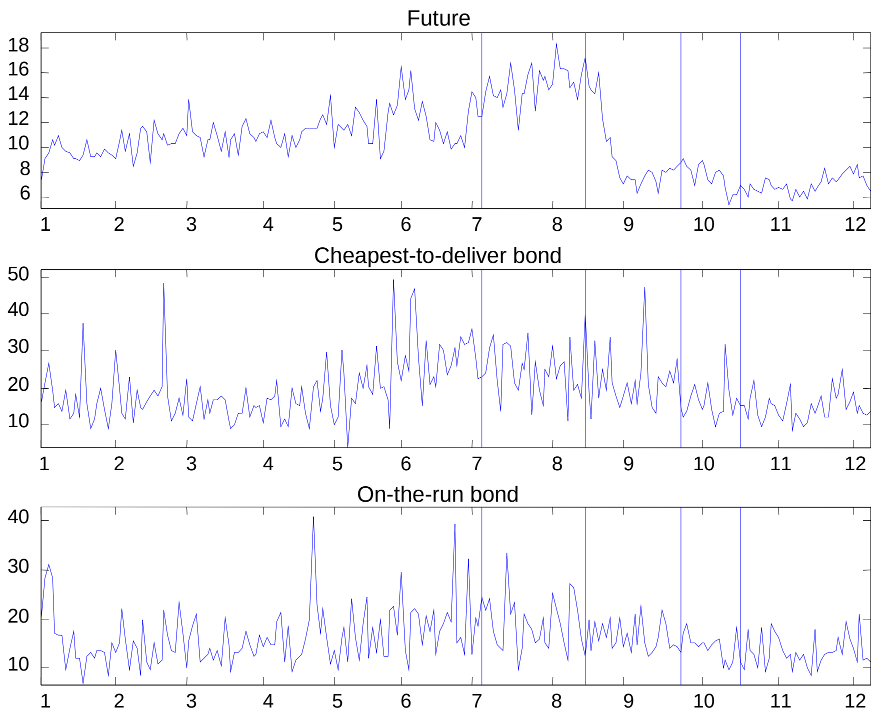
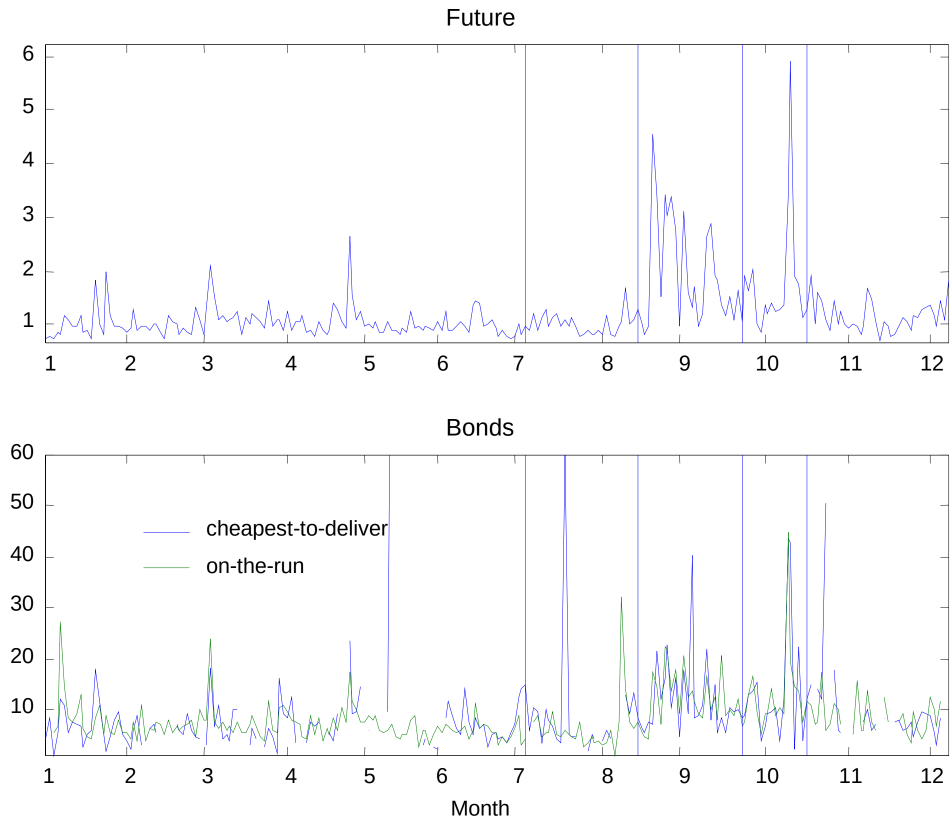


