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The tail wags the dog: time-varying information shares in the Bund market

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Abstract

The paper analyses the information content of trades in Bund futures and German government bonds before and during the 1998 financial market turbulences and tests whether the contributions to price discovery of the two market segments were constant over time. The results suggest that, under the normal market conditions prevailing in the first half of the year, between 19% and 33% of the variation in the efficient price was due to trading in the spot market. In the aftermath of the recapitalisation of LTCM, by contrast, the bond market's share in price discovery dropped to zero, with information becoming incorporated into prices only in the futures market. This decline can be traced to an unusually high proportion of large client trades that were executed against dealer inventory, which suggests that they were primarily motivated by liquidity rather than by information. On the methodological side, the paper computes information shares and factor weights based on the Gonzalo-Granger decomposition in markets with different trading frequencies. In addition, the paper captures variations over time by using a sequence of break point tests.

JEL Classification Numbers: G13, G14

Keywords: Information shares, bond futures, upstairs markets

Contents

The tail wags the dog: time-varying information shares in the Bund market[1]

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Futures on government bonds require much smaller cash outlays than the underlying bonds for taking positions in long-term interest rate risk; they are very liquid and feature among the most heavily traded financial contracts worldwide. Given the attractiveness of bond futures, it is not surprising that price discovery has increasingly shifted from the spot to the futures market, as is shown by a growing literature which includes this paper. However, little is known about how the informational role of the futures market is affected by market stress. The paper extends the literature on the relationship between spot and futures markets by analysing the contributions to price discovery of trading in the Bund future and the underlying German government bonds in 1998 and tests whether they were stable over time. The Bund future is the most heavily traded government bond contract in the world and has become a prime vehicle for hedging long-term interest rate risk in the euro area, while the underlying 10-year Bundesanleihen have established themselves as the benchmark in the long-term segment of the euro yield curve.[4] The year 1998 is especially suited to analysing the

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[1] Most work on the paper was undertaken while the authors were economists at the Deutsche Bundesbank. We thank Claudio Borio, Felix Hüfner, Bruce Lehman, Thilo Liebig, Frank Packer, Jörg Rocholl and Philip Wooldridge as well as seminar participants at the Bank for International Settlements, Deutsche Bundesbank and Studienzentrum Gerzensee for their valuable comments. The opinions expressed in this paper are the authors' own and do not necessarily reflect those of the Bank for International Settlements, the Deutsche Bundesbank or the European Central Bank.

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[3] European Central Bank. Directorate General Economics.

[4] Although 1998 preceded the advent of the euro, at that stage EMU was taken for granted by most market participants.

behaviour of markets under stress since it featured the default of Russia in mid-August, the near-bankruptcy of the hedge fund Long-Term Capital Management (LTCM) the following month and other episodes of stress.

The contributions to price discovery of trading in spot and futures markets are measured by the information shares of Hasbrouck (1995) and factor weights obtained from a Gonzalo-Granger decomposition. Both methods are based on a vector error correction model (VECM) and allow the separation of long-run price movements based on information from short-run microstructure noise. Since there are by an order of magnitude more transactions in the futures market than in the underlying bonds, the VECM is rewritten in state space form to handle missing observations with the Kalman filter. In a second step, the robustness of the estimates is checked using a sequence of break tests.

The results show that a number of structural breaks in the pricing relationship between the spot and futures markets occurred during 1998. In particular, the information share of the spot market dropped from between 19% and 33% of the variation in the efficient price in the first half of the year to virtually zero during the two weeks after the LTCM recapitalisation on 23 September. By contrast, the informational content of spot trading had hardly changed in the aftermath of the Russian default five weeks earlier, even though the tests indicate a break in the parameters of the VECM. The information content of bond trades appears to be linked to large client trades that do not affect dealer inventory. Such transactions tend to have a larger price impact than trades in which dealers enter as counterparties, which is consistent with them being more likely to be motivated by information. Approximately 40% of all large trades fell into this category in the first, tranquil part of the year. This number changed only slightly following Russia’s default in mid-August 1998, but dropped to less than one third in late September and early October when the information share of the spot market dropped to zero.

Price discovery in bonds and bond futures is also analysed by Mizrach and Neely (2005) for the United States and Campbell and Hendry (2006) for Canada. Mizrach and Neely find that US Treasury notes and bonds dominated price discovery until 1999, after which both the Gonzalo-Granger factor weight and the information share of spot trading dropped below one half. Campbell and Hendry report that bonds accounted for approximately 30% of price discovery in the Canadian market in the early 2000s.[5]

This paper differs from these studies by explicitly testing whether the pricing relationships found under normal market conditions continue to hold in periods of stress. This is important because the 1998 turbulences saw the breakdown of several pricing relationships that market participants had taken as given, leading to substantial losses at many market participants, most prominently LTCM. Previous work on price discovery under stress has focused on single market segments only and has ignored any linkages between markets. For example, Upper (2001) studies liquidity in the German government bond market during 1998, whereas Furfine and Remolona (2002) and (2005) analyse price discovery in the US Treasury market during the same period. While a good understanding of a single, large market is clearly important, these studies do not give much indication as to how stress affects the pricing relationships

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[5] Most other studies comparing the contributions to price discovery of futures and cash instruments (or different types of futures) focus on the pricing relationship between individual US stocks and stock index futures (for references see Hasbrouck (2003)). They generally find the futures market dominant in terms of price discovery, although there are also measurable effects in the reverse direction. However, it is not clear to what extent these findings can be transferred to bonds and bond futures, which refer to a single bond chosen from a basket of deliverables rather than to an index (see Subrahmanyam (1991)). A related literature focuses on the lead-lag relationships between futures and spot markets. For example, Scalia (1998) finds that futures prices lead Italian bond prices by up to 20 minutes, although the lead weakens on days with a lot of “bad news”. Another strand of the literature (eg Hasbrouck (2003), Kurov and Lasser (2004), Ates and Wang (2005), Chou and Chung (2006)) studies the contributions to price discovery of conventional, pit-traded futures contracts, electronically traded E-minis and exchange-traded funds (ETFs). To the extent that the choice between futures and bonds is also affected by differences in the microstructures of the two markets and not only by different instrument characteristics, the present paper is also related to a large body of literature that studies the impact of trading mechanisms on price discovery. We will turn to some papers in this vein when discussing the effect of market microstructure on informed investors’ choice of where to trade.

between markets, which could have important implications for the usefulness of hedging strategies.[6]

The remainder of the paper is structured as follows. Section 1 describes differences in instrument characteristics and market microstructure that may affect the decision of informed investors as to where to trade. Section 2 discusses the data and section 3 the econometric methodology used to compute the contributions to price discovery. The estimation results are presented in section 4 and are related to information on the composition of trades in section 5. A final section concludes.

