# Price discovery in government bond markets

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**Abstract**

This paper investigates the process of price discovery in government bond markets. By using a new data set including interdealer trades, customer trades, trade types and dealer identities, the paper explores the role of dealers in the price formation process and seeks to identify their sources of information. At the aggregate level the results show that interdealer order flow is highly informative, explaining one fourth of daily yield changes, while customer order flow has little explanatory power. At the individual dealer level the results reveal that dealers contribute differently in the price discovery process. They appear to be heterogeneously informed and have different sources of information. While some informed dealers extract information from their customer trades, others could acquire information through their skill in collecting and interpreting relevant information. This suggests that dealers are not mere intermediaries of customer trades, but play an independent role in the price discovery process in government bond markets.

*Keywords*: Government Bond Markets, Market Microstructure, Price Discovery, Dealers

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# 1 Introduction

The process of price formation is largely ignored in traditional economic models, which assume that prices adjust instantaneously to new information. The assumption of immediate price adjustment applies equally to public and private information. The market microstructure literature advocates a different view. In microstructure models the process of price formation is crucial and private information plays a key role. Private information is defined by Lyons (2001) as information, not known by all, that produces a better price forecast than public information alone. According to the market microstructure literature the process of price formation is carried out through two channels; a direct channel where prices adjust immediately to new public information, and an indirect channel, referred to as price discovery, where prices adjust over time to private information conveyed through order flow.[1] The gradual adjustment of prices through the indirect channel implies that prices do not fully reflect all available information at any point in time.

Hasbrouck (1991), Evans and Lyons (2002) and Brandt and Kavajecz (2004) support the market microstructure view by showing that order flow plays an important role in the price formation process in stock markets, foreign exchange markets and government bond markets, respectively. They find that order flow contains private information and explains a substantial part of daily price changes in these asset markets. This paper further explores the process of price discovery in sovereign bond markets. A new data set including interdealer trades, customer trades, trade types and the identities of the buying and selling dealers, allows for an investigation into the role of dealers in the price discovery process and the sources of information in interdealer order flow.

This study has two major contributions. The first is to compare the informational content of interdealer order flow to that of customer order flow. The paper measures the price impact of interdealer order flow, total customer order flow, and a measure of informed customer order flow on bond yields. Previous studies employ either interdealer order flow or customer order flow, but not both. Brandt and Kavajecz (2004), Anand and Subrahmanyam (2008) and Evans and Lyons (2002) use interdealer order flow from the

[1] Order flow is a measure of the net buying pressure in the market, and is calculated by subtracting seller initiated trades from buyer initiated trades during a time interval. A buyer-initiated trade will have a positive sign and a seller-initiated trade will have a negative sign.

bond, equity and currency markets respectively. Evans and Lyons (2005) use customer order flow from the currency market and Menkveld, Sarkar and van der Wel (2011) use customer order flow from the bond futures market. This paper employs a unique data set that enables the identification of interdealer trades, customer trades and delayed publication trades. Delayed publication customer trades are used as a proxy for informed customer trades. These trades are not visible to other traders until after a period of delay. Dealers are likely to choose this alternative if they believe a customer trade contain private information, and they can benefit from this information before it becomes available to their competitors.

The second contribution of this paper is to explore whether dealers are heterogeneous and play different roles in the price discovery process. Are dealers differently informed and do they have different sources of information? Are some dealers pure intermediaries while other dealers possess skill in collecting and interpreting relevant information that they subsequently trade on? Unlike the data sets used in previous studies, this data set includes the identities of the buying and selling dealers for each trade. It is therefore possible to compare the contribution of each dealer in the price formation process. This type of individual dealer analysis has not been undertaken so far due to a lack of data. By studying the characteristics of the dealers, including market share, relative activity in the interdealer market and the correlation between customer order flow and interdealer order flow, we may infer the sources of information of different dealers.

In sovereign bond markets private information can be divided into types along two dimensions. The first dimension is related to whether private information reflect fundamental or non-fundamental information. Fundamental private information is related to macroeconomic factors, for example heterogeneous interpretations of macroeconomic indicators like consumer and producer surveys for future inflation, employment and GDP growth. Examples of non-fundamental private information are changes in liquidity conditions, auction volumes or hedging demands. Fundamental private information will influence expected future short rates and risk premia through the macroeconomic outlook, while non-fundamental private information related to, for example, supply conditions will influence liquidity risk premia.

The second dimension is related to the source of private information. Many empirical

studies employ interdealer order flow, and two frequently mentioned sources of information in interdealer order flow are customer trades and dealer skill. If the information in interdealer order flow reflects the information in customer order flow only, this indicates that the dealer does not add any information. In this case dealers are passive intermediaries of customer orders and customer trades are considered to be the source of information in interdealer order flow. If interdealer order flow is more informative than customer order flow, this indicates that dealers possess more information than their customers. Dealers may obtain extra information by using skill in collecting and interpreting relevant information. Anand and Subrahmanyam (2008) find that dealers contribute more to price discovery than their customers and conclude that dealers are better informed than other market participants. In this case dealer skill can be considered to be a source of information. In equity markets, insider information related to for example mergers or new orders may be a third source of information, but this type of information is unlikely to be of importance in sovereign bond markets. Two possible sources of information in interdealer order flow are considered in this paper: customer trades and dealer skill.

The results in this study show that interdealer order flow in the Norwegian government bond market contains information about bond yields. Aggregate interdealer order flow explains one fourth of daily yield changes in 3, 5 and 10 year government bonds. Order flow is divided into short, medium and long term order flow according to the remaining time to maturity of the bonds included.[2] All three order flow groups have a significant impact on yield changes of all maturities, but the strongest effect is on the same maturity yield change. Short term order flow thus has the highest impact on 3 year yield changes, but has a significant impact on 5 and 10 year yield changes also. These results indicate that there is information in the order flow of short term, medium term and long term bonds and that the information to a large extent, but not only, causes parallel shifts in this part of the yield curve. The information in interdealer order flow may thus be related to interpretations of macroeconomic news influencing 3 to 10 year yields by roughly the same, but also to other private information related to for example news on hedging and investment strategies influencing some maturities only.

