Does the “Bund” dominate price discovery in Euro bond futures? Examining information shares

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Abstract

This paper examines the relative information shares of the Bund, i.e. the ten year Euro bond future contract on German sovereign debt, versus two futures with shorter maturity. We confirm that the Bund is most important in price discovery of the interest rate level. However, the Bund does not dominate price discovery but the other contracts also have relevant – and at many days even higher – information shares. In examining determinants of information shares, we add order flow measures to market state variables and macro announcements. More order flow in a contract consistently increases the information share for all futures, whereas announcements are mainly incorporated via the Bund.

JEL-Classification: G 14 (information efficiency), G 13 (futures pricing), C 32 (time-series)
Keywords: Bond futures, information shares, macro announcements, order flow, price discovery, microstructure

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1 Introduction

The so-called "Bund" future contract is often regarded as the single most important asset in the Euro bond markets. The Bund is a standardized contract on German sovereign bonds with ten year maturity. Due to its benchmark status the trading of this contract is expected to reflect the flow of news into this market more accurately than other assets. Accordingly, the Bund would dominate price discovery in the Euro bond markets, i.e. the formation of interest rates. However, price discovery can occur over the whole yield curve and some news may be more important at shorter interest rates than ten years. Therefore, we examine the relative weight of the Bund future in price discovery versus two other liquid Euro bond future contracts. We find that the Bund is important indeed, but that it is not dominating at all.

The Bund future derives its benchmark status for European bond markets mainly from three facts (see Menkveld et al., 2004). First, Germany is the largest economy in the Euro area and its federal debt has the lowest risk spread. Second, future markets seem to be generally more important than spot markets in price discovery, in particular if they are more liquid as it is the case here. Third, among future contracts on German sovereign debt the Bund has about twice the trading volume than contracts on shorter maturities. Overall, there are good reasons to assume a leading role for the Bund in the process of discovering the interest rate level. There is indeed empirical evidence that German debt has a dominating role in the Euro area and we know that the Bund future dominates the ten year bond (Upper and Werner, 2007). However, we do not know of an empirical examination of the relative importance of the Bund in comparison to other Euro bond future contracts.

Our research addresses exactly this issue, which contract (which market) is relatively most important in incorporating permanent price changes first, i.e. which contract is relatively most important in price discovery. We apply a standard econometric approach, i.e. the Gonzalo and Granger (1995) identification of "information shares". This vector error correction approach aims for identifying the relative importance of some time series to a common development. By applying it to financial markets one can analyze, for example, the relative contribution of single stock return histories to stock market development (Harris et al., 2002), the relative contribution of two markets or the relative contribution of two trading instruments. In our case, we are – to the best of our knowledge – the first to analyze the relative contribution of three bond future contracts to bond price development. In particular, we examine the relative information shares of the Bund in comparison to the contracts with five and two year maturity.

Moreover, we examine possible determinants of information shares in order to better understand where or when price discovery takes place. These determinants come from three directions: first, we consider market state-related variables (see Mizrach and Neely, 2008), such as trading volume and spread, second, we take up the insight that announcements of macroeconomic variables are informative, a market influence which has been modeled in the literature in various ways. Third, and according to our knowledge new to the literature on information shares, we consider order flow which is important for incorporation of news in bond markets too.

We find indeed that the Bund has the largest information share and thus seems to be most important in price discovery of the interest rate level. Interestingly, however, despite its benchmark status, the Bund does not really dominate price discovery. Instead, all three considered contracts have significant information shares and seem thus to be relevant. We gain further insight in the special roles of the single contracts by analyzing determinants of information shares. We see that market state-related variables are important determinants of information shares and that the effects behave consistently over all three future contracts as expected. By contrast, macroeconomic announcements have diverse effects on the three contracts: essentially, the Bund is the preferred medium to incorporate macro news, with the exception of press conferences of the European Central Bank which have effects more on the Schatz, i.e. on the shorter end of the yield curve. Finally, we confirm from our perspective that order flow is a medium of information incorporation. In particular unexpected order flow is informative, as suggested by Pasquariello and Vega (2007), and medium-sized trades, indicating the existence of “stealth trading” as found in the equity market (Barclay and Werner, 1993, Chakravarty, 2001).

This research fits into varies lines of earlier work on price discovery in bond markets and extends earlier findings, first, by focusing on the European bond market, and second, by including order flow as determinant of information shares. For the U.S. market, Fleming and Remolona (1997, 1999a) find the importance of news, a direction extended by Green (2004). Brandt and Kavajecz (2004) reveal the impact from order flow on prices, Brandt et al. (2007)

show that future markets have to be considered in this respect. Mizrach and Neely (2008) are closest to our work as they also apply the information share-approach, although comparing for the U.S. the information shares of spot and future markets. There is less research on European markets. Upper and Werner (2007) are relatively closest to us as they also apply the information share-approach, however, to the ten years maturity only and without considering any determinants. Dunne et al. (2007) question the benchmark status of German sovereign debt, although without covering the most liquid future contracts in their analysis and Andersson et al. (2009) strictly focus on volatility-effects due to macroeconomic announcements.

The paper is organized in the following steps: Section 2 describes the data and Section 3 outlines the econometric approach. Section 4 provides information shares and Section 5 examines its determinants, thus supporting an economic interpretation. Section 6 concludes.

2 Data

The study is based on high frequency data of trading in the three most liquid Euro bond future contracts between 2004 and 2007. In addition, we use macro announcements as well as order flows for our analyses.

The data on German government bond futures' trading ranges from 01.06.2004 to 26.11.2007. The three considered contracts are – with increasing maturity – the two years maturity "Bundesschatzanweisungen" (in short: "Schatz"), the five years "Bundesobligationen" ("Bobl") and the then years "Bundesanleihen" ("Bund"). These three contracts are the most liquid futures in the Euro area and they are all AAA-rated (S&P). The underlyings are the maturity-related bonds each with a face value of 100.000 EUR and a yearly coupon payment of six per cent.

To concentrate our analyses to the most liquid contracts we make use by the 'auto roll' procedure, briefly described by Andersson et al. (2009). Contracts' trading is compared on a daily basis and the one with the highest volume is included into the data set. With this in hand and combined with the findings of Brandt and Kavajecz (2004) and Pasquariello and Vega (2007) who postulate that liquidity is related to the time to maturity, we focus our attention on 'on-the-run' contracts which dominate the price process (see Brandt and Kavajecz, 2004).