1. Market microstructure and the choice of where to trade

Why would informed market participants prefer to trade in bonds rather than futures?[7] The higher liquidity of the futures does not provide an ultimate reason for the choice of trading, since liquidity is largely endogenous. Instead, the decision must be related either to the nature of the instruments or to the microstructure of the two markets.

The key characteristics which distinguish a futures contract from the underlying security are summarised in table 1. Perhaps the most important differences between these two types of contracts are the amount of cash required to attain a given exposure and the timing of the cash injections. Cash requirements for trading in the futures market are much lower than those for

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[6] See CGFS (1999) for an overview of the 1998 turbulences. For a more conceptual approach to the provision of liquidity under stress and the lessons learned from 1998, see Borio (2004).

[7] In fixed-income markets, informed traders are those with a superior ability of forecasting interest rate developments or with inside knowledge of the order flow.

Table 1

Bonds and bond futures

	Bundesanleihe	**Bund future**
1. Contract features		
Cash requirements	high	low
Timing of payments	immediately	initial + variation margin, settlement at expiry
Short positions	difficult	easy
2. Market microstructure		
Concentration of trading	fragmented	concentrated
Matching of counterparties	by search	automated
Centralised order book	no	yes
Transparency …		
… of order book	no	yes
… disclosure of past trades	no	yes
…. anonymity of counterparty	no	yes

the spot market as traders merely have to post a margin when entering a position rather than purchasing a bond outright. While margins are adjusted each day, settlement of the future takes place at maturity. Moreover, only a few transactions are settled by physical delivery as traders tend to close positions by offsetting trades. The low cash requirements in the futures market should make these instruments particularly attractive for speculative trading, which presumably contributes more to price discovery than liquidity trading. However, this advantage may diminish if prices are volatile, since margin calls tend to drive up cash requirements in the futures market.

Another advantage of futures over bonds is that they can easily be used to take short positions. Shorting a bond is more difficult since traders first have to enter a repo transaction to borrow the bond they wish to sell. As a consequence, we would expect both the hedging of and position-taking in long-term interest rate risk to occur in the futures market, which should drive up its information share. This is in line with evidence from Naik and Yadav (2003) that dealers in UK government bonds hedge almost entirely by trading in futures rather than in bonds.

In 1998, the year of the sample, the microstructure of the futures market for German government bonds was very different from that of the spot market, although the differences have narrowed since then. First of all, bond trading was much more dispersed than futures trading, both in terms of the number of contracts active at any given point in time and in terms of trading venues. While trading in Bund futures was concentrated on Eurex,[8] bonds were mainly traded over the counter, either by telephone or through inter-dealer brokers. In addition, they were listed on the Frankfurt Stock Exchange and on regional exchanges, but those transactions were generally small and their share in total turnover low.[9] In addition, while trading in the futures market was concentrated on the nearby maturity, existing bonds continued to be traded after a new one was issued. Moreover, the most recent issue was generally more liquid than the cheapest-to-deliver. The fragmentation of the spot market should matter in particular under volatile market conditions, when the costs of searching for a counterparty are high. However, while this should reduce the attractiveness of bonds for informed investors, it may not eliminate it completely if there are liquidity traders who, for whatever reason, cannot switch to another market. Chowdhry and Nanda (1991) argue that informed traders may use such transactions to “hide” their trades.

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

[9] 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. While these developments may have reduced the dispersion of bond trading across trading venues (although multiple platforms continue to exist), they have not reduced the fragmentation of liquidity across the different bonds.

A second difference concerns the matching of counterparties. In the futures market, the electronic limit order book of Eurex ensures the immediate execution of trades at predictable costs, whereas trading in the spot market may involve search costs and the risk of price movements. In fast markets, however, it may not be attractive for traders to place limit orders as prices may move against them, which would suggest a higher contribution to price discovery of the spot market. This reasoning has been confirmed in previous work comparing electronic trading of Bund futures on the DTB (the predecessor of Eurex) and floor trading on LIFFE. For example, Martens (1998) shows that trading on the DTB contributed more to price discovery than trading on LIFFE when volatility was low, but the ordering was reversed in fact markets. Similarly, Frino, McInish and Toner (1998) find that bid-ask spreads on the DTB were below those at LIFFE except when volatility was high. However, it is not clear to what extent comparisons between floor and electronic trading translate to the case of electronic trading and decentralised OTC markets, where search costs are higher than on the floor of an exchange.

The third factor related to differences in market microstructure that may affect the location of informed trading is the precise nature of transparency. While the limit order book of Eurex is open to all market participants and information on price and volume of past transactions is disseminated in real time, this was not the case in the spot market during our period of analysis. Even so, one cannot say that the futures market was more transparent than the spot market, where dealers could observe the identity of their immediate counterpart. The electronic limit order book of Eurex, by contrast, is fully anonymous. In this regard, the bond market was similar to the “upstairs” markets which are an important feature of many stock markets.[10] Two hypotheses have been put forward to explain the existence of upstairs markets

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[10] The analogy is not perfect for a number of reasons, including differences in the contract traded. In addition, many downstairs markets rely on floor brokers who know the identity of their counterpart, rather than being

alongside organised trading, be it on the floor or electronically. First, the lack of anonymity of upstairs markets, together with the ability to negotiate the precise terms of a deal, may render them attractive for large transactions, provided clients can convince dealers that their trades are not motivated by information. This is akin to the function of upstairs markets in the model of Seppi (1990).

Another factor explaining the attractiveness of upstairs trading stems from the observation that it is costly for investors to participate continuously in all markets or submit limit orders that are contingent on every state of the economy (Grossman (1992)). Upstairs brokers solve this problem by matching orders with the unexpressed demand (i.e. possible wishes to trade that have not been expressed in limit orders) of other market participants, facilitating trades that would otherwise not have occurred (Madhavan and Cheng (1997), Bessembinder and Venkatamaran (2004)). This matching function of upstairs markets is independent of whether or not trades are motivated by information. Indeed, one may even argue that the upstairs markets are particularly attractive for informed investors owing to their flexibility in handling non-standard order types or hiding potential liquidity.[11,12] The empirical literature is inconclusive on whether informed traders prefer anonymity. While the results of Grammig, Schiereck and Theissen (2001) suggest that they do, Reiss and Werner (2005) find that, in the London inter-dealer market, informed dealers tend to trade directly, i.e. without the added

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fully anonymous as with Eurex. Another difference is that, unlike the Bund market, upstairs markets tend to have certain requirements regarding the publication of past trades.