[2] Short term order flow includes the trades in bonds with a remaining time to maturity from 1 to 4 years, medium term order flow includes trades in bonds with a maturity greater than 4 years up to 7 years and long term order flow includes trades in bonds with a maturity greater than 7 years up to 11 years.

The results further document that customer trades are far less informative than interdealer trades. Aggregate customer order flow explains up to 1 percent of daily variation in yields, compared to 24 percent for aggregate interdealer order flow. When using a proxy for informed customer order flow, leaving out uninformed customers, the explanatory power of customer order flow increases to 2 percent of the daily variation in bond yields. The increased explanatory power of informed customer order flow indicates that dealers, at least partially, are able to identify their informed customers. The differences in the explanatory power of interdealer order flow and customer order flow suggest that dealers are better informed than their customers. By aggregating information from their own customer trades and the trades of other dealers, and by processing public information related to bond markets, dealers could be better informed than their customers.[3]

At the dealer level, the results show that dealers are heterogeneous and that they contribute in different ways to the price discovery process. The order flow of large dealers, measured by market share, has the largest price impact. The interdealer order flows of the two largest dealers have the highest price impact on 3 and 5 year bonds, whereas the order flows of the fourth largest dealer has the highest price impact on 10 year bonds. Also, order flow at different maturities has a different price impact depending on dealer. Whereas the medium term order flow has the highest price impact on all yield changes for one dealer, the long term order flow has the highest price impact for other dealers. This suggests that dealers specialize in trading at different segments of the yield curve and therefore concentrate their interdealer trading to this segment. The fact that a dealer's interdealer order flow in one segment influences both short, medium and long term yields confirms the results at the aggregate level that much of the information contained in the order flow of government bonds is common for all the segments of the yield curve included in this study.

The results at the dealer level also show that the connection between customer order flow and interdealer order flow varies among dealers. Whereas customer order flow explains a substantial part of interdealer order flow for some dealers with high price impact, customer order flows appear to be unrelated to the interdealer order flow of other

[3] Customers in the government bond market include insurance companies, institutional investors, domestic firms, foundations and individuals.

high-impact dealers. This indicates that dealers to a varying degree possess information additional to what they learn from their customer trades. Additional information could be acquired through dealer skill in collecting and processing relevant news. Examples of this type of information would be interpretation of macroeconomic data and the aggregation of dispersed private information held by other market participants. This is in line with the findings of Manaster and Mann (1996) who study the market for commodity futures, Osler, Mende and Menkhoff (2007) who study the foreign exchange market, and Anand and Subrahmanyam (2008) who study the equity market. Their findings indicate that dealers are not mere intermediaries of customer trades, but that they actively seek and aggregate information.

In all, the findings in this study show that dealers play an important role in the price formation process in the Norwegian government bond market and that the contribution varies substantially among dealers. One source of information in interdealer order flow appears to be customer orders, but the results also suggest that there is an additional source of information which could be related to dealer skill. The rest of the paper is organized as follows. Section 2 briefly discusses related literature. Section 3 describes the market settings and data. Section 4 discusses possible dealer strategies. Section 5 presents the econometric framework and the results. Section 6 concludes.

## 2 Related literature

This study is related to Brandt and Kavajecz (2004) who examine the price formation process in the US Treasury market. They divide interdealer order flow into six maturity groups along the yield curve and control for the effect of lagged yields by including the lagged three first principal components of yields. They then separate days with macroeconomic news from days with no news and investigate the effect of order flow on contemporaneous yield changes on no-news days. They find that up to 26 percent of daily yield changes on no-news days can be accounted for by interdealer order flow. They control for inventory effects by investigating whether the yield changes are reversed within the next few days, and conclude that the yield changes are permanent and therefore due to new information. This paper employs a similar method by dividing order flow into three

maturity groups and by including the lagged first principal component of bond yields in the price impact regressions. The paper extends the work by Brandt and Kavajecz (2004) by including both customer order flow and interdealer order flow as well as individual dealer order flow.

This paper is also related to studies concerned with the sources of private information and the role of dealers in the price formation process. Manaster and Mann (1996) study the behavior of market makers in various futures contracts at the Chicago Mercantile Exchange (CME). They conclude that market-makers are active profit-seeking individuals with heterogeneous levels of information and trading skill. Osler, Mende and Menkhoff (2007) investigate the process of price discovery in currency markets, and find that it takes place in the interdealer market rather than in the customer market. Anand and Subrahmanyam (2008) study price formation in equity markets and find that intermediaries (dealers) are better informed than their clients because of their advantage and skill in actively seeking and trading on information. Menkveld, Sarkar and van der Wel (2011) study the Treasury futures market, and find that customer order flow is crucial for price discovery since it conveys information about customer's risk preferences and endowments.

This paper differs from the existing literature by employing a new, comprehensive data set including all the trades in the secondary market for government bonds. Instead of examining either the interdealer market, like Brandt and Kavajecz (2004), the customer market, like Menkveld, Sarkar and van der Wel (2011), or a purely electronic market including both dealer initiated and customer initiated trades, like Anand and Subrahmanyam (2008), the analysis in this paper includes the complete bond market and can examine the relationship between the different parts. Osler, Mende and Menkhoff (2007) also include both the interdealer and customer markets, but only for one dealer. Also, the paper differs from the existing literature because it can identify all major dealers and therefore explore the role of each dealer in both markets. It is thus possible to observe to what extent customer trades are reflected in the interdealer trades of the different dealers. This enables the investigation of the sources of information in bond market order flow.