Our data are recorded at EUREX which is the only supplier of an electronic trading platform for fixed income futures in Germany and offers regular trading hours from 8:00 a.m. up to 6:00 p.m. till 20.11.2005 and up to 10:00 p.m. afterwards. The collected raw data indicate beside marked error trades the exact timestamp, last bid, ask and transaction price as well as its quantity. This gives us the possibility to construct trade related variables. Buy and sell identifications take place via the direct comparison of the transaction price and the quoted bid and ask. If the trade hits or understates the bid price, the order is classified as a sell and vice versa. In order to bring this information into a final data set which gives the opportunity of a comparison at the highest possible frequency we assign each contract for each second during the trading day an average possible trading price, represented by the midquote. This virtual price is computed as the half of summing up the bid and ask price. As we cannot observe a chainsaw pattern in our time series as reported by Brandt et al. (2007) we do not need to regress the raw data on a delivery variable to remove any trend.

Table 1 sums up the major characteristics of our sample. Consistent with the U.S. Treasury market most of the trading per day is concentrated in the ten-year future (see Brandt et al., 2007). With 16,579 transactions per day on average and a total turnover of 954,281 contracts, it outreaches nearly twice the two-year and the five-year contract and nurtures the view that the Bund future might be seen as the benchmark in the European bond market (i.e. Dunne et al., 2007).

Releases of macroeconomic announcements induce strong movements in the U.S. bond as well as in the German Bund future market (Fleming and Remolona, 1999a, Andersen et al., 2007, Andersson et al., 2009). Thus it is necessary to analyze their impact in our sample, too. In determining our data set of U.S., German and Euro Area specific announcements, our selection is strongly influenced by Fleming and Remolona (1999a). We consider their five most influential U.S. macroeconomic announcements (on the five-year on-the-run GovPX bond) and select their European and German equivalents, too. In detail, we take the unemployment statistics, producer and consumer price indexes, GDP and retail sales releases. Finally, given a high impact of the federal fund target rate, we include days with Fed or ECB press conferences.

3 The econometric approach

Information shares are a standardized measure of price discovery for cointegrated time series in multiple markets or assets. We choose a standard econometric method to conduct the analyses of interest, i.e. the Gonzalo and Granger (1995) approach which has been applied to financial markets for example by Harris et al. (2002).

An alternative method to examine relative information shares has been suggested by Hasbrouck (1995). De Jong (2002) works out the strong econometric relation between both measures which also show a high correlation in practice (see Theissen, 2002). Nevertheless, Hasbrouck (2002) discusses examples in which both approaches report different results so that both measures should be considered ex ante (see Lehmann, 2002). In our context we decide against the Hasbrouck (1995) approach because of an economic argument. Like Campbell and Hendry (2007) we sometimes get "negative" information shares, i.e. a kind of misguided price discovery in certain markets. As the Gonzalo and Granger (1995) approach aims at returns, these negative information shares are correctly recorded as "losses". By contrast, the Hasbrouck (1995) approach aims at variances so that no distinction is made between negative and positive contributions (see Korenok et al., 2008). This results in our case – where we sometimes have negative information shares – in a distortion as such "losses" are wrongly considered as being the same of true information shares.

3.1 Methodology

The core issue is to extract the efficient price process p_t^* from the impure but observable midquote prices which are defined as:

$$p_{i,t} = \lambda_{i,t} p_t^* + \varepsilon_t \qquad (1),$$

with $p_{i,t}$ as the actual quote price and ε_t representing any transitory noise[1]. Given N price series which solely follow a random walk but taken as a whole are cointegrated, Engle and Granger (1987) suggest to rewrite them in an error-correction representation:

$$\Delta p_t = c + \gamma\alpha' p_{t-1} + \sum_{i=1}^{s} \Gamma_i \Delta p_{t-1} + \varepsilon_t \qquad (2),$$

which is a modified vector moving average of order s in first differences. The term $\alpha' p_{t-1}$ defines the error correction term and includes the price differentials between the markets. γ reveals the speed of convergence to the new equilibrium. If we would expect the Bund future as the benchmark bond in the future market, we should observe $\gamma' = [1,0]$. That is, the ten year contract does not react to any price differential which implies an information share of 100%.

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[1] Detailed discussions about the efficient price process offer or Hasbrouck (1991a) and Hasbrouck (2007).

Thus, the elements of the orthogonal of the error correction parameter, $\gamma'_\perp$ [2], define the information share of future i, IS_i, in the following way:

$$IS_i = \frac{\gamma_{\perp,i}}{\sum_i^n \gamma_{\perp,i}} \quad (3).$$

Gonzalo and Granger (1995) postulate the use of a common factor approach for estimating $\gamma'_\perp$. In their framework prices are decomposed into a permanent, f_t, and temporary, $\tilde{p}_t$, component,

$$p_t = Af_t + \tilde{p}_t \quad (4),$$

where A is a factor loading matrix. As pointed out by Baillie et al. (2002), if Δf_t is not autocorrelated, the permanent component follows a martingale process and is applicable to financial data. In general, two conditions are sufficient to identify the long-run impact-vector f_t:

1. f_t is a linear combination of p_t, more precisely $f_t = \gamma'_\perp p_t$.
2. Af_t and $\tilde{p}_t$ form a permanent-transitory decomposition, i.e. temporary effects do not Granger-cause the permanent component.

Under theses conditions $\gamma'_\perp$ can be estimated by a reduced rank regression as introduced by Johansen (1991). In detail, the long-memory common factor is given by the last N-r columns of the eigenvector received from the necessary eigenvalue-eigenvector decomposition, with r as the rank of the system.

3.2 Preparatory analysis

The main purpose of this section is to test the time series for its two basic requirements; non-stationarity of each contract and the cointegration of all three futures. First, we conduct the augmented Dickey-Fuller test on a daily basis. Table 2 reports the results. The applied lag length is estimated by the Bayesian information criteria and differs over the three contracts, ranging from 4 at the ten-year's future up to 7 in the two-year's one. Over the whole sample, we cannot reject the unit root characteristic for any of the three futures. Second, we apply the Johansen likelihood ratio (LR) test for the whole system to receive its rank (see Johansen, 1988). The optimal lag length is determined by the LR test and on average 4 in both cases.

[2] The orthogonal fulfil the following condition: $\gamma_\perp' \gamma = 0$.

Table 2 shows the average test statistics which reject the null hypotheses of no cointegrating vector. Consistent with Mizrach and Neely (2008), we are not able to reject the null of no cointegration at all days. Because our intention is to receive unique information shares we drop out the observed deviations. Their inclusion would lead to a long-memory factor and thus to an information share with more than one column. This approach leaves us left with a data sample of 787 days on which we are able to apply the Granger and Gonzalo information share-approach.

4 Information shares of the bond future contracts

This section reports information shares of the Bund, Bobl and Schatz futures. We find a strong and stable dominance of the ten-year future which decreases after the reduction of the minimal tick size in the five-year future.

Table 3 reports the average daily information shares for the Bund, compared to the five and two year contract each. Although there are some fluctuations of the estimated values, up to the mid of 2007 the ten-year contract clearly is the relatively most important contract for price formations, as it overreaches the relative price contribution of shorter maturity contracts on nearly nine out of ten days. After the Bobl's reduction of the minimal tick size at June 8, 2007, this dominance has become weaker and seems to have resulted in an equal importance relative to the five-year future.