Figure 4

Effective bid-ask spreads



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

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

---

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

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

6. Spot-future pricing relationship

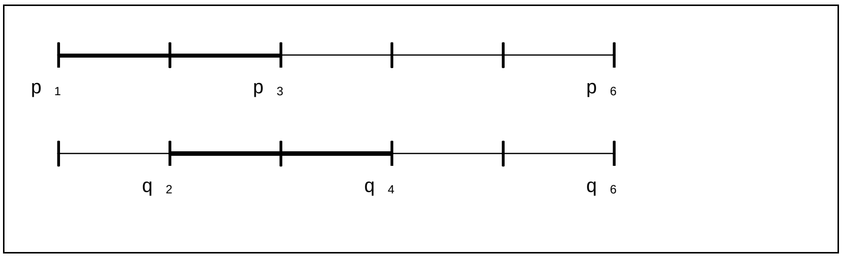
6.1 Short-run information flow

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

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

Figure 5

Sampling at irregular intervals



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

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

or, after taking expectations, as

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

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

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

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

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

---

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

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

Figure 6

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

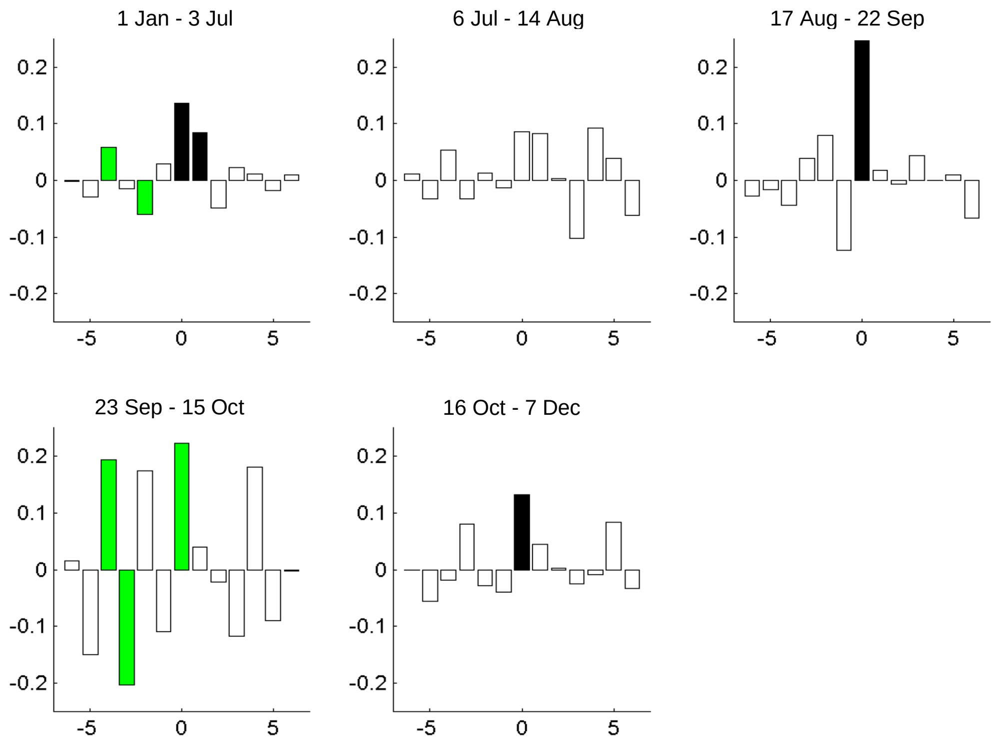
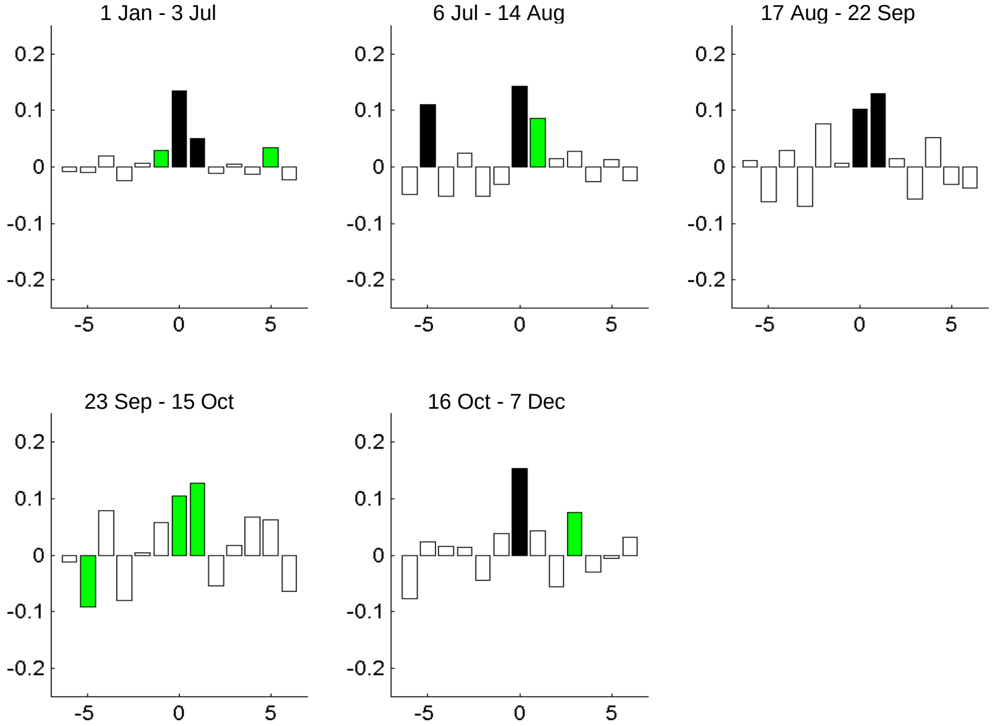