[11] Unlike other electronic trading systems, e.g. that of the French Stock Exchange, Eurex does not permit traders to hide limit orders.

[12] At the NYSE, this function in performed by floor brokers, who often execute much more complex orders than those permissible on electronic systems and have considerable discretion as to the timing of the trades (Blume and Goldstein (1997), Sofianos and Werner (2002)). Werner (2003) finds that orders executed by floor brokers tend to have a higher information content than those submitted electronically. See also Cooney and Sias (2004).

anonymity of an inter-dealer broker, because prices in anonymous markets reflect the risk of asymmetric information.

To sum up, instrument characteristics and market microstructure should make futures more attractive than bonds for informed traders, which should result in a larger contribution to price discovery of that market. However, futures may lose some of their edge when volatility is high, as margin calls drive up cash requirements and placing limit orders becomes more risky. We would therefore expect the information role of the spot market to increase in times of stress.

2. Contract details and data

The Bund future refers to a notional German government bond with a face value of DM 250,000[13] and a coupon of 6%. At expiry of the contract, the seller of the future can choose to deliver any German government bond (Bundesanleihe) with a residual maturity of 8½ to 10½ years 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 the obligations arising from a futures position by delivering one rather than another issue. Consequently, only one of the bonds contained in the basket, the so-called cheapest-to-deliver (ctd), tends to be delivered.

The data used in this paper covers all transactions in the Bund future and the cheapest-to-deliver bonds that took place in Germany between 2 January and 7 December 1998. Although the ctd bond was not the most actively traded deliverable bond during the period (see Upper

(2001) for activity and liquidity measures of all deliverable bonds in 1998), trading strategies that link futures and spot markets tend to focus on this issue rather than the more liquid on-the-run bond.

Prices and trading volumes of the Bund future are from Deutsche Börse AG and cover the contracts with the expiry dates March, June, September and December 1998. While this data is generally of high quality, it does not contain any information on the counterparts of the individual trades. A second data set from the German regulator (Bundesanstalt für Finanzdienstleistungsaufsicht – BaFin) covers both the Bund future and the underlying bonds. In contrast to the data by Deutsche Börse, it also includes OTC transactions. This is particularly important for the bond market, where trades typically take place outside organised exchanges. In addition to providing information on prices and volumes, the reporting dealers have to state whether (i) they traded on their own account or for a client, and (ii) whether the transaction affected their own position in the respective asset. This information will later be used to distinguish between informed trading and transactions motivated by liquidity needs. One drawback of the BaFin data is that it contains separate entries for the two legs of each transaction. Unfortunately, matching the data proves to be very difficult,[14] which reduces the reliability of the series concerning the number and volume of trades. By contrast, matching problems should not have much of an impact on the series for prices and trade sizes.

Neither data set contains information on trades executed outside Germany. In particular, they do not cover trading in Bund futures on LIFFE, which in the first quarter of 1998 accounted

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[13] The Euro Bund future, which replaced the Bund future in the transition to EMU, has a contract value of EUR 100,000.

[14] A detailed description of the data and the matching procedure can be found in Upper (2001).

for approximately one third of all trading in this type of contract. However, trading on LIFFE quickly faded in the second quarter of 1998 and was discontinued towards the end of the year, implying that the presence of the London-traded contract should not have any bearing on our results for most of the year. Ignoring offshore trading in the underlying bonds may potentially be more serious, but discussions with market participants suggested that, just as in the futures market, a considerable proportion of the bond trading that used to take place outside Germany had migrated back by 1998. Anyway, significant London trading would only be an issue if the London and Frankfurt markets were not fully integrated.

The analysis is based on transaction prices rather than quotes. This is important in the case of the spot market as quotes were not binding and, according to market contacts, most trading took place at prices inside the bid-ask bracket. Using traded prices does, however, introduce a certain amount of noise due to the bid-ask bounce. Nevertheless, this should not affect the permanent component on which the measures for price discovery are based.

Given the staggered nature of the Bund future, we create a long time series by considering only the contract that was most actively traded on a given trading day. Since trading is concentrated in the nearby maturity and switches to a new contract within a few days, our spliced series contains more than 95% of all transactions. A similar series is constructed for the underlying bond. The difficulty here is predicting which bond is cheapest-to-deliver at the maturity of the future. Fortunately, as long as market interest rates remain below 6%, the formula used to compute the conversion factors implies that this will be the bond with the lowest duration in the basket. Since 10-year yields stood at around 4% in 1998, the probability of a switch in the cheapest-to-deliver was virtually zero. In order to ensure comparability with the future, bond prices are converted into future-equivalents. For this purpose, we require repo rates with maturities coinciding with the expiry dates of the future contracts, which could not be obtained. Instead, we use the two-month FIBOR to calculate the cost of carry. This should not have any consequences for our results concerning the transmission of information in the very short term, since the spread between the two rates tends to move relatively slowly.

Summary statistics of the two series are reproduced in table 2. Trading activity in the futures market far exceeds turnover in any deliverable bond. In 1998, there were around 50 times as many transactions in the future as in the on-the-run bond (not shown), and more than 100 times more than in the ctd. This discrepancy is huge by any standards and unlikely to be an artefact due to the imperfect matching or ignoring of trades outside Germany. Although there were, by an order of magnitude, fewer transactions in the underlying bonds, their average size was double that in the futures market. This is in line with what we would expect if the bond market played the role of an upstairs market. The number of client trades (as opposed to

Table 2

Summary statistics

(2 January to 7 December 1998)

Series	**Bund future**	**Cheapest-to-deliver bond**
Number of trades	2,111,602	19,186
Total volume (DM billion)	20,786	375
Average trade size (DM million)	9.8	19.6
Client trades		
% of transactions	41%	37%
% of turnover	42%	53%
Client trades affecting dealers’ holdings		
% of transactions	0%	23%
% of turnover	0%	35%
Effective bid-ask spread[1] (bps of face value)	1.2	10.5

[1] Roll (1984) statistic.

market segments, although client trades in bonds were much larger on average than client transactions in futures or inter-dealer transaction in any market segment. Another difference between the two market segments concerns the importance of dealer inventory. While client trades in futures almost never affected dealer inventory (with the exception of two OTC trades in the first half of the year), dealers in the bond market often took positions in client trades. Finally, the futures market was far more liquid than the bond market, as is indicated by the far lower effective bid-ask spreads. This difference appears to be too large to be solely explained by differences in trade sizes.