In order to identify the possible existence of a structural break caused by the reduction of the Bobl's minimal tick size we subdivide the year 2007 in two periods. The first one reports information shares before the breakpoint and the second one information shares afterwards. The comparison of the two subperiods in 2007 indicates an increase of the two- and five-year contracts' information shares after the break. Both, the Mann-Whitney-U-test and the Kolmogorov-Smirnov-test signal a structural change at least at the five per cent level. Intuitively, the tick size reduction enables traders to price the five-year contract nearer to its efficient price than before and, moreover, reduces the costs of information incorporation. As a consequence, informed trading shifts partially out of the Bund, which lowers its predominant position.

Surprisingly, up to this point the five-year future does not reach the position of a price leader. On the one hand this seems to contradict previous findings about the price discovery via order flow. Brandt and Kavajecz (2004) attribute the highest price impact to the five year

Treasury order flow and refer to the duration of the majority of fixed income portfolios, which is near five years. Considering the U.S. spot and future market, Brandt et al. (2007) point out that the five year's order flow of both markets has the most important role in pricing fixed income assets. On the other hand the much higher trading volume in the ten-year contract supports the price discovery process as it reduces transaction costs as well as liquidity risk.

We conclude that there is a breakpoint which has to be considered in the following analyses. In doing so, one may consider two measures, i.e. the relative spread and a dummy variable which captures the aftermath of the structural break. However, this will cause a multicollinearity problem, shown by the fact that the dummy's variance inflation factor (VIF) receives a value much higher than ten[3]. Consequently, we respect this fact in the following analyses in two ways. Either we introduce a dummy variable which takes a value of one in the aftermath of the tick size reduction or we consider the relative spread of a future. This relative spread is a contract's spread for time t divided by the spread summed over the two contracts considered, which will always include the Bund and either the Bobl or the Schatz.

5 Determinants of information shares

This section presents the results of three groups of determinants which may help to explain information shares. Section 5.1 considers market state-related variables. Section 5.2 contains variables about macroeconomic variables and in Section 5.3 we introduce order flow by three new variables, i.e. (i) total order flow, (ii) unexpected order flow and (iii) medium-sized trades. Finally, in Section 5.4 the variables from the three earlier sections are considered together. Results extend our economic intuition of price discovery in the bond market.

5.1 Determinants of information shares: market state variables

The analysis of information shares has shown that they can vary considerably over time and that this variation may be related to variables indicating varying market states. Potentially relevant market states include spread, trading volume and volatility (see Fleming, 2003, Brandt et al., 2007). The analysis of market state variables has two motivations: first, one may learn from this analysis under which market conditions information is preferably compounded into prices. Second, one may think about market state variables as exogenous control vari-

[3] As a rule of thumb a value of ten is seen as the critical threshold, indicating multicollinearity.

ables which help to reveal the unconditional information shares of a certain market, such as the Bund.

Our analysis in the following is inspired by Mizrach and Neely (2008) who are the first to consequently consider the three above introduced market state variables in the Gonzalo and Granger (1995) approach. Mizrach and Neely (2008) show that spread, volatility and traded contracts are able to explain price discovery shifts between the U.S. spot and future market. Thus we conduct the regression,

$$IS_{i,t} = b_1 \times time - to - delivery + b_2 \times delivery \quad day + b_3 \times \frac{S_{i,t}}{\sum_{j=1}^{2} S_{j,t}} + b_4 \times \frac{RV_{i,t}}{\sum_{j=1}^{2} RV_{j,t}} + b_5 \times \frac{Vol_{i,t}}{\sum_{j=1}^{2} Vol_{j,t}} + \varepsilon_t \quad (5),$$

with i representing contract's maturity and the standardized variables IS the maturity-specific daily information share, S the average spread, Vol the cumulated contracts traded and RV the realized volatility on day t. Checking for any future market specific distortions we consider the time-to-delivery and the delivery day, which is a dummy variable with a value of one, if a new contract is issued.

The expectations on coefficient signs are that a relative higher spread of a future contract increases the price of incorporating non-common knowledge and so hampers the tatonnement. In sharp contrast, a higher share of trading volume indicates more information processing – or at least facilitates informed trading – and thus increases the information share. Finally, the impact from realized volatility may be ambiguous: this may be seen as an indicator of present noise traders in the market, so that more volatility decreases the information share, but it can be seen as sign of heterogeneously distribution information processing which would explain a positive sign. Although these results are confirmed for the spot-future-relation in the bond market (Mizrach and Neeley, 2008) and for stocks and options (Chakravarty et al., 2004), they should not be seen as stylized facts. For example, Campbell and Hendry (2007) partly report counterintuitive results for the Canadian and U.S. bond market. In some cases a higher share of trading volume harms the speed of price discovery. In other cases a relative increase of the spread or the volatility raises the information share.

Our estimated coefficients – shown in Table 4 – confirm the observation that market state variables are able to describe fluctuations in the information shares of bond future contracts. Expected signs are revealed for spread and volume at both maturities. The strongest effect results from a change of the relative spread in the five-year contract. A one standard deviation higher share of the spread reduces the information content by 34.9%. According to the intuition given above, an increase in the trading volume is of similar important for both futures. The realized variance has ambiguous signs, although insignificant for the five-year future, which is a bit puzzling.

5.2 Determinants of information shares: macroeconomic announcements

There is no doubt that the announcement of macroeconomic fundamentals is an important element of the price discovery process in bond markets and should therefore be considered in an analysis of information shares. Again, as with market state variables, this consideration may provide interesting insights by itself and may also be regarded as a consideration of necessary control variables.

Among the first in this line of research are Upper and Werner (2007) who show that two markets' contributions to the common trend may depend on incoming economic news. As an example they refer to the LTCM crisis (September 24th to October 8th, 1998) during which the importance of the German spot compared to its future market tended to be zero. Mizrach and Neeley (2008) generalize this thesis by reporting a negative impact of macroeconomic announcements on the importance of the spot market. Andersson et al. (2009) report significant price impacts of domestic, European and U.S. announcements for the German ten-year bond future. Furthermore, Andersen et al. (2007) detect strong but short-lived news-effects on the five-year contract in an international context. Given these results, we form dummy variables for our scheduled announcement data set on a daily basis which take a value of one if there is a release and zero otherwise.

To pure reveal this potential effect, we consider any announcement effect isolated from trading related variables which leads to a parsimonious regression of the time-to-delivery-, a delivery day-, a breakpoint- and the dummy-variable D^a,

$$IS_{i,t} = b_1 \times time - to - delivery + b_2 \times delivery \quad day + b_3 \times BP + b_4 \times D^a + \varepsilon_t \qquad (6).$$

As previously mentioned, the breakpoint variable BP takes the value of zero before the structural break and one afterwards which enables us to absorb distortions due to the reduction of the minimal tick size in the five year contract. Results are reported in columns one and three of Table 5.