Figure 7

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



6.2. Equilibrium adjustment

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

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

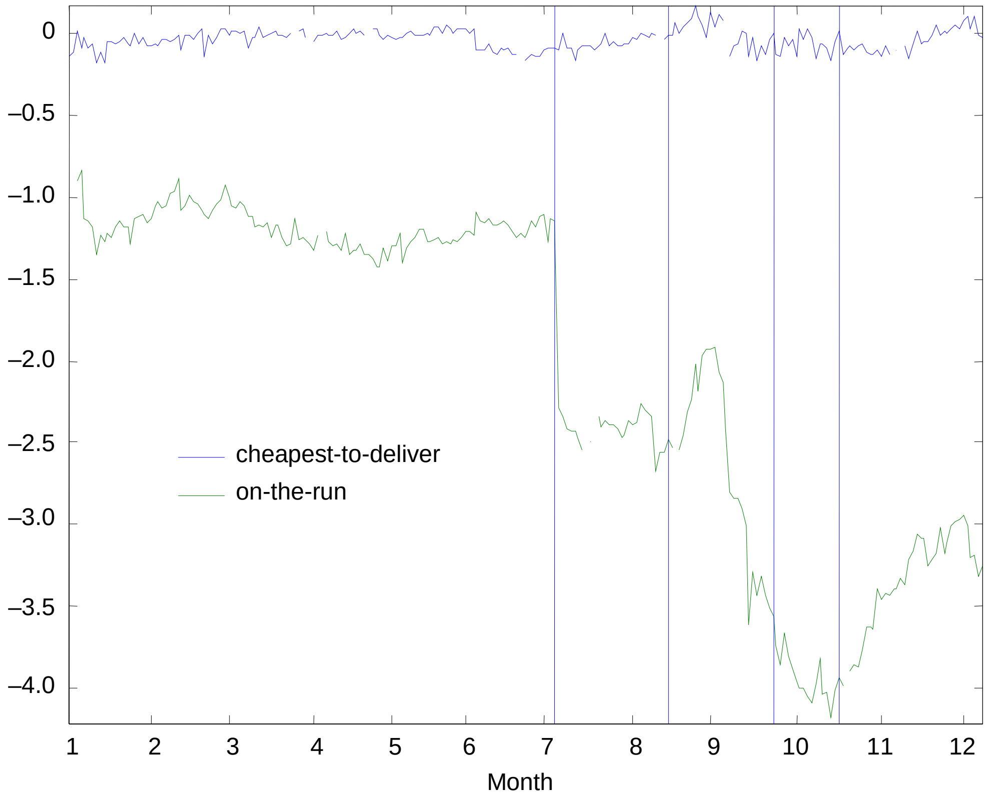
$$\Delta s_t = \alpha_s(f_{t-1} - \mu - \theta s_{t-1}) + a_{1s}\Delta s_{t-1} + a_{2s}\Delta s_{t-2} + \ldots + b_{1f}\Delta f_{t-1} + b_{2f}\Delta f_{t-2} + \ldots$$