# 3 Market structure and data

The Norwegian government market is organized similarly to major government bond markets. A system of primary dealers contributes a liquid and well functioning market. Primary dealers have a set of rights and obligations formalized in contracts with the Treasury. The obligations include continuous quoting of firm bid and ask prices at a maximum spread and a minimum amount for each bond. Primary dealers are also expected to participate in auctions of government bonds. Rights include an exclusive repo arrangement administered by the Central Bank. Under this arrangement primary dealers can borrow a fixed amount in each benchmark bond at a low cost from the Treasury for a period from one up to ten days. The facility is meant to contribute to a more liquid market by increasing the dealers' ability to continuously quote prices and thus limit large price movements. In order to quickly replenish inventory after a sale a dealer can therefore borrow this bond from the Central Bank.

The secondary market for Norwegian government bonds is a two-tier market consisting of an interdealer market and a customer market. Figure 1 shows a simplified overview of the trading environment. Only dealers can execute trades in the electronic trading system administered by the Oslo Stock Exchange (OSE). Therefore, customers must trade through dealers and cannot trade directly with each other. As illustrated in Figure 1, dealers have access to both markets as they can trade with each other and with their customers, whereas customers only have access to the customer market. Dealers are defined as exchange members that are approved for bond trading. To be approved for bond trading members must comply with a set of rules and obligations including technical requirements. Typical exchange members are banks and brokerage firms. Customers are defined as all traders that are not exchange members. The majority of interdealer trading activity involves primary dealers.

Auctions in government bonds are held six to eight times a year according to a pre-announced auction calendar. The number of outstanding bonds varies between 4 and 6 benchmark bonds. In 2000 there were five outstanding benchmark bonds with a daily average turnover in each bond of about 200 million US dollars. Every other year a new 11 year benchmark bond is launched. It is reopened regularly until it has reached a size

deemed sufficient. Table 1 lists the 7 benchmark bonds that were outstanding and traded in the secondary market during the sample period. The interdealer share of the trading activity is roughly 35 percent. Customer trades are on average larger than interdealer trades.

The amount of outstanding central government debt in Norway was about 33 billion US dollars in 2000. In comparison central government debt in 2000 amounted to 34 billion US dollars in Ireland, 137 billion US dollars in Sweden and 169 billion US dollars in the Netherlands. The US government debt amounted to more than 3 trillion US dollars.[4] Average daily turnover in government bonds was close to 1 billion US dollars including repos in Norway compared to 2.1 billion US dollars in Sweden and 290 billion US dollars in the United States.[5] In Norway, the number of primary dealers in government bonds has varied between eight and six in the period 1999 to 2005. The number of primary dealers in government bonds was in 2000 six in Ireland, eight in Sweden, thirteen in the Netherlands and twenty in the US Treasury market. Compared to other government bond markets the Norwegian market is relatively small. However, in order to promote liquidity the government has limited the number of bonds to a few large benchmark bonds. Thus, the results in this study should be relevant for other sovereign bond markets.

The unique data set used in this paper includes all transactions in the interdealer market and the customer market, as well as the best bid and ask prices submitted by dealers at the OSE over the period from September 6, 1999 to September 30, 2005. For each transaction the date, time, price, amount, the identity of the buying and the selling dealer and the type of trade is observed. Different types of trades include auto-match (electronic) trades, ordinary over-the-counter trades, non-standard settlement over-the-counter trades, trades registered outside market opening hours, repo trades, delayed publication trades and auction allocations in the primary market. Repo trades, auction allocations, and trades with a trade amount of less than 1 million Norwegian kroner (180 000 US dollars) are excluded from the data set as the informational content of these trades is assumed to be limited. The total number of trades included in the analysis is 66,650.

[4] Outstanding government debt in percent of current GDP in USD and PPPs was in 2000 about 20 percent in Norway, 56 percent in Sweden, 31 percent in Ireland, 36 percent in the Netherlands and 31 percent in the United States.

[5] Average daily turnover in year 2000 was 8 billion NOK including repos and 2 billion NOK without repos.

Trading takes place both in the electronic trading book and in the over-the-counter market. The share of electronic trading and the average electronic trade size has increased gradually since the inception of an electronic order book in 1999. Still, a majority of interdealer trades are over-the-counter trades. Also most customer trades are over-the-counter trades. It is important to note that the customer trades and interdealer trades are distinguished by using the identities of the buying and selling dealers. Trades which have different dealers on the buy side and the sell side are defined as interdealer trades, and trades which have the same dealer on both sides are defined as customer trades. In a customer trade the dealer will appear as both the buyer and the seller of the bonds because customers must trade through a dealer. When a trade with a customer is agreed upon, the dealer will enter both sides of the transaction in the OSE trading system, SAXESS. Also proprietary trades and brokered trades are registered with the same dealer as the buyer and seller, and are thus classified as customer trades in this study.[6] Information on dealer identities is not available to all market participants, only to the dealers involved in the trade.

Delayed publication trades are trades entered into the trading system without immediately appearing on the screen of the other dealers and are thus unobservable for a certain time period. This type of trade was granted in order to make it easier for primary dealers to accommodate the requests of large customers and to allow market makers to unwind their inventory positions at minimal cost. The conditions for delayed publication trades, including the period of delay, has changed over the sample period. From 1999 to 2002 there was a two hour delay for trades amounting to 200 million Norwegian kroner or more. From May 2002, with the inception of SAXESS, publication was delayed to the end of the trading day which is 4 p.m., no matter when the trade was entered into, and the size limit was abandoned. Also, SAXESS opened up for the possibility to choose delayed publication as default. Some dealers may have opted for this as the number of delayed publication trades increased from mid-2002.

In this study, delayed publication customer trades are used as a proxy for informed customer trades. It is likely that dealers will choose to enter trades from informed cus-

[6] Proprietary trades are in a sense internal customer trades or informed customer trades. Brokered interdealer trades are interdealer trades through a broker where the real counterparty is unknown.

tomers as delayed publication trades in order to benefit from the trade information before it becomes available to other dealers. If dealers can identify their informed customers, and enter these trades as delayed publication trades, they will gain private information that will be hidden from the other market participants. They can then trade on this information in the interdealer market before prices are updated with this information. When these trades become visible to the other dealers, prices will be, at least partially, updated accordingly. In the analysis the sample is divided into two sub-periods to control for the effects of the changes in the conditions for delayed publication trades from mid-2002.