In the case of the *five-year contract*, German, European and U.S. announcements have a non-negligible impact on daily information shares and follow the same pattern. They are negative on the five-year contract and positive on the Bund. That means, the information share of the Bund goes up on days where these macroeconomic announcements are made and thus the relative share of the other future goes down. This is consistent with the claim that price discovery in the Euro bond futures regarding macro news is dominated by the Bund.

Starting with the U.S. releases underlines their importance for estimating European yields (Andersen et al., 2007, Faust et al., 2007, and Ehrmann and Fratzscher, 2005). Besides financial and economic integration, Andersson et al. (2009) suggest earlier U.S. release dates as a possible explanation. In particular, we find significant impacts of inflation and economic indicators, in form of jobless claims, consumer price index (CPI) and retail sales. The last indicator reveals the highest impact on price discovery's location, which is consistent with the results of Andersson et al.: in times of a tightening monetary policy of the ECB, U.S. retail sales show one of the strongest impacts on Bund futures.[4]

Turning to the European variables, we observe a significant impact of jobless claims and GDP, i.e. two variables that are related to growth but that are not inflation figures. This may be a bit surprising and may indicate that unemployment is important for the ECB too (as for the Fed) or may indicate the relevance of an indirect channel of price pressure via growth.

Another explanation for the missing significance of inflation variables at the European level is provided by discussing the German dummies. Here the inflation variables – producer price and consumer price index – are significant, the latter at the ten percent level, whereby the former one has the strongest effect among all announcements. The importance of German inflation dummies is not surprising because European announcements offer a summary of the previously published national figures. So, recent developments in Europe's biggest economy help to predict the common development of the monetary union. However, why does this argument not apply to the German growth-related variables? Here, jobless claims is often known to the market before the official release time (Andersson et al., 2009)[5], and GDP is released before the regular trading hours.

[4] The strongest volatility effect is related to the ISM manufacturing index, which we do not consider in our analysis.

[5] Goldberg and Leonhard (2003) report no market reactions of German bond yields to German unemployment releases. Andersson et al. (2009) offer an extensive collection of news reports which document some information leakage.

The result for the *two-year contract* is qualitatively the same but less often significant. Interestingly, we observe exactly one event, which does not increase the dominance of the Bund, i.e. ECB press conferences. Information about the recent and future path of the relevant yield policy is primarily relevant for the short end of the yield curve.

5.3 Determinants of information shares: order flow

This section investigates the role of order flow in shifting the share of price discovery, i.e. the information share, between the Bund and the two other future contracts. There are two motivations why order flow may be a relevant determinant in this analysis. First, order flow is a medium for incorporating non-common knowledge into prices (e.g. Killeen et al., 2006). In bonds' spot and future markets this measure plays an important role in explaining price dynamics (see Brandt and Kavajecz, 2004, Brandt et al., 2007 and Underwood, 2007). Second, Green (2004) documents news processing via an indirect channel, i.e. via order flow.[6]

In line with earlier studies on the possible impact of order flow on prices we proceed with the analysis in three steps, from general to specific, i.e. considering (1) total order flow, (2) unexpected order flow and (3) medium-sized order flow. We note that these time-series are not significantly correlated with each other.

(1) Total order flow

Order flow is a measure of signed trades and thus indicates buying pressure (assuming that buys are coded positive). It is well documented that order flow is positively related to contemporaneous returns in many markets. This is often interpreted as an indication for order flow being the medium for incorporating information into prices. According to this reasoning one might expect that order flow will also impact information shares.

We test this in the simplest way by regression relative order flow, i.e. between the Bund and the Bobl, on the information share between both contracts. In order to do so we divide the maturity-specific order flow by the sum over both futures. Moreover, in order to distinguish the net trading effect on announcement and non-announcement days, we create two dummy variables, each capturing one state. These dummies are multiplied with the order flow. Table 6 Panel A shows that the coefficient is indeed positive and statistically significant for days

[6] See Evans and Lyons (2008) for the exactly distinction between the direct and indirect channel.

with announcements. In case of the Schatz, the coefficients are significant also for days without announcements.

(2) Unexpected order flow

However, it has been argued that order flow may contain elements that are not related to information. One way to extract the truly informative part of order flow has been suggested by Pasquariello and Vega (2007). They argue that only the unexpected order flow of each contract is evidently linked to information processing in the bond market, whereas the expected part of order flow does not contain information (as it can be expected by rational market participants). To extract the pure informative part from the order flow we follow Pasquariello and Vega (2007) and run a regression of the lagged returns and order flows on the current order flow[7],

$$OF_{i,t} = c + b_1 \sum_{k=1}^{K} OF_{i,t-k} + b_2 \sum_{l=1}^{L} R_{i,t-l} + UOF_{i,t} \quad (7).$$

OF and R refer to the half-hour volume-weighted order flow respectively the return in contract i, with i representing the two-, five- and ten-year contract. The appropriate lag-lengths K and L are chosen to eliminate the serial correlation in the trading interval and are set such that a whole trading day is covered as we can see day-to-day dependencies in the returns. The residuals of this regression reveal the amount of unexpected order flow in a half-hour interval and are summed up per day. This gives us a measure for informed order flow, possibly nurtured by customer order flow (Menkveld et al., 2007).

In the next step we reproduce the steps as described in (1) above. The two columns in Panel B of Table 6 present the results of the following regression, whereby D^a (D^{na}) stands for a dummy variable, representing (non-) announcement days:

$$IS_{i,t} = b_1 \times time-to-deliver + b_2 \times delivery\ \ day + b_3 \times BP + b_4 \times \frac{OF_{i,t}}{\sum_{j=1}^{2} OF_{j,t}} \times D^{na}$$
$$+ b_5 \frac{OF_{i,t}}{\sum_{j=1}^{2} OF_{j,t}} \times D^{a} + b_6 \times \frac{UOF_{i,t}}{\sum_{j=1}^{2} UOF_{j,t}} \times D^{na} + b_7 \frac{UOF_{i,t}}{\sum_{j=1}^{2} UOF_{j,t}} \times D^{a} + \varepsilon_t \quad (8).$$

[7] Hasbrouck (1991b) introduced this methodology for the estimation of the unanticipated component of a trade.

Both order flow measures, i.e. total and unexpected order flow, positively affect the relative weight of each contract. Coefficients are even larger for the Schatz contract.