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

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

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

Figure 8
Basis



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

[16] Or last available during the previous hour.

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

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

Table 3
Error correction model[1]

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

[1] t-values in parenthesis.

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

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

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

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

7. Conclusions

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

We find that trading costs rose considerably, first in the wake of the Russian default in mid-August and, more severely, in early October. The former episode coincided with much heavier trading than normal. This suggests that part of the rise in trading costs may be due to the fact that effective spreads tend to get larger as transaction size increases. The rise in bid-ask spreads thus seems to overstate the reduction in liquidity. We are not as confident when it comes to explaining the skyrocketing of spreads on 8 and 9 October. Turnover was somewhat higher than normal in the futures market but close to normal in the spot market. This indicates that the provision of liquidity was severely impaired.

The finding that markets seem to have weathered the Russian default better than the deleveraging during the LTCM episode comes as a surprise. Although in both cases the trigger was outside the German financial system, some local banks were heavily exposed to Russia but apparently much less so to LTCM. If anything, we would therefore have expected the strain on German markets to be more severe in August than in October.

In the second part of the paper we analysed the pricing relationship between the futures and the spot market. We find that the link between the bund future to the underlying cheapest-to-deliver remained relatively stable, although the short-run information flow between the two market segments seems to have changed during the turbulence. Those investors that used the bund future to hedge positions in bonds other than the cheapest-to-deliver could have suffered heavier losses, though. For example, the pricing relationship between the future and the on-the-run bond is not particularly stable even during normal times. During the turbulence, faced with a massive inflow of funds related to the flight into quality and liquidity, the relationship broke down and any hedge became much less effective.

References

Bank for International Settlements (1999): *A review of financial market events in autumn 1998*, Committee on the Global Financial System, October.

Brady (1989): *Report of the presidential task force on market mechanisms*.

De Jong, F and T Nijman (1997): “High frequency analysis of lead-lag relationships between financial markets”, *Journal of Empirical Finance*, 4, pp 259-77.

De Jong, F, R Mahieu and P Schotman (1998): “Price discovery in the foreign exchange market: an empirical analysis of the yen/dmark rate”, *Journal of International Money and Finance*, 11, pp 5-27.

Deutsche Bundesbank (2000): “The impact of financial market crises on the German securities markets”, *Monthly Report*, April, pp 15-30.

European Central Bank (2001): *The monetary policy of the ECB*, Frankfurt.

International Monetary Fund (1998): *World economic outlook and international capital markets interim assessment*, December.

Roll, R (1984): “A simple implicit measure of the effective bid-ask spread in an efficient market”, *Journal of Finance*, 39, pp 1127-40.

Schulte, W and R Violi (2001): “Interactions between cash and derivatives bond markets: some evidence for the euro area”, *BIS Papers*, no 5.

Steiner, M and C Bruns (2000): *Wertpapiermanagement*, 7th ed, Stuttgart: Schäffer Poeschl.

Upper, C (2000): “How safe was the ‘safe haven’? Financial market liquidity during the 1998 turbulences”, Economic Research Group of the Deutsche Bundesbank, *Discussion Paper 1/00* (reprinted in Bank for International Settlements (2001)), “Market liquidity: proceedings of a workshop held at the BIS”, *BIS Papers*, no 2.

Upper, C (2001): “Measuring liquidity under stress”, in Bank for International Settlements (2001), “Market liquidity: proceedings of a workshop held at the BIS”, *BIS Papers*, no 2.