3. Methodology

Under the assumption that no arbitrage opportunities exist, the theoretical price p^{*f} of a futures contract corresponds to the price p^s of the underlying plus a cost of carry c:

$$p^{*f} = p^s + c \,. \tag{1}$$

In the case of bond futures, c can be decomposed into the interest earned on the bond and the cost of financing the bond position, typically through a repo transaction. Since c can readily be computed and is outside our focus of analysis, it is more convenient to work with adjusted spot prices $\overline{p}_t^s \equiv p_t^s - c_t = p^{*f}_t$ that correspond to the theoretical futures price derived from the no-arbitrage condition (1).

The deviation of the adjusted spot price and the *actual* futures price on the market is called the basis. In algebraic terms, $b_t \equiv \overline{p}_t^s - p_t^f$. In practice, the basis is normally close to, but not identical to, zero, suggesting 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 becomes profitable. Another reason for a basis different from zero is the fact that, in the real world, arbitrage does involve risks. Potential arbitrageurs face at least three distinct types of risk. First, prices may move between the execution of the different legs of a transaction if it is not possible to transact in the spot, futures and repo markets simultaneously. Second, holding a position may be subject to capital requirements or margin calls even if it is fully hedged. Third, the holder of a short position in bonds and a long position in the future risks ending up with the "wrong" bond if the cheapest-to-deliver changes. All these factors imply that we should 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.

In empirical work, it has proved convenient to model the process driving the prices in the futures and spot markets as a vector error correction model (VECM)

$$\Delta \mathbf{p}_t = \Pi \mathbf{p}_{t-1} + \sum_{j=1}^{k-1} \mathbf{A}_j \Delta \mathbf{p}_{t-j} + \mathbf{u}_t \ , \tag{2}$$

where $p_t = \left(\bar{p}_t^s, p_t^f\right)$. From equation (1) it follows that the adjusted spot and futures prices should be cointegrated with a cointegrating vector (1,-1)', which is imposed by assumption. As a consequence, the matrix $\boldsymbol{\Pi}$ has rank one and can be written as

$$\Pi = \begin{pmatrix} \alpha_1 & -\alpha_1 \\ \alpha_2 & -\alpha_2 \end{pmatrix},$$

where α_1 and α_2 are the adjustment coefficients or loading factors.

The VECM (2) forms the basis of two competing methodologies to measure the relative contributions of the two markets to price discovery: the information shares introduced by Hasbrouck (1995) and the factor loadings based on the Gonzalo and Granger (1995) decomposition.[15] Both are based on a decomposition of transaction prices into a permanent component associated with the fundamental or efficient price of the asset, and a transitory component which reflects noise such as the bid-ask bounce. In the case considered here, the fundamental or efficient price should be identical in both markets while the transitory component may differ. The question is in which market information is first incorporated into the efficient price.

The two methodologies differ in terms of how the permanent component is identified. Hasbrouck's information shares (IS) are based on a Stock and Watson (1988) common stochastic trend decomposition to decompose transaction prices into a random walk, which can be interpreted as the efficient price, and noise. The information shares correspond to the contribution of each market to the variance of the efficient price. Unfortunately, they are not uniquely defined if the price innovations in the two markets are correlated. In this case, upper (lower) bounds for the information shares have to be computed by attributing as much (little) news as possible to each market.

The second approach based on the Gonzalo Granger (GG) decomposition, used e.g. by Booth, So and Tse (1999), does not suffer from this problem as the contributions of each market are uniquely defined. Transaction prices are decomposed into a permanent component, which is integrated of order 1, and a transitory component that is stationary. They are unique assuming (i) that the permanent component is a linear combination of the prices in both markets, and (ii) that the transitory component does not Granger-cause the permanent component in the long run. One drawback of the GG approach is that the permanent component need not be a random walk and may therefore be forecastable. As pointed out by Hasbrouck (2002), this violates the condition that the efficient price should be a Martingale. A second limitation,

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[15] A special issue of the Journal of Financial Markets has been devoted to an assessment of the relative merits

pointed out by Baillie et al (2002), is that the GG factor weights, in contrast to the information shares approach, do not take into account the information contained in the variances of the price innovations.

Transactions in financial markets take place at irregular intervals that differ between market segments. The usual approach to handling this is to split the time axis into subperiods of a fixed length and only consider the last transaction in every interval. If an interval is empty, then the last available value is used. This “fill-in” approach has a major drawback: non-trading may produce a lower information share for the less frequent trading market even if the trades that take place do contain information. To circumvent this problem we use a state space method to handle the missing value problem.

The VECM (2) can be written in a state space form with a state equation

$$\begin{pmatrix} \mathbf{p}_t \\ \mathbf{p}_{t-1} \\ \vdots \\ \mathbf{p}_{t-p+1} \end{pmatrix} = \begin{bmatrix} \mathbf{A}_1^* & \mathbf{A}_2^* & \cdots & \mathbf{A}_p^* \\ \mathbf{I} & \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \vdots & \vdots & \vdots & \vdots \\ \mathbf{0} & \cdots & \mathbf{I} & \mathbf{0} \end{bmatrix} \begin{pmatrix} \mathbf{p}_{t-1} \\ \mathbf{p}_{t-2} \\ \vdots \\ \mathbf{p}_{t-p} \end{pmatrix} + \begin{pmatrix} \mathbf{u}_t \\ \mathbf{0} \\ \mathbf{0} \\ \mathbf{0} \end{pmatrix} \qquad (3a)$$

and an observation equation

$$\mathbf{y}_t = \begin{bmatrix} \mathbf{I} & \mathbf{0} & \cdots & \mathbf{0} \end{bmatrix} \begin{pmatrix} \mathbf{p}_t \\ \mathbf{p}_{t-1} \\ \vdots \\ \mathbf{p}_{t-p+1} \end{pmatrix}, \qquad (3b)$$

where $\mathbf{A}_1^* = \mathbf{I} + \begin{pmatrix} \alpha_1 & -\alpha_1 \\ \alpha_2 & -\alpha_2 \end{pmatrix} + \mathbf{A_1}$, $\mathbf{A}_p^* = -\mathbf{A_{p-1}}$, and $\mathbf{A}_j^* = \mathbf{A}_j - \mathbf{A}_{j-1}$ for j = 2,...p-1. **I** stands for the identity matrix and **0** for a matrix of zeros.