(3) Medium-sized order flow

In a next step we further augment the regression by also considering medium-sized order flow. Medium-sized order flow is often found to be preferably used by informed traders, the so-called stealth-trading hypothesis (Barclay and Werner, 1993). In order to reduce their price impact and so to lower their trading costs, informed investors split up large trades. If this applies, then middle trades have a larger price impact than small or large trades (evidence in Chakravarty, 2001, for equities, and in Menkhoff and Schmeling, 2008, for foreign exchange).

We compute contract i's daily share of medium-sized trades, MID_i, in three steps. First, we standardize all trades of a day. Next, we define the 20% and 80% critical trade sizes of each subsample.[8] Finally, the amount of the maturity-specific trades between the borders is divided by the sum over the two relevant futures. The average shares of the five- and two-year contracts, each compared to the Bund, are 32.5% and 21.6%.

$$\begin{aligned} IS_{i,t} &= b_1 \times time-to-delivery + b_2 \times delivery \quad day + b_3 \times BP \\ &+ b_4 \times \frac{OF_{i,t}}{\sum_{j=1}^{2} OF_{j,t}} \times D^{na} + b_5 \frac{OF_{i,t}}{\sum_{j=1}^{2} OF_{j,t}} \times D^{a} + b_6 \times \frac{UOF_{i,t}}{\sum_{j=1}^{2} UOF_{j,t}} \times D^{na} \\ &+ b_7 \frac{UOF_{i,t}}{\sum_{j=1}^{2} UOF_{j,t}} \times D^{a} + b_8 \times \frac{MID_{i,t}}{\sum_{j=1}^{2} MID_{j,t}} \times D^{na} + b_9 \frac{MID_{i,t}}{\sum_{j=1}^{2} MID_{j,t}} \times D^{a} + \varepsilon_t \end{aligned} \qquad (9).$$

Panel C in Table 6 reports our results which are qualitatively unchanged to the earlier reported Panels A and B. The other order flow measures keep their signs and significances. Medium-sized order flow provides an additional contribution in determining information shares in the expected direction as a higher share of such trades increases the information share. Accordingly, the R^2s are with 12.2% and 9.28% slightly higher than before.

Overall, we conclude that order flow is a powerful determinant in explaining information shares which provides another form of evidence that order flow contains information.

[8] The use of the 10% and 90% interval does not change our results.

5.4 Determinants of information shares: market state, macro announcements and order flow

In a final analysis, we consider all so far considered useful variables in a comprehensive approach. This provides some insight whether the variables found so far are possibly capturing common sources or whether they are orthogonal to each other. We find that only macroeconomic announcements lose some importance.

Formally, we test the following specification which can be seen as integrating variables from Section 5.1 to 5.3:

$$IS_{i,t} = b_1 \times time - to - delivery + b_2 \times delivery\_day + b_3 \times D^a + b_4 \times \frac{S_{i,t}}{\sum_{j=1}^{2} S_{j,t}} D^{na}$$
$$+ b_5 \times \frac{S_{i,t}}{\sum_{j=1}^{2} S_{j,t}} D^a + b_6 \times \frac{Vol_{i,t}}{\sum_{j=1}^{2} Vol_{j,t}} D^{na} + b_7 \times \frac{Vol_{i,t}}{\sum_{j=1}^{2} Vol_{j,t}} D^a + b_8 \times \frac{RV_{i,t}}{\sum_{j=1}^{2} RV_{j,t}} D^{na}$$
$$+ b_9 \times \frac{RV_{i,t}}{\sum_{j=1}^{2} RV_{j,t}} D^a + b_{10} \times \frac{OF_{i,t}}{\sum_{j=1}^{2} OF_{j,t}} D^{na} + b_{11} \times \frac{OF_{i,t}}{\sum_{j=1}^{2} OF_{j,t}} D^a + b_{12} \times \frac{UOF_{i,t}}{\sum_{j=1}^{2} UOF_{j,t}} D^{na}$$
$$+ b_{13} \times \frac{UOF_{i,t}}{\sum_{j=1}^{2} UOF_{j,t}} D^a + b_{14} \times \frac{MID_{i,t}}{\sum_{j=1}^{2} MID_{j,t}} D^{na} + b_{15} \times \frac{MID_{i,t}}{\sum_{j=1}^{2} MID_{j,t}} D^a + \varepsilon_t \qquad (10).$$

Results are given in Table 7. Mainly, they confirm our previous results. The major deviation from the earlier presented partial regression, documented in the three panels of Table 6, is that less macroeconomic announcements keep their significant coefficients and that their composition changes somewhat, in particular with respect to German news.

The detailed consideration of announcements does not reduce the relevance of the order flow variables, with the exception of the medium-sized order flow of the five-year future.

However, we do not see these points as a qualitative change in findings but rather as a confirmation of the overall storyline: market state variables, order flow and unexpected order flow are the driving forces for determining information shares.

6 Conclusions

Our study analyses price discovery in the Euro bond future market by applying the information share approach. We contribute to the literature, according to our knowledge, in two ways: first, we extend the price discovery analysis in the European market to several future contracts. Second, we extend the so far considered determinants of information shares by also making use of order flow data. Both contribution reveal interesting insights.

In covering the European bond market, we calculate information shares for the Bund, i.e. the ten year German bond future, versus two other – so far neglected – future contracts, i.e. the five year Bobl and the two year Schatz. We find that the Bund is indeed the single most important contract for price discovery but that it does not dominate to an extent that the two other contracts would be unimportant. By contrast, there are many days, where the Bund is less important than another future contract.

In extending the determinants of information shares we complement market state and macro announcement variables by so far neglected order flow variables. Order flow has often been found to be a relevant measure in analyzing information flows in financial markets, so that it seems a natural extension to consider it as determinant of information shares too. Indeed, it proves to be a very important determinant beyond the earlier variables. Interestingly, this holds for various measures of order flow which provides room for deeper analyses examining the particular role of certain kinds of order flow and its interaction with other determinants. We leave this for future research.

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Table 1: Eurex future trading data: summary statistic

This table shows descriptive statistics for the underlying data set. Transactions and quotes are collected from the Eurex trading platform and cover the time range between June 01st, 2004 and November 26th, 2007. Market relevant information include the future's specific return (multiplied with 100), the quantity and the number of buys, sells, order flow and the trading volume. The columns contain the estimated means, standard deviations, maximums, minimums and the first order autocorrelation for the five-years and ten-years futures. A '*', '**' or '***' shows the significance of the first-order autocorrelation at the 10%, 5% or the 1% level.