The bid-ask spreads prevailing at the time right before the trade are used to determine the direction of the trades. Since order flow is a measure of the net buying pressure in the market it is necessary to know whether a trade is initiated by the buyer or the seller of the bond in order to calculate it. A buyer-initiated trade is given a positive sign and a seller-initiated trade is given a negative sign. As this information is not observed in the data set the method of Lee and Ready (1991) is used to sign the trades.[7] The signed trades are then aggregated into daily order flow. The signed trades can be given equal weights, in which case each buyer initiated trade is given the value +1 and each seller initiated trade is given the value -1, or they can be measured according to size, in which case the trade volume in Norwegian kroner is used as weight. Order flow can thus be measured in number of trades or volume. As a main rule the former method is used in this study. This is in line with Fleming (2003) who finds that using the number of trades gives better explanatory power than using the volume. However, in section 5.3, when studying the relationship between interdealer and customer order flow for individual dealers, order flow is measured as the net volume of trades in Norwegian kroner. To determine the extent to which informed customer trades are a source of information in interdealer order flow, order flow based on volume is used. This will indicate how much of the customer trade volume is passed on to the interdealer market and provide a more precise relationship between the customer trades and interdealer trades of a dealer. Trading strategies vary between dealers and a large customer trade can be passed on to the interdealer market as one large trade or as many small trades.

[7] Trades that are executed at a price less than the mid price are classified as seller-initiated, and trades that are executed at a price higher than the mid price are classified as buyer-initiated. For trades executed at the mid price, the tick rule is used.

In order to measure the price impact of daily order flow, daily changes in synthetic 3, 5 and 10 year government bond yields are employed. These yields are based on end of day prices of the bonds in Table 1 and are calculated by Norges Bank[8]. Order flow is divided into three matching maturity groups. The first, short term order flow, contains trades in bonds with a remaining time to maturity between 1 and 4 years. The second, medium term order flow, contains trades in bonds with a remaining time to maturity greater than 4 years up to 7 years. The third group, long term order flow, contains trades in bonds with a remaining time to maturity greater than 7 years up to 11 years. The three maturity segments of interdealer order flow are labelled $\text{OF}^S$, $\text{OF}^M$ and $\text{OF}^L$ respectively, and the corresponding segments of customer order flow are labelled $\text{COF}^S$, $\text{COF}^M$ and $\text{COF}^L$.

The data set used in this study contains 1505 days. Several studies of bond markets distinguish between days with macroeconomic news and days with no news, and include either news days or no-news days depending on the questions addressed. Studies like Brandt and Kavajecz (2004) which are exploring the role of price discovery include no-news days only. This is to eliminate price movements due to the release of public news. If the sensitivity of prices to order flow is lower than usual around the announcement of economic news, the effect of order flow on prices should be lower on news days than on no-news days. Brandt and Kavajecz (2004) therefore eliminate the direct effect of public news on prices by excluding the three days surrounding announcement days from their sample. In order to assess the effect of public information on Norwegian bond yields, the data set is divided into news days and no-news days in Table 2. The most influential news for the Norwegian bond market are related to inflation and changes in the monetary policy rate. News on domestic GDP, unemployment and other macroeconomic indicators have little impact on the prices in the bond market. News days are thus identified as the 3 days surrounding the release of the monthly Consumer Price Index and the press release from Monetary Policy meetings.

Table 2 displays descriptive statistics of daily yield changes, interdealer and customer order flow of different maturity groups on all days, no-news days and news days. The table shows that average yield changes are larger on news days than on no-news days, indicating that news on inflation and monetary policy has considerable impact on bond

[8] Norges Bank is the Norwegian Central Bank.

yields. Table 2 further indicates that average interdealer order flow is about the same on news days and no-news days for long term order flow. For medium term order flow the mean is smaller on news days than on no-news days, and for short term order flow the mean is larger on news days than on no-news days. Differences in customer order flow between news days and no-news days are also relatively small and we conclude that order flow is not greatly influenced by the direct effect of news on inflation and monetary policy. This paper therefore includes all days in the analysis. If any, the effect of including all days instead of no-news days only should be that the effect of order flow on prices is smaller than otherwise. Table 3 displays descriptive statistics for informed customer order flow and interdealer order flow orthogonal to informed customer order flow for the three maturity groups.

Table 4 shows the unconditional correlations between yield changes and order flows of different maturities. Yield changes are strongly and positively correlated with each other indicating that a large part of yield changes occurs as parallel shifts in the yield curve. The correlations between yields and interdealer order flow are significant and negative indicating that positive order flow is related to higher bond prices and lower yields. This suggests that interdealer order flow contains news relevant for bond prices. In contrast, the correlations between yield changes and customer order flow are much weaker and only significant for long term customer order flow.

Table 5 shows common yield factors and common order flow factors extracted by performing principal components analysis. The principal components of the bond yields are in line with those found for the US Treasury market in Brandt and Kavajecz (2004). The first common factor explains nearly 99 percent of the variation in yields and loads about equally on all maturities. This factor is therefore referred to as the "level" factor by Litterman and Scheinkman (1991). The second and third factors are labelled the "slope" and the "curvature" factors. The slope factor explains one percent, and the curvature factor almost none, of the variation in the 3 to 10 year bond yields during this period. The principal components of order flow are also extracted. There appears to be one dominant factor in interdealer order flow explaining 48 percent of the variation. The factor loads a little more on intermediate and short maturities than on long maturities. Customer order flow seems to have no dominant factor as the three factors explain about one third of the

variation each. The factor structure of interdealer order flow combined with relatively low correlations across maturities indicates that there is less commonality in different maturity order flow than in different maturity yields. This could imply that the information reflected by order flow in the different maturity segments is different.