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of the two measures. See Lehman (2002) for an overview.

Since the state vector is only partially observable because of the missing values, the likelihood is computed using the Kalman filter.[16] As starting values, we use OLS estimates from an auxiliary data set containing the price of the last available transaction.

To assess potential time variation in the information share measures, we test for structural changes using a method proposed by Bai (1997), which is based on a sequence of tests for unknown break points. The classification of different time periods gives almost the same information as time-varying parameters.

The test is based on a parametric model with parameter vector **β,** the null hypothesis

$$H_0\text{: } \boldsymbol{\beta}_t = \boldsymbol{\beta}_0 \text{ for all } t \geq 1,$$

and an alternative with change point $\pi \in (0,1)$ [17]

$$H_1(\pi) : \beta_t = \begin{cases} \boldsymbol{\beta}_1(\pi) & \text{for } t = 1,\cdots,T\pi \\ \boldsymbol{\beta}_2(\pi) & \text{for } t = T\pi + 1,\cdots,T. \end{cases}.$$

H_0 is rejected in favour of H_1 if $\sup_{\pi \in \Pi} F(\pi)$ is greater than the critical value computed by Andrews (1993). In principle, Wald, Likelihood Ratio or Lagrange Multiplier could be used, but in our case only the latter is feasible in terms of computing time as it is based on the parameters estimated under the null hypothesis.

4. Contributions to price discovery

The VECM (2) is estimated with three lags. While computational difficulties prevented the use of formal information criteria, coefficients on fourth-order lags were not significant, and

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[16] The treatment of missing values in the Kalman filter iterations is standard and explained, for example, in Harvey (1989), section 3.4.7.

[17] If T is the sample size, then πT is the time of change.

the fact that their inclusion substantially slowed the rate of convergence suggests that three lags are appropriate.

The results for the test for parameter stability are collected in table 3. The test statistic peaks on 4 June (observation 105), suggesting that this is the most likely break point. The VECM is reestimated for the two periods before and after this date, and the tests are repeated for each of the two subsamples. While the estimates appear to be stable in the period up to 4 June, there is evidence for a break in the latter part of the year, with 20 July as the most likely break point. This procedure is repeated until all the subsamples are stable. As a robustness check, adjacent intervals are combined and the most likely break dates are reestimated, which yields the same dates.

It is interesting to note that two of the subperiods identified by the break tests, namely the one ranging from 21 August to 23 September and the one from 24 September to 8 October, correspond closely to the Russia and LTCM phases identified in the post-mortem of the 1998 turbulences in the international financial markets published by the Bank for International Settlements (1999). One difference is that the tests used here identify 20 August and not 17 August, the day of the Russian debt moratorium, as the most likely break. This could indicate that market participants initially expected a bailout by the IMF and the sell-off occurred only after that failed to materialise. The second difference concerns the end of the period one may refer to as the LTCM episode. While the CGFS (1999) report identified the Federal Reserve's inter-meeting rate cut on 15 October as the end of this period, the results in this paper point to the sharp appreciation of the Japanese yen on 7/8 October as the defining event. Of the other break points identified by the tests, only the ones on 20 July and 12 November are associated with any identifiable event (the first public mention of LTCM losses and the request for a formal IMF programme by Brazil, respectively).

Table 3

Test statistics and break points

Sample	Dates	Sup-LM[1]	Break Date
[1-236]	2 Jan. – 7 Dec.	120.24*	105
[106-236]	5 June – 7 Dec.	59.12*	136
[106-136]	5 June – 20 July	6.15	-
[137-236]	21 July – 7 Dec.	17.12*	183
[137-183]	21 July – 23 Sept.	43.95*	159
[137-159]	21 July – 20 Aug.	32.05*	145
[146-159]	3 Aug. – 20 Aug.	5.28	-
[137-145]	21 July – 31 July	2.21	-
[160-183]	21 Aug. – 23 Sep.	8.27	-
[184-236]	24 Sep. – 7 Dec.	33.18*	194
[184-194]	24 Sep. – 8 Oct.	11.89	-
[195-236]	9 Oct. – 7 Dec.	16.14*	219
[195-219]	9 Oct. – 12 Nov.	8.12	-
	Robustness		
[146-183]	3 Aug. – 23 Sep.	50.51*	159
[160-194]	21 Aug. – 8 Oct.	49.12*	184
[184-219]	24 Sep. – 12 Nov.	23.04*	194

[1] A star signals significance at the 1% level. The critical value depends on the number of parameters and the fraction π_0 of the symmetric interval $[\pi_0, 1-\pi_0]$ used for the estimation. We use $\pi_0 = 0.2$ and the critical value is 15.09; see Andrews (1993), p. 840.

Estimates for the GG and IS measures as well as the variance of five-minute futures returns as a measure of volatility for the various subperiods are assembled in table 4. The parameters of the VECMs of the different subsamples are given in table A2 of the Appendix. During the first five months of the year, until 4 June, the lower and upper limits of the information share of the bond market were 19% and 33%, respectively, while the GG factor weight stood at

Table 4

Information content of bond trading*

Period	Dates	GG	IS (lower limit)	IS (upper limit)	σ^2
Early 1998	2 Jan. – 4 June	17%	19%	33%	0.026
		[8%, 27%]	[4%, 40%]	[13%, 56%]	
	5 June – 20 July	8%	7%	14%	0.021
		[-2%, 46%]	[0%, 95%]	[0%, 92%]	
	(21 July – 31 July)[**]	*(34%)*	*(45%)*	*(57%)*	0.017
	3 Aug. – 20 Aug.	2%	0%	7%	0.023
		[-41%, 18%]	[0%, 39%]	[0%, 39%]	
Russia	21 Aug. – 23 Sep.	20%	14%	37%	0.052
		[-11%, 40%]	[0%, 47%]	[2%, 72%]	
LTCM	24 Sep. – 8 Oct.	-8%	0%	2%	0.048
		[-28%, 5%]	[0%, 12%]	[0%, 21%]]	
	9 Oct. – 12 Nov.	11%	9%	25%	0.044
		[-49%, 39%]	[0%, 67%]	[0%, 80%]	
	13 Nov. – 7 Dec.	25%	20%	38%	0.030
		[-89%, 47%]	[0%, 62%]	[0%, 75%]	

[*] The 95% confidence bounds are in square brackets.