	Mean	Stdev.	Max.	Min.	ρ(1)	p-value
	2-Year					
Daily Return	-0.002	0.075	0.310	-0.440	-0.052	0.08 *
Number of Buys	1,993	875	7,633	299	0.576	0.00 ***
Volume of Buys	234,791	88,711	632,714	29,940	0.384	0.00 ***
Number of Sells	-2,023	908	-173	-7,225	0.580	0.00 ***
Volume of Sells	-236,412	90,973	-25,071	-655,901	0.390	0.00 ***
binary Order Flow	-30	439	1,967	-2,645	0.174	0.00 ***
quantitative Order Flow	-1,622	31,827	138,017	-119,220	0.076	0.01 ***
Traded Contracts	4,016	1,728	14,558	472	0.604	0.00 ***
Traded Volume	471,203	176,857	1,288,615	55,011	0.397	0.00 ***
	5-Year					
Daily Return	-0.004	0.188	0.643	-0.961	-0.048	0.10 *
Number of Buys	3,821	1,390	11,131	666	0.575	0.00 ***
Volume of Buys	257,478	87,676	556,966	38,302	0.400	0.00 ***
Number of Sells	-3,795	1,403	-553	-10,960	0.553	0.00 ***
Volume of Sells	-257,652	89,592	-29,114	-605,430	0.399	0.00 ***
binary Order Flow	26	507	2,187	-1,999	0.062	0.03 **
quantitative Order Flow	-174	23,913	93,573	-85,443	0.038	0.20
Traded Contracts	7,616	2,746	22,091	1,219	0.581	0.00 ***
Traded Volume	515,130	175,658	1,162,396	67,416	0.406	0.00 ***
	10-Year					
Daily Return	-0.003	0.278	1.007	-1.345	-0.038	0.20
Number of Buys	8,280	3,550	25,432	1,135	0.686	0.00 ***
Volume of Buys	475,876	166,855	1,300,099	56,528	0.442	0.00 ***
Number of Sells	-8,299	3,665	-1,035	-24,357	0.686	0.00 ***
Volume of Sells	-478,405	172,252	-42,819	-1,284,278	0.444	0.00 ***
binary Order Flow	-19	773	3,602	-3,976	-0.043	0.14
quantitative Order Flow	-2,529	42,604	179,715	-248,798	0.116	0.00 ***
Traded Contracts	16,579	7,174	49,789	2,170	0.694	0.00 ***
Traded Volume	954,281	336,463	2,584,377	101,527	0.449	0.00 ***

Table 2: Augmented Dickey-Fuller test and Johansen rank test

The table reports the average results of the Augmented Dickey-Fuller-test and the Johansen rank test. The appropriate lag-length is determined by the likelihood ration test and in both cases on average four. The one percent critical value of the Augmented Dickey-Fuller-test is -3.458. The one percent critical value of the trace statistic is 19.935 and 18.520 of the eigenvalue statistic.

Augmented Dickey-Fuller-test	
maturity	ADF t-statistic
2-year	0.4789
5-year	0.4472
10-year	0.4311

Johansen rank test				
	maturity			
	5-year		2-year	
hypothesis	trace	eigenvalue	trace	eigenvalue
r=0	140.58	137.62	76.55	73.58

Table 3: Yearly information shares

Results below are the annual averages of the daily information shares estimated by the Gonzalo-Granger permanent-transitory decomposition approach on a secondly frequency. Formally, the information share is the maturity-related eigenvector in the last column of an eigenvalue-eigenvector decomposition divided by the sum of the column. Days with a rank of less than two are dropped out which reduced our data set to 787 daily observations. The year 2007 is subdivided into two sequences. The "2007 before" label refers to the trading period until 8th of June 2007since then the five year's minimum tick size is reduced from one basis point to its half. Therefore, the "2007 afterwards" shows the computed information shares for the time after system's change. Structural break test results are indicated by a and b and are explained below.

	maturity	
year	5-years	2-years
2004	34.88%	28.38%
2005	32.88%	24.98%
2006	30.20%	24.34%
2007 before	31.00%	24.67%
2007 afterwards	50.06%^{a,b}	29.5%^{a,b}

An a indicates unequal means at least at the five per cent level of the Mann-Whitney-U-test for the 2007 afterwards sample compared to the rest of the time series.
A b indicates a different distribution at least at the five per cent level of the two-sample Kolmogorov-Smirnov-test for the 2007 afterwards sample compared to the rest of the time series.

Figure 1: Monthly information shares of the two- and ten-year future

This figure shows the developments of monthly information shares in the two- and ten-year German bond future. The calculations are based on the Gonzalo-Granger (1995) approach and represent the means of the daily information shares. Our data set starts at June 2004 and ends at November 2007.

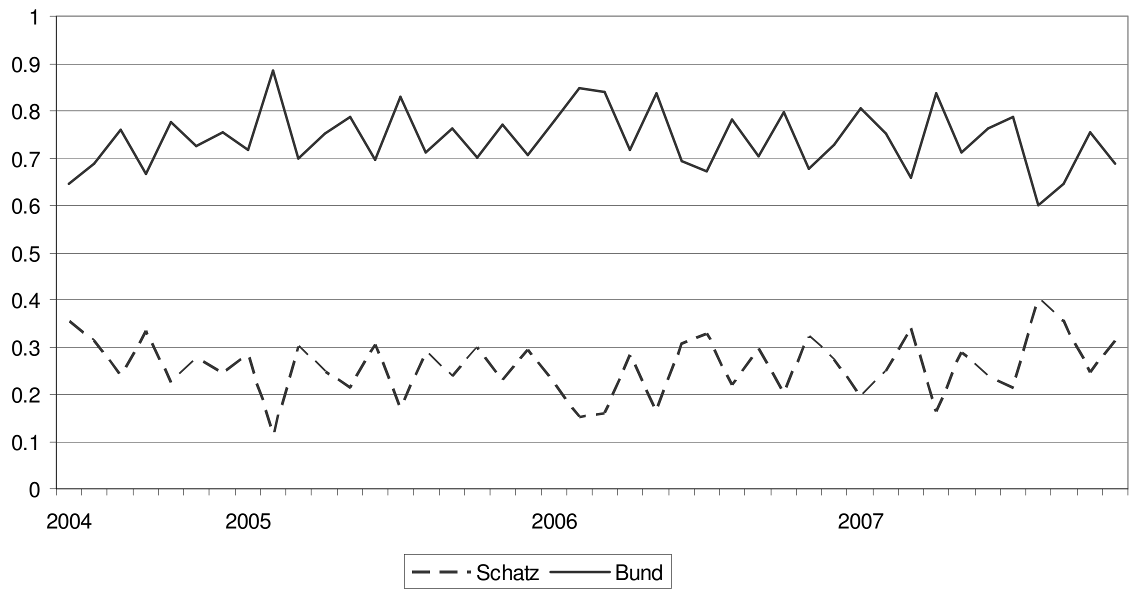

Figure 2: Monthly information shares of the five- and ten-year future

This figure shows the developments of monthly information shares in the five- and ten-year German bond future. The calculations are based on the Gonzalo-Granger (1995) approach and represent the means of the daily information shares. Our data set starts at June 2004 and ends at November 2007.