# 4 Dealer strategies

This paper investigates the role of dealers in the process of price discovery in bond markets. Do dealers have an active role in price discovery or are they just passive intermediaries of customer orders? One approach to this topic is to study the interaction between the customer market and the interdealer market. Figure 1 showed the connection between the customer and interdealer markets and illustrated how dealers report all trades into the SAXESS trading system. Customer trades (C-trades) and interdealer trades (I-trades) are distinguished by who the buying and the selling dealers are. As mentioned in the previous section, customer trades have the same buying and selling dealer while interdealer trades involve two different dealers. After a trade with a customer is executed, the dealer can pass it on to other dealers, or let her inventory change. If she chooses to pass it on to other dealers she can use market orders or limit orders. Market orders are trades that are transacted to the prevailing market prices and agreed on by the two parties over the phone (over-the-counter trades) or by the trader by accepting the quote in the order book (electronic trades). Limit orders are orders placed at a price differing from the prevailing market price either by phone or by entering a bid or an ask quote in the electronic order book. Market participants who use market orders are, unlike those who use limit orders, the initiators of trades. While market orders are executed immediately, it can take time before limit orders are executed. Limit orders also have a risk of not being executed. An impatient trader is thus likely to use market orders and a patient trader is likely to use limit orders.

In order to investigate whether dealers acquire information from their customer trades, this paper analyzes the relationship between a dealer's trades in the customer market and the interdealer market. If a dealer's order flow is informative and there is a positive relationship between her customer order flow and her interdealer order flow, it is concluded

that customer trades is an important source of information. However, this conclusion is based on the assumption that the dealer uses market orders. This is because a dealer's interdealer order flow by definition consists of her initiated interdealer trades. If a dealer uses market orders when she passes on her customer trades to other dealers, the customer trades will be reflected in her interdealer order flow. If she passes the customer trades on to other dealers by using limit orders, the customer trade will not be reflected in her interdealer order flow, but in her counterparty's interdealer order flow. The use of limit orders instead of market orders will thus reduce the link between the dealer's interdealer order flow and customer order flow.

The interaction between the two markets can be discussed in the context of market microstructure models of the Glosten-Milgrom type.[9] In these models there are one market-maker (dealer) and two types of traders (customers); informed and uninformed. An informed trader possesses private information about the true value of the asset, and will trade on this information. She will buy the asset only if she has positive information and sell it only if she has negative information. An uninformed trader, often called a liquidity trader, trades for reasons exogenous to the model. Uninformed trades could for example be related to the rebalancing of indexed portfolios or raising cash. An uninformed trader is expected to be equally likely to buy and sell the asset as the trades are independent of the expected future value of the asset. The market maker in this model will set prices equal to her conditional expectation of the value of the asset given the type of trade, a buy or a sell, that occurs. Expectations are assumed to be updated through a Bayesian learning model containing prior probabilities for the occurrence of informed versus uninformed traders and the occurrence of good versus bad news. The model is mainly concerned with the price process and how a market-maker sets quotes.[10] It does not describe the trading behavior of the dealer, but the logic of the model can be used to derive possible dealer strategies.

Based on the reasoning in this type of model a dealer may choose the trading strategy depicted in Figure 2. The strategy requires that she can identify her informed customers. In Figure 2 the dealer first receives a customer trade and then decides whether the trade is

[9] See O'Hara (1995) for a description of these types of models.

[10] Quotes are the bid and ask prices set by a market-maker.

informed or not. If the customer trade is considered informed the dealer will subsequently initiate a trade in the same direction in the interdealer market.[11] If the customer trade is considered uninformed the dealer will enter a limit order in the same direction in the interdealer market or let her inventory change. Figure 2 thus illustrates a strategy where the dealer off-loads risk in the interdealer market by using market orders if the customer is considered informed and limit orders if the customer is considered uninformed. In the latter case the dealer can also choose to add the uninformed customer trade to her inventory. She could then wait for an uninformed customer trade in the opposite direction to change her inventory again.

The strategy described above assumes that a dealer can identify her informed customers. A dealer may identify an informed customer based on conversations prior to the trade or on past trading history. A dealer who possess private information is likely to be an impatient market participant who would like to trade right away in order to benefit from this information. If she has to wait the price may change before she is able to utilize her informational advantage. If the dealer identifies the customer as uninformed she is likely to be patient as the risk of a substantial price change is perceived as little. A strategy where a dealer uses market orders in the interdealer market after receiving informed customer trades and limit orders when receiving uninformed customer trades thus seems to be reasonable. This is also in line with Osler (2008) who concludes that a dealer in the foreign exchange market is more likely to place a market order after trading with an informed customer than after trading with an uninformed customer. If dealers follow this strategy, interdealer order flow should be more informative than customer order flow. While interdealer order flow will reflect informed customer trades, customer order flow reflects the sum of uninformed and informed customer order flow.

Dealers may follow strategies different from the one described above. Dealer strategies can vary according to market settings, risk limits and other market conditions. However, if a majority of the dealers normally follow the strategy described in Figure 2, aggregate interdealer order flow should be more informative than aggregate customer order flow. This paper will focus on the strategy described above. Interdealer order flow can also be more informative than customer order flow because dealers are better informed than

[11] If the customer buys from the dealer, the dealer will buy in the interdealer market and vice versa.

their customers. By aggregating information from observed trades and interpreting public information a dealer can acquire superior information. Thus, interdealer order flow can be informative because it reflects informed customer trades or because dealers are skilled in acquiring superior information.

Customer trades and dealer skill appear to be two important sources of information in interdealer order flow. If a dealer's main source of information is her customer trades and she follows the strategy in Figure 2, her informed customer trades will reflected in her interdealer order flow. In this case, we would expect a high correlation between the customer order flow and interdealer order flow of the dealer. If she has a high share of informed customer trades her interdealer order flow will be more informative than if she has a low share. It will also be less informative if she has problems to distinguish informed and uninformed customers. If a dealer's main source of information is her skill in obtaining superior information. Superior information could be gained through the dealer's skill in interpreting private and public information. In this case the dealer will trade in the interdealer market independently of her trades in the customer market and one would expect that the link between the customer order flow and interdealer order flow is relatively low.