[**] Estimates are not reliable because we could not achieve strong convergence for the maximum-likelihood estimation due to the short sample.

17%. The point estimates thus suggest that price discovery took place mainly in the futures market, albeit with a non-negligible contribution of the underlying bond. This is in line with the priors derived from the theoretical and empirical literature surveyed in section 1. The point estimates are very close to those of Campbell and Hendry (2006) for Canada, where the bond market contributed approximately 30% to the variation in the efficient price. They are also not too different from those by Booth et al (2002), who find that the upstairs market for US stocks contributed less to price discovery than the floor. That said, the relatively wide confidence intervals (obtained using a bootstrap procedure explained in the Appendix) do not allow us to reject the hypothesis of equal information shares. By contrast, the GG factor weight of the bond market is clearly below one half.

The results for the second half of the year vary considerably between the individual phases. The information content of bond trading was considerably lower during June, much of July and the first half of August than during the first part of the year, although the estimates are not very precise.[18]

It is interesting to compare the information shares and factor weights during the turbulence in the international financial markets in the wake of Russia’s devaluation and default on 17 August to those of the period following the LTCM recapitalisation five weeks later. Both episodes were characterised by a similar level of volatility and turnover, but differed considerably in the respective contributions to price discovery of the two market segments. In the five weeks following the Russian default, the relative contributions of price discovery remained roughly comparable to the tranquil first five months of the year, while daily trading volume (shown in table 5) more than doubled. The stability of the information share during this episode is not in line with our priors, which pointed towards an increase in the information share of the spot market in episodes of high volatility. However, this may be related to the limited precision of the estimates, as indicated by the wide confidence banks.

This qualifier does not apply to our next finding, namely that the information share of the bond dropped to essentially zero in the aftermath of the LTCM recapitalisation on

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[18] The subperiod 21 July to 31 July is omitted because of econometric problems associated with the low number of observations.

23 September, although neither volatility nor trading volumes changed much compared to the previous five weeks. The confidence intervals for this period are very narrow, and it is easy to reject the hypothesis that the information shares in both markets were equal. The point estimate for the GG factor share is even negative, as the coefficients on the error correction term have the same sign in both equations of the VECM.[19] This suggests that only the price of the bond adjusted towards the equilibrium, while the futures price moved away from it. This does not mean that equilibrium will not be restored eventually, but it suggests that all adjustment takes place in the bond market.

The LTCM episode lasted until 8 October. Afterwards, the information content of the spot market gradually increased and after mid-November reached values similar to those during the reference period during the first, tranquil half of the year.

5. Composition of trades

The finding that the contributions to price discovery of the spot market remained steady after Russia defaulted on its debt in August 1998 but dropped in the wake of the LTCM recapitalisation, despite a similarly high level of volatility in both periods, suggests that one cannot make broad statements about price discovery based solely on volatility. Instead, one has to look further to identify why such shifts in informed trading occurred. This section presents an attempt in this direction. It analyses data on the composition of trades that may shed some more light on the types of orders that contain information and thus contribute to

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[19] Negative factor weights could also arise if prices are not cointegrated. However, the fact that both adjustment coefficients are statistically significant (albeit marginally, in the case of the future) suggests that this is likely to be the case here.

price discovery in the spot market. The analysis is based on the discussion in section 2, where we argued that the bond market shows parallels to an upstairs market where large orders are executed.

As mentioned before, the BaFin data allows us to distinguish between three types of transactions:

(i) client trades that are executed against dealer inventory,

(ii) client trades that do not affect dealer inventory, and

(iii) inter-dealer trades.

If inter-dealer trading is motivated mainly by inventory considerations and not by information, as most microstructure papers suggest, then this allows us to test for the information content of the two types of client trades. It seems natural that dealers try not to take informed trades onto their books but instead prefer to execute them as agents on a best execution basis. This suggests that transactions that are executed against dealer inventory are less likely to be motivated by information.

In order to test whether this reasoning is borne out by the data, we compute the price impact of client trades that affect dealer inventory and those that do not. In a first step, client trades are classified into sales and purchases according to the tick rule.[20] Out of 6,710 client trades that affect dealer inventory, 2,470 are classified as purchases and 2,553 as sales. The remainder take place at the same price as the last prior transaction and cannot therefore be classified. Out of the 4,147 client trades that do not affect inventory, 1,574 are purchases and

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[20] A trade is classified as a sale if its price is lower than the last transaction price and as a buy if it is higher.

1,255 are sales. The cumulative change in futures prices[21] following a client trade is then regressed on a constant and a dummy indicating whether or not it affected dealer inventory. Separate regressions are estimated for purchases and sales in each of the four size quantiles. The estimated coefficients for the dummy variable and their t-values are collected in table 5.

The results are consistent with the hypothesis that client trades affecting dealer inventory are less likely to be motivated by information than agency trades, although the evidence is not particularly strong. While the dummy for potentially informed trading is not significant for sales in any size category, there is weak statistical evidence, at the 10% level, that medium to large volume bond purchases that do not affect dealer inventory have a greater positive impact on futures prices than those in which dealers take a position. It takes seven to 10 minutes for the futures market to react to spot trades, and the impact evaporates after 12 to 14 minutes.

Table 6 shows data on the types of trades during the base period (2 January to 4 June), the five weeks after the Russian default (21 August to 23 September) and the LTCM episode (24 September to 8 October).[22] Activity in each of the two market segments was much higher during the two episodes of stress than during the first five months of the year, in terms of both the number of transactions and trading volume. Although turnover was fairly similar across the two turbulent periods, there are important differences in the composition and size of client trades. The Russian episode was characterised by much larger client trades, with an average of 34.6 million relative to the 25.3 million during the first half of the year. This could be

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[21] We consider the effect on futures prices because activity is much higher in this market segment. An alternative would be to measure the impact on the efficient price, which would force us to use a five-minute rather than a one-minute frequency.

[22] The average size of dealer trades during the period from 2 January to 4 June is distorted by a very small number of extremely large trades. These were executed over the counter and are therefore contained in the BaFin data only and not in the Eurex file.