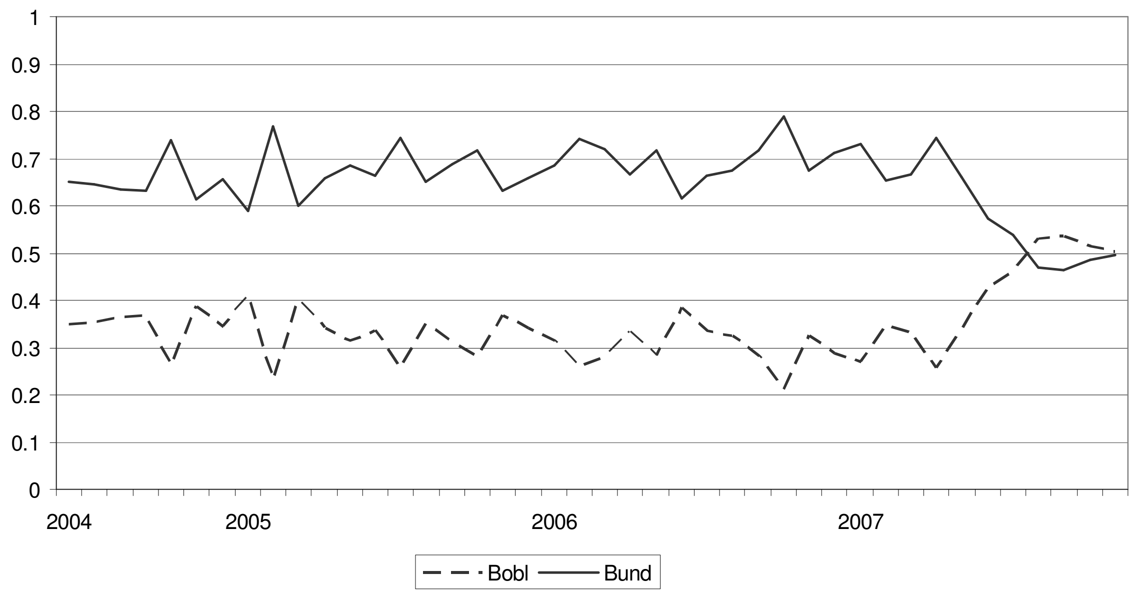

Figure 3: Monthly relative spread fluctuations

This figure shows the developments of the monthly relative spreads in the five- and ten year German bond future. The relative spread is measured as the spread of a contract in relation to the sum of the both spreads. The time period is between June 2004 and November 2007.

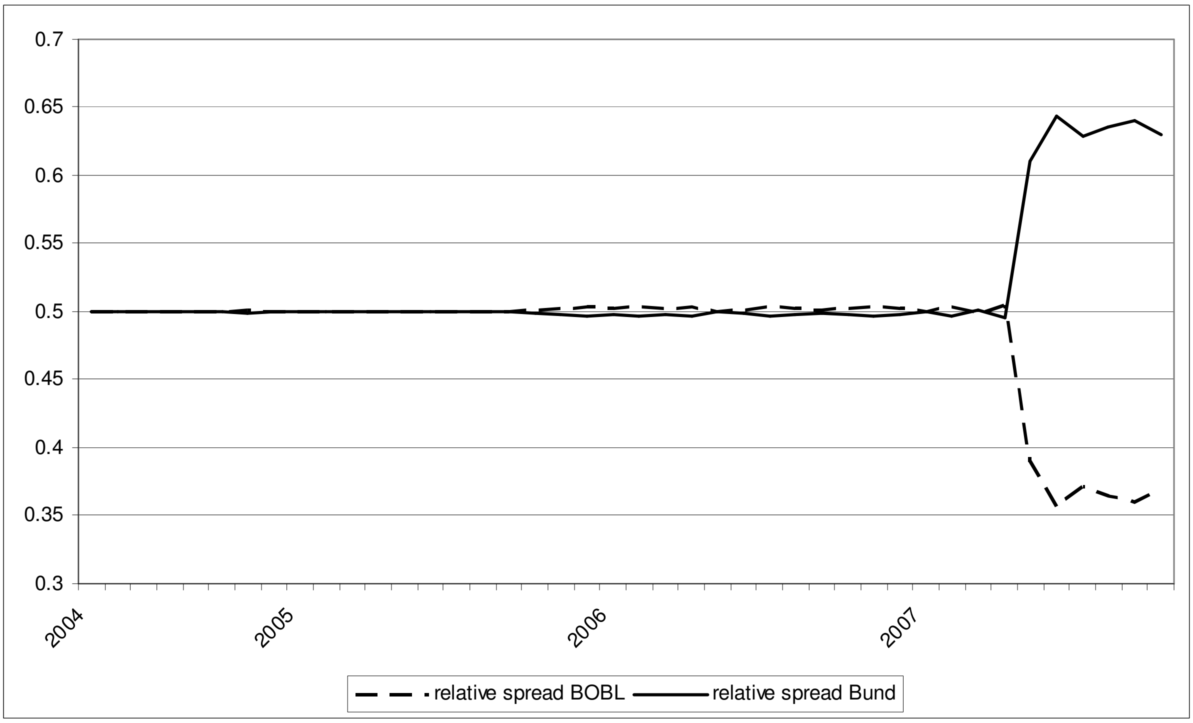

Table 4: Responses of information shares to liquidity related variables

The table mirrors the regression results of microstructure variables on daily information shares of the two and five years future against the ten years contract, which takes the following form:

$$IS_{i,t} = b_1 \times time-to-delivery + b_2 \times delivery\ \ day + b_3 \times S_{i,t} / \sum_{j=1}^{2} S_{j,t} + b_4 \times N_{i,t} / \sum_{j=1}^{2} N_{j,t} + b_5 \times RV_{i,t} / \sum_{j=1}^{2} RV_{j,t} + \varepsilon_t ,$$

with i representing the maturities, S the average five minute quoted spread, N the number of traded futures per day and RV midquote's realized volatility for the given day. The delivery day represents a dummy variable with a value of one when the day of delivery is reached and zero otherwise. The trend variable is inversely increasing in the time-to-maturity and is reset to zero if the maturity date is hit. The 10% (5%, 1%) significance level is marked with a * (** / ***).

	maturity			
	5-year		2-year	
variable	coefficient	t-statistic	coefficient	t-statistic
time-to-delivery	0.0008**	2.20	0.0001	0.31
delivery day	0.0282	0.54	0.0711	1.24
trading related				
spread	-0.3489***	-33.18	-0.0373***	-2.69
volume	0.1771***	5.33	0.2453***	9.87
variance	-0.0359	-1.12	0.1318***	4.73
R^2 / adjustedt R^2	13.53%	13.06%	9.56%	9.08%