# 5 Econometric framework and results

In order to explore the role of dealers in the price discovery process we first investigate the price impact of aggregate order flow. If aggregate interdealer order flow explains daily yield changes we conclude that at least some dealers possess relevant information and play a role in the price formation process. If aggregate customer order flow can explain daily yield changes we conclude that customer trades contain information relevant for bond yields. If both interdealer order flow and customer order flow can explain daily yield changes we conclude that customer trades are one source of information for dealers. However, aggregate customer order flow consists of both informed and uninformed customer trades. As the trades of informed and uninformed customers could cancel each other out, it would be preferable to have a measure that includes informed customer trades only. We employ delayed publication customer trades as a proxy for informed customer trades. Comparing

the informational content of this proxy to aggregate customer order flow will indicate whether dealers are able to identify their informed customers. We then investigate whether informed customers could be an important source of information for dealers by comparing the informational content of informed customer order flow to that of interdealer order flow orthogonal to informed customer order flow.

We then investigate the informational content of order flow at a disaggregated level. We compare the informativeness of interdealer order flow at the individual dealer level. The availability of dealer identities enables the calculation of individual dealer interdealer order flow and individual dealer customer order flow. First, the contribution of short, medium and long term interdealer order flow to 3, 5 and 10 year yield changes are explored for each dealer. Then the relationship between each dealer's interdealer order flow and customer order flow is investigated. If customer order flow explains a significant part of interdealer order flow for a dealer, and the dealer's interdealer order flow is informative, it could indicate that the dealer has informed customers who are the source of her information. If customer order flow does not explain interdealer order flow, and the dealer's interdealer order flow is informative, it is likely that her main source of information is something else, which could be dealer skill in collecting and interpreting relevant information. These hypotheses are tested below.

### 5.1 Aggregate order flow

To compare the price impact of aggregate interdealer order flow and aggregate customer order flow in the Norwegian government bond market we run the following regression,

$$dY_t^i = c + F1_{t-1} + OF_t^S + OF_t^M + OF_t^L + COF_t^S + COF_t^M + COF_t^L + e_t, \qquad (1)$$

where $dY_t^i$ is the yield change of the $i^{th}$ maturity from day $t-1$ to day $t$ where $i = 3$, 5 and 10 years, $c$ is a constant, $OF_t^S$, $OF_t^M$ and $OF_t^L$ are short, medium and long term aggregate interdealer order flows and $COF_t^S$, $COF_t^M$ and $COF_t^L$ are short, medium and long term aggregate customer order flows on day $t$. To control for the impact of past yield changes, the lagged first principal component of yields, $F1_{t-1}$, is also included in the regression.

The results are presented in Table 6. The $R^2s$ document that interdealer order flow explains about one fourth of daily yield changes, which is in line with Brandt and Kavajecz (2004). This indicates that the price formation process in the Norwegian government bond market is consistent with that of the Treasury market, and suggests that the findings in this study are relevant for sovereign bond markets in general. It further appears that while interdealer order flows of all maturities are highly significant, customer order flows only have significant effects on 10-year yield changes. The lagged yield factor, $F1_{t-1}$, has no significant effect on any maturity. Interdealer order flow of all maturities has a significant effect on all yield changes, and the effect is greatest on same maturity yield changes. An increase in short term interdealer order flow of one standard deviation will lead to a decrease in the 3 year yield of 1.3 basis point. This corresponds to an annual decrease of 3.4 percentage points. The results indicate that interdealer order flow has a much larger effect on daily yield changes than customer order flow.

The results in Table 6 indicate that the trading strategy depicted in Figure 2 is followed by at least some dealers. Aggregate customer order flow has no impact on 3 and 5 year yield changes. Long term customer order flow has a significant impact on 10 year yield changes, but the effect is smaller than for long term interdealer order flow. These results may indicate that there are many uninformed customers, and that the trades of these customers "offset" the trades of informed customers.

According to market microstructure theory price changes caused by order flow could be due to private information or to inventory effects. While inventory effects are expected to be temporary, new information will lead to a permanent change in prices. To control for inventory effects, an unrestricted VAR model is employed. Endogenous variables in the VAR model are interdealer order flow and yield changes. By calculating accumulated impulse responses over a 10 day period, it is possible to observe whether the price impact is permanent or not.[12] The results are shown in Figures 3 to 5. Figure 3 shows that a unit shock to short term interdealer order flow leads to a reduction of 2 to 3 basis points in the 3 year yield. Figures 4 and 5 illustrate that a unit shock to interdealer order flow of all maturities leads to a reduction of about 2 basis points in the 5 and 10 year yields. The figures confirm the results in Table 6 which show that each maturity has the largest

[12] A lag-length of 2 is employed, which in line with the Aikaike and Schwartz information criteria.

response to its "own" order flow imbalance. The impulse responses clearly indicate that the effect of order flow on yield changes is permanent. This is in line with Brandt and Kavajecz (2004) who find that interdealer order flow contains private information relevant for bond prices. The results also supports the findings of Manaster and Mann (1996), Osler, Mende and Menkhoff (2007) and Anand and Subrahmanyam (2008), but appear to be in opposition to the findings in Menkveld, Sarkar and van der Wel (2011).

In order to check the consequences of including all days versus including no-news days only, we have compared the effect of order flow on yield changes in both cases. News days were identified as the 3 days surrounding the release of the monthly Consumer Price Index and the press release from Monetary Policy meetings. The results, that are not shown in the paper, indicate that the effects of order flow were higher on no-news days than on all days.[13] Another reason for including all days is that there is a stream of more or less important public news every day. It is thus difficult to eliminate the direct effect of public news completely. In addition, some studies show that the indirect channel of price formation is at work on news days also. Green (2004) finds that order flow helps determine the influence of new information on prices in the minutes after an announcement is made. These findings support the inclusion of all days when measuring the price impact of order flow.