Table 5

Price impact of different trade types

	1st quantile		2nd quantile		3rd quantile		4th quantile	
Upper threshold (DM mill.)	5.0		10.0		20.0		1,218.0	
	Buys	Sells	Buys	Sells	Buys	Sells	Buys	Sells
# transactions								
Uninf.	691	699	691	655	641	626	1,146	1,225
Inform.	492	430	264	226	289	228	826	607
Cumulative returns over the next … minutes								
1	-0.029	-0.192	0.247	-0.109	0.144	-0.278	0.015	0.315
	(0.13)	(0.89)	(0.72)	(0.31)	(0.42)	(0.72)	(0.05)	(1.04)
2	0.094	-0.066	0.339	-0.327	0.297	-0.250	0.195	0.694
	(0.33)	(0.21)	(0.78)	(0.63)	(0.71)	(0.53)	(0.66)	(0.22)
3	0.122	-0.159	0.326	-0.070	0.388	-0.013	0.244	-0.022
	(0.37)	(0.44)	(0.69)	(0.14)	(0.96)	(0.03)	(0.91)	(0.07)
4	-0.019	-0.064	0.207	0.078	0.536	0.083	0.359	0.152
	(0.04)	(0.13)	(0.37)	(0.12)	(1.02)	(0.16)	(1.08)	(0.42)
5	0.242	0.144	0.562	-0.019	0.613	0.121	0.442	0.002
	(0.58)	(0.28)	(0.98)	(0.03)	(1.08)	(0.21)	(1.15)	(0.00)
6	0.275	0.130	0.628	0.191	0.580	0.371	0.371	-0.151
	(0.61)	(0.23)	(0.93)	(0.25)	(0.94)	(0.61)	(0.96)	(0.33)
7	0.254	0.040	0.607	0.089	0.693	0.036	0.586	0.102
	(0.43)	(0.01)	(0.76)	(0.11)	(0.97)	(0.52)	(1.39)*	(0.20)
8	0.393	0.550	0.745	0.277	0.849	0.595	0.642	0.236
	(0.61)	(0.79)	(0.89)	(0.29)	(1.17)	(0.80)	(1.51)*	(0.49)
9	1.012	0.418	0.071	0.080	1.069	0.580	0.589	-0.004
	(1.42)*	(0.54)	(1.31)*	(0.08)	(1.40)*	(0.69)	(1.23)	(0.01)
10	0.234	0.313	0.857	0.140	1.038	0.454	0.755	-0.029
	(0.36)	(0.39)	(1.04)	(0.14)	(1.37)*	(0.54)	(1.56)*	(0.05)
11	0.325	-0.102	1.062	-0.009	1.121	0.581	0.698	-0.011
	(0.46)	(0.12)	(1.18)	(0.01)	(1.36)*	(0.64)	(1.38)*	(0.02)
12	0.132	0.053	0.735	0.107	0.852	0.687	0.467	-0.048
	(0.18)	(0.06)	(0.80)	(0.10)	(1.04)	(0.70)	(1.00)	(0.08)
13	0.108	-0.194	0.734	-0.406	1.071	0.223	0.731	-0.047
	(0.13)	(0.19)	(0.74)	(0.33)	(1.18)	(0.20)	(1.29)*	(0.07)
14	0.041	-0.027	0.947	0.037	1.032	0.575	0.841	0.320
	(0.54)	(0.03)	(0.91)	(0.03)	(1.05)	(0.52)	(1.39)*	(0.44)
15	0.053	-0.468	1.100	-0.408	1.094	0.411	0.628	-0.020
	(0.06)	(0.44)	(1.05)	(0.32)	(1.18)	(0.38)	(1.15)	(0.03)

Point estimate (t-value) of dummy that is zero if trades are executed against dealer inventory and one otherwise. Constant omitted for brevity. Estimation by OLS with White-correction for heteroscedasticity. Significant at the *10% confidence level.

Table 6

Trade types during selected episodes

Dates		Daily # of trades[1]	Share client trades[2]	Trades size (DM million) [2]		Client trades affecting dealer inventory[2]	
				client trades	dealer trades	% of client trades	Trade size
2 January – 4 June	Bond	64	39%	25.3	12.9	60.1	29.5
		(21)		(39.3)	(24.7)		(41.2)
				[10.0]	[5.0]		[10.0]
	Future	6,358	35%	9.8	49.2	0.7	10.8
		(1,895)		(18.6)	(15,515.5)		(14.1)
				[5.0]	[5.0]		[6.75]
21 August – 23 September	Bond	134	34%	34.6	14.4	57.7	30.4
		(52)		(44.8)	(34.9)		(33.7)
				[20.0]	[5.0]		[20.0]
	Future	14,755	43%	7.2	6.4	0	-
		(3,341)		(15.2)	(11.2)		
				[2.5]	[2.5]		
24 September – 8 October	Bond	114.3	29%	27.3	10.6	67.5	28.5
		(30.3)		(37.1)	(20.3)		(39.3)
				[10.0]	[5.0]		[10.0]
	Future	15,652	37%	7.0	6.1	0	-
		(4,656)		(13.7)	(10.1)		
				[2.75]	[2.25]		

Standard deviations of individual trading days in round brackets; median in square brackets.

[1] Future: Eurex data; bond: matched BaFin data. [2] Unmatched BaFin data.

related to the substantial inflows of capital into the German government bond market during that period, which were reversed in later months (Deutsche Bundesbank (2000)). These flows involved mainly German investors repatriating their funds from abroad rather than inflows of genuine foreign capital. This may explain why a larger proportion of trades than normal were perceived as being informed. Despite this increase in trade size, the proportion of client trades affecting dealer inventories, i.e. uninformed trades according to our hypothesis, remained roughly in line with that of the tranquil reference period. After the LTCM bailout, the average size of client trades reverted to normal, but an unusually large proportion of these trades appeared to be uninformed. These two observations are in line with the previous finding that the contribution to price discovery of the spot market appeared to be unaffected by the turbulences after the Russian default, but collapsed after 24 September.