Table 5: Daily information shares' fluctuation and macroeconomic announcements

Results report regression results of trend variables and announcement dummies on the daily information shares of the two- and five-years contract, each compared to the ten-years contract. Robust standard errors (Newey-West, 1987) are used. The introduced time-to-delivery variable is linear increasing until the day of delivery and restarts at zero afterwards. Delivery day represents a dummy variable with a value of one when the day of delivery is reached and zero otherwise. Announcement dummies are classified in the way if the respective announcement is released at this day. The break point dummy receives a value of one in the aftermath of the tick size reduction of the five-year future. The 10% (5%, 1%) significance level is marked with a * (** / ***).

	maturity			
	5-year		2-year	
variable	coefficient	t-statistic	coefficient	t-statistic
time-to-delivery	-0.0009	-0.92	-0.0009	-1.00
delivery day	0.0585	0.82	0.1309	0.98
break point dummy	0.9273***	23.78	0.1744***	6.35
announcement dummies				
US				
Jobless Claims	-0.1004**	-2.27	0.0087	0.17
PPI	0.0183	0.15	0.0096	0.09
GDP	-0.0805	-1.16	-0.1198	-1.12
Retail Sales	-0.1915***	-3.28	-0.1062	-1.07
CPI	-0.0973***	-3.33	-0.1466**	-2.27
FOMC	0.0513	0.30	0.0199	0.11
Euro Area				
Jobless Claims	-0.1705**	-2.23	0.0123	0.12
PPI	0.0019	0.01	0.1003	1.18
GDP	-0.1187***	-2.83	-0.2219***	-3.52
Retail Sales	-0.0270	-0.33	0.2524	0.86
CPI	-0.0824	-1.15	-0.0889	-0.81
ECB conferences	0.1991	1.13	0.3228*	1.73
German				
Jobless Claims	0.0580	0.29	0.2141	1.10
PPI	-0.3445**	-2.42	-0.2879**	-2.07
GDP	-0.1010	-0.82	0.0072	0.12
Retail Sales	-0.0843	-1.16	-0.0717	-1.09
CPI	-0.1509*	-1.70	0.1897	1.26
R^2 / adjustedt R^2	12.00%	9.67%	2.65%	0.12%

Table 6: Daily information shares' fluctuation and order flows

Results report regression results of trend variables and step-by-step added standardized shares of order flows, unexpected order flows and medium-sized order flow on the daily information shares. (Non-) Announcements variables are constructed by setting the standardized variables on non-relevant days to zero. Robust standard errors (Newey-West, 1987) are used. The considered variables delivery-day, time-to-delivery and the break point dummy are not reported for brevity. The 10% (5%, 1%) significance level is marked with a * (** / ***).

Panel A	maturity			
	5-year		2-year	
variable	coefficient	t-statistic	coefficient	t-statistic
order flow				
non-announcement	-0.0109	-0.55	0.1405***	7.05
announcement	0.1221***	5.94	0.1964***	5.27
R^2 / adjustedt R^2	11.42%	10.94%	3.43%	2.91%

Panel B	5-year		2-year	
variable	coefficient	t-statistic	coefficient	t-statistic
order flow				
non-announcement	-0.0086	-0.41	0.1494***	7.82
announcement	0.1283***	5.61	0.1933***	4.88
unexpected order flow				
non-announcement	0.0875***	4.51	0.1825***	6.74
announcement	0.0903***	4.82	0.1583***	6.82
R^2 / adjustedt R^2	12.21%	11.49%	6.28%	5.52%

Panel C	5-year		2-year	
variable	coefficient	t-statistic	coefficient	t-statistic
order flow				
non-announcement	-0.0167	-0.81	0.1441***	7.89
announcement	0.1179***	4.72	0.1631***	4.01
unexpected order flow				
non-announcement	0.0872***	4.35	0.1642***	6.02
announcement	0.0830***	4.43	0.1394***	6.59
medium-sized oder flow				
non-announcement	0.0972**	2.47	0.1247***	2.84
announcement	0.1013***	5.42	0.2496***	7.86
R^2 / adjustedt R^2	13.19%	12.23%	10.12%	9.15%

Table 7: Impact parameters on daily information shares' fluctuation

Results report regression results of trend and trading-related variables and announcement dummies on the daily information shares of the two- and five-year contract, obtained by using robust standard errors (Newey-West, 1987). Volume, volatility, spread, order flow, unexpected order flow and medium sized order flow are measured as standardized proportions. The time-to-delivery variable is linear increasing until the day of delivery and restarts at zero afterwards. Delivery day represents a dummy variable with a value of one when the day of delivery is reached and zero otherwise. Announcement dummies are classified in the way if the respective announcement is released at this day. The 10% (5%, 1%) significance level is marked with a * (** / ***).

	maturity			
	5-year		2-year	
variable	coefficient	t-statistic	coefficient	t-statistic
time-to-delivery	0.0017***	3.83	-0.0009	-1.34
delivery day	-0.0528	-0.81	0.0941**	2.12
trading-related				
spread	-0.3408***	-30.12	-0.0282**	-2.47
volume	0.1725***	5.59	0.1757***	5.76
volatility	-0.0475**	-2.16	0.0920***	3.85
announcement dummies				
US				
Jobless Claims	-0.0656*	-1.78	0.0226	0.55
PPI	0.0575	0.65	0.1021	1.21
GDP	0.0010	0.02	-0.0317	-0.50
Retail Sales	-0.1614***	-4.04	-0.0688	-0.88
CPI	-0.0043	-0.24	-0.0472	-0.95
FOMC	0.0607	0.43	-0.0578	-0.44
Euro Area				
Jobless Claims	-0.1735***	-3.07	0.0740	0.97
PPI	0.0302	0.31	0.0617	0.75
GDP	-0.0935***	-2.63	-0.1263***	-2.59
Retail Sales	0.0103	0.25	0.3061	1.59
CPI	-0.1129*	-1.95	-0.1348***	-2.23
ECB conferences	0.0916	0.62	0.0972	0.76
German				
Jobless Claims	0.0911	0.69	0.1942*	1.79
PPI	-0.2781**	-2.37	-0.1546	-1.24
GDP	-0.1276	-1.33	0.0131	0.24
Retail Sales	0.0033	0.06	0.1209**	1.99
CPI	-0.1010	-1.40	0.1403	1.07
informed trading related				
order flow				
non-announcement day	-0.0195	-0.98	0.1141***	5.84
announcement day	0.1081***	6.18	0.1388***	6.17
unexpected order flow				
non-announcement day	0.0843***	5.06	0.1429***	4.32
announcement day	0.0751***	3.33	0.1197***	6.37
middle trades				
non-announcement day	0.0020	0.04	0.0184	0.36
announcement day	-0.0040	-0.19	0.1211***	3.70
R^2 / adjustedt R^2	15.63%	12.43%	14.57%	11.38%