### 5.2 Informed customer order flow

The results so far show that aggregate interdealer order flow contains information while aggregate customer order flow does not. This does not imply that all customers are uninformed, but indicates that the trades of informed customers are not reflected in aggregate customer order flow. One way to explore whether some customers are informed, is to find a proxy for informed customer order flow. By utilizing the data set available in this study, it is possible to construct order flow based on the trade type delayed publication. Since dealers have the option to enter an additional code for delayed publication when they register a trade, it can be assumed that dealers will choose to do this when they receive a perceived informed customer trade. After May 2002 dealers were able to set the code for delayed publication as a default, and it is possible that some dealers then included both

[13] The results are available upon request.

informed and uninformed customer trades in this category. This change can have altered the information content in delayed publication trades, and we will test for this. In order to explore whether informed customer trades are a source of information in interdealer order flow, we first use delayed publication customer trades as a proxy for informed customer order flow in the following model

$$dY_t^i = c + F1_{t-1} + resOF_t^S + resOF_t^M + resOF_t^L + HCOF_t^S + HCOF_t^M + HCOF_t^L + u_t, \quad (2)$$

where $dY_t^i$ is the yield change of the $i^{th}$ maturity from day t-1 to day t and i=3, 5 and 10 years, $F1_{t-1}$ is the first principal component of yields lagged one day, $HCOF_t^S$ , $HCOF_t^M$ and $HCOF_t^L$ are short, medium and long term informed customer order flow and $resOF_t^S$, $resOF_t^M$ and $resOF_t^L$ are short, medium and long term interdealer order flow orthogonal to the informed customer trades in the same maturity group. These variables are derived as follows

$$OF_t^i = c + HCOF_t^i + \mu_t^i, \qquad \mu_t^i = resOF_t^i, \quad (3)$$

where $i = S, M, L$ is short, medium and long term order flow and $\mu_t^i$, is the residual obtained by regressing informed customer order flow on aggregate interdealer order flow for each maturity group. By orthogonalizing the interdealer order flow in this way we remove the part of the order flow that is related to informed customer trades. The model in equation (2) states that daily yield changes are explained by the lagged yield factor, contemporaneous interdealer order flow unrelated to informed customer trades and contemporaneous informed customer order flow. The model is run for the whole sample period and for two sub-periods. The conditions for entering delayed publication trades were changed in May 2002 and this may have lead to a change in dealer behavior. Since the size limit was lifted in May 2002, some dealers can have used the possibility to delay the publication of their customer trades regardless of whether they were considered to be informed or not. This is consistent with an increase in the number of delayed publication trades seen in the data from mid-2002. In order to investigate any change in the information content the order flow based on these trades we split the sample period in two. The first sub-period is from September 1999 to May 2002 and the second sub-period is from May 2002 to September 2005.

Table 7 presents the results for all yield changes. The first column for the 3, 5 and 10 year yield changes show the results for the whole sample period. Short, medium and long term interdealer order flow orthogonal to informed customer order flow have significant explanatory power for daily yield changes. The coefficients are significant for all maturities and are of the same order of magnitude as the coefficients for interdealer order flow in Table 6. Also long term informed customer order flow has significant explanatory power for daily yield changes over the whole period. The second and third column for each bond maturity in Table 7 show the results for the two sub-periods. The results indicate that the effect of informed customer order flow on yield changes was strongest in the first period when the conditions for entering delayed publication trades were stricter than in the second period. This supports the assumption that the informed customer trades are more likely to contain both informed and uninformed customer trades in the second sub-period. The effect of long term informed customer order flow on 3-year yield changes is only significant in the first sub-period. The effect of long term informed customer order flow on 10-year yield changes is significant in both sub-periods, but the coefficient is higher in the first sub-period. The results show that interdealer order flow orthogonal to informed customer order flow has significant explanatory power for daily yield changes of all maturities. Only long term informed customer flow has a significant effect on yield changes and the effect is considerably smaller than that of interdealer order flow. Taken together these findings suggest that dealer skill can be a source of information in interdealer order flow.

In order to test whether our proxy of informed customer trades contains more information than total customer trades we compare the explanatory power of the order flows based on these trades. Aggregate customer order flow reflects the trades of both informed and uninformed customers whereas delayed publication customer order flow is assumed to reflect the trades of informed customers only. We therefore expect our proxy of informed customer order flow to contain more information than aggregate customer order flow. We employ the following two models to explore this:

$$dY_t^i = c + COF_t^S + COF_t^M + COF_t^L + \varepsilon_t, \tag{4}$$

$$dY_t^i = c + HCOF_t^S + HCOF_t^M + HCOF_t^L + \epsilon_t, \tag{5}$$

where $dY_t^i$ , $i = 3, 5, 10$, represent changes in 3, 5 and 10 year government bond yields.

The results of the two models are displayed in Table 8. The results from the model presented in equation (4) are shown in the first four lines and the results from the model in equation (5) are shown in the next four lines. The results reveal that informed customer order flow has some explanatory power for daily yield changes while aggregate customer order flow has close to zero. The higher explanatory power of informed customer order flow, especially in the first sub-period, indicates that the proxy works best in the first period. In the second period the proxy is more imprecise due to the changes in the conditions for entering delayed publication trades in mid-2002.

The results in Table 8 show that short and medium term aggregate customer order flow cannot explain daily yield changes. Long term customer order flow, however, has significant impact on daily yield changes. The results further show that the proxy for informed customer order flow has somewhat higher explanatory power than the total customer order flow. In line with the results in Table 7, the informational content of delayed publication trades appear to be higher in the first sub-period than in the second.