6. Conclusions

Under normal market conditions, the information share of the Bund future is considerably higher than that of the underlying bonds. This does not mean, however, that the spot market does not process any information at all, as it still contributes 19% to 33% of the variation in the efficient price. In times of stress, the informational role of the spot market *may* break down. For example, the information share of the bond market declined to zero during the two weeks following the recapitalisation of LTCM on 24 September, although it had remained stable after Russia defaulted on its debt five weeks before. Both episodes were characterised by high volatility and an average number of transactions per trading day almost twice as high as during the reference period in the first part of the year. One difference between these two episodes that could explain why the information share of the bond market collapsed after the LTCM capitalisation but not after the Russian default is the lower share of client transactions during the former, in particular those affecting dealer inventory, which were more likely to be motivated by information.

In the absence of more detailed data on the identity of individual market participants, one can only guess who these informed traders were and why their importance fluctuates over time. Balance of payments data reported in Deutsche Bundesbank (2000) suggests that they were mainly German, but the available data precludes any further breakdown.

The microstructure of the market for German government bonds has changed considerably since 1998, mainly due to the advent of electronic trading. Of course, this is likely to have implications for price discovery, although it is not clear whether electronic trading by itself is sufficient to tip the balance of price discovery from the futures to the spot market. It would be interesting to repeat the exercise of this paper with a more recent dataset that includes transactions on electronic trading platforms. In the absence of bond market turbulences such as that which occurred in 1998, it is not possible, though, to test whether these pricing relationships also hold in periods of stress.

Appendix: Confidence intervals for the information share measures

The information share measures are a non-linear function of the underlying parameters. Confidence intervals for the information shares are constructed using a parametric bootstrap method. Given the asymptotic multivariate normal distribution of the VECM parameters, we draw from this distribution to generate the distribution for each information share measure and use the simulated distribution to construct the corresponding confidence intervals. In our case, the simulations are based on 10,000 draws. The computational steps are the following:

1. For the point estimate of the VECM parameters, we compute the variance-covariance matrix of the parameter vector.
2. We draw from a multivariate normal distribution with mean equal to the point estimate of the parameter vector and covariance equal to the variance-covariance matrix of the point estimate.
3. Using the random parameter vector, we compute the information share measures.

Steps 2 and 3 are repeated 10,000 times and the resulting distribution of the information share measures is then used to compute the confidence intervals.

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Table A1

Chronology

Dates	**Events**
6 July – 14 August	Mounting tensions
	6 July: Salomon Brothers arbitrage desk disbanded
	14 July: IMF approves Russia loan package
	20 July: First Wall Street Journal mention of LTCM losses
17 August – 22 September	Russia
	17 August: Russian effective default and rouble devaluation
	1 September: Malaysia imposes capital controls
	2 September: LTCM shareholder letter issued
	4 September: First WSJ headline on Lehman Brothers' losses
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: BankAmerica reports 78% fall in earnings
	15 October: Federal Reserve cuts rate between meetings
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).

Table A2a

Estimation of the VECM

	2 January – 4 June (Reference period)		5 June – 20 July	
	Future	Spot	Future	Spot
ECM	-0.035	0.166	-0.004	0.048
	(-7.67)	(13.22)	(-1.77)	(6.22)
Future(-1)	0.041	0.610	-0.094	0.449
	(4.20)	(14.16)	(-5.90)	(5.01)
Future(-2)	0.012	0.314	0.009	0.553
	(1.93)	(7.09)	(0.85)	(6.15)
Future(-3)	0.008	0.238	0.003	0.149
	(2.05)	(5.610)	(2.01)	(5.27)
Spot(-1)	-0.015	-0.818	-0.003	-0.590
	(-2.27)	(-26.37)	(-0.49)	(-14.50)
Spot(-2)	-0.014	-0.589	-0.011	-0.549
	(-2.05)	(-18.35)	(-5.06)	(-16.12)
Spot(-3)	-0.010	-0.296	-0.0007	-0.035
	(-2.41)	(-12.19)	(-2.11)	(-2.41)

Table A2b

Estimation of the VECM

	3 August – 20 August		21 August – 23 September (Russia)	
	Future	Spot	Future	Spot
ECM	-0.009	0.359	-0.025	0.101
	(-18.75)	(8.93)	(-3.19)	(6.72)
Future(-1)	0.004	0.443	-0.003	0.491
	(16.05)	(9.18)	(-0.23)	(10.30
Future(-2)	0.001	0.208	-0.013	0.329
	(8.58)	(7.63)	(-3.41)	(6.62)
Future(-3)	0.0002	0.038	0.005	0.165
	(1.90)	(2.98)	(3.68)	(6.38)
Spot(-1)	-0.005	-0.497	-0.001	-0.696
	(-21.38)	(-11.05)	(-0.09)	(-21.11)
Spot(-2)	-0.002	-0.295	0.018	-0.409
	(-11.46)	(-9.20)	(2.18)	(-11.01)
Spot(-3)	-0.0005	-0.101	-0.007	-0.215
	(-4.52)	(-6.389)	(-2.84)	(-6.33)

Table A2c

Estimation of the VECM

	24 September – 8 October (LTCM)		9 October – 12 November	
	Future	Spot	Future	Spot
ECM	0.026 (1.91)	0.345 (8.60)	-0.023 (-2.84)	0.182 (7.69)
Future(-1)	-0.025 (-7.70)	0.53 (6.04)	0.031 (1.69)	0.354 (4.49)
Future(-2)	0.011 (9.81)	0.432 (7.92)	-0.012 (-0.74)	0.131 (1.66)
Future(-3)	0.006 (7.3)	0.097 (6.16)	-0.003 (-0.69)	0.204 (3.01)
Spot(-1)	0.002 (0.23)	-0.698 (-12.45)	-0.026 (-1.71)	-0.646 (-14.08)
Spot(-2)	0.011 (2.86)	-0.504 (-8.80)	0.018 (0.99)	-0.434 (-8.82)
Spot(-3)	-0.016 (-9.41)	-0.250 (-6.89)	0.003 (0.64)	-0.270 (-7.79)

Table A2d

Estimation of the VECM

	13 November – 7 December			
	Future	Spot	Future	Spot
ECM	-0.046 (-19.50)	0.138 (6.36.)		
Future(-1)	0.020 (18.43)	0.399 (9.97)		
Future(-2)	0.011 (38.13)	0.331 (10.75)		
Future(-3)	0.003 (18.43)	0.167 (8.77)		
Spot(-1)	-0.026 (-33.04)	-0.68 (-13.57)		
Spot(-2)	-0.011 (-51.76)	-0.374 (-10.46)		
Spot(-3)	-0.003 (-20.07)	-0.148 (-8.63)		