In all, the results in this section suggest that dealers possess more information than their customers, and that dealers appear to play an important role in the price formation process in sovereign bond markets. Aggregate interdealer order flow explains up to 25 percent of contemporaneous yield changes. There is little information in aggregate customer order flow. A proxy for informed customer trades, delayed publication customer trades, contains more information than aggregate customer trades, but works best in the first period of the data set, until May 2002, due to changes in the conditions for entering delayed publication trades. Informed customer trades thus appear to be one source of information in interdealer order flow. However, the fact that interdealer order flow orthogonal to informed customer trades explains most of the daily yield changes, indicates that dealers have other sources of information. One important source could be dealer skill. Examples of dealer skill are superior interpretations of public information, effort in collecting information from other dealers through trading in the interdealer market and dealer skill in identifying and aggregate information in customer trades. In order to further explore the role of dealer skill and customer trades as sources of information in interdealer order flow, the next section explores the sources of information in individual dealer interdealer order

flow.

### 5.3 Individual dealer order flow

The previous two sections document that dealers play an important role in the price formation process in government bond markets. In order to better understand how bond prices are formed it would be useful to know whether dealers play different roles in the price formation process and whether they have different sources of information. One of the main contributions of this paper is to explore the effects of individual dealer order flow on yield changes. This facilitates an investigation of whether information is symmetrically distributed among dealers or not. By determining the relationship between a dealer's interdealer order flow and her customer order flow, it is possible to decide whether customer orders are an important source of information or not. Seven dealers, constituting about 85 percent of the sample, are included in this part of the analysis. These seven dealers have been trading in government bonds throughout the whole sample period.[14] The dealers are characterized by size, the size of their customer base and their interdealer activity. Size is measured as a dealer's total market share in the customer market and the interdealer market combined. The size of the customer base is measured as a dealer's market share in the customer market. Interdealer activity is measured as the value of a dealer's initiated interdealer trades relative to the value of her customer trades. This ratio may indicate whether a dealer possesses private information. If she is informed she is likely to be impatient and initiate trades because she wants to utilize this information before other dealers learn about it. A high share of initiated interdealer trades may thus indicate that a dealer is exerting effort to collect relevant information and is skilled in interpreting it. A low share of initiated interdealer trades may indicate that a dealer is passive because she has no skill.

Table 9 presents the characteristics of the seven dealers. They are numbered according to size as shown in column 1. Size which is measured by the total market share of each dealer is displayed in the second column. There are four large dealers, with a total market share in the customer and interdealer market ranging from 17 to 24 percent, constituting

[14] The order flow of dealers who were not present in the market for a substantial part of the sample period and dealers who only sporadically traded, are not included in this section.

85 percent of the seven dealers's total market share. The remaining three dealers are small, with a total market share of 15 percent. The third column shows the size of each dealer's customer base as reflected in their market share in the customer market. The four large dealers also have the largest customer bases. The fourth column displays the measure of interdealer activity which is initiated interdealer trades over customer trades. Among the four large dealers, Dealer 2 appears to be passive, with a low share of initiated trades in the interdealer market. Dealer 3 appears to be active in the interdealer market which can indicate that she is informed. Among the small dealers, Dealer 7 is very active in the interdealer market while having a very small customer base.

To measure the contemporaneous price impact of the different dealers, the following model is employed

$$dY_t^i = c + F1_{t-1} + OF_{j,t}^S + OF_{j,t}^M + OF_{j,t}^L + u_t, \tag{6}$$

where $OF_{j,t}^S$ , $OF_{j,t}^M$ *and* $OF_{j,t}^L$ are the short, medium and long term interdealer order flow of Dealer j ( $j = 1, 2, 3, 4, 5, 6, 7$) at time t.[15] The results are displayed in Table 10 and suggest that dealers are heterogeneous. All dealers appear to play a significant role in price discovery, but the impact varies between dealers. The interdealer order flow of some dealers appear to have a stronger effect on daily yield changes than that of others, and while the order flow of some dealers have explanatory power for short term yield changes, the order flow of others can explain long term yield changes. Also, the table shows that the short, medium and long term interdealer order flow of different dealers has different impact on daily yield changes. In the price discovery process for 3-year bonds, Dealer 1 plays the most important role as a one standard deviation increase in her short term order flow leads to a decrease of more than one basis point in the 3-year yield. Dealer 1 is a large dealer measured by total market share and has a relatively high interdealer activity which could indicate that she is informed. The interdealer order flow of Dealer 1 also has the largest impact on 5 year yield changes. However, Dealer 4 plays the most important role in the price discovery process for 10 year yields, closely followed by Dealer 1 and Dealer 2. Also Dealer 4 is a large dealer with a relatively high interdealer activity.

[15] The correlations between the interdealer order flows of the different dealers are ranging from -18 to +15 percent indicating that the order flows could have different effects on yield changes.

The order flows of Dealer 2, Dealer 5 and Dealer 6 also have significant explanatory power for daily yield changes. This indicates that smaller dealers also contribute to the process of price discovery in bond markets. The table further shows that dealers appear to have different information in their short, medium and long term order flow. While the short and medium term interdealer order flow of Dealer 1 appear to be most informative for 5 year yield changes, the long term interdealer order flow of Dealer 2 is most informative for the same maturity yield changes.

Since the interdealer order flow of individual dealers contribute differently to the price discovery process, we check whether dealers have different sources of information. In order to do this we investigate the link between customer order flow and interdealer order flow for each dealer by running the following regression:

$$OF^i_{j,t} = c + COF^i_{j,t} + COF^i_{j,t-1}, \tag{7}$$

where $OF^i_{j,t}$ is the interdealer order flow of Dealer j, $COF^i_{j,t}$ and $COF^i_{j,t-1}$ are the customer order flow of Dealer $j$ at time $t$ and time $t-1$ for $i = S$ (short term), $M$ (medium term) and $L$ (long term), and $j$=1, 2, 3, 4, 5, 6 and 7.

The results are presented in Table 11. The explanatory power of contemporaneous and one day lagged customer order flow for interdealer order flow varies substantially between dealers. For Dealer 1 today's and yesterday's customer order flow explain a lot of Dealer 1's short term interdealer order flow. This indicates that customer trades are an important source of information for Dealer 1. For Dealer 4 there appears to be no link between long term customer order flow and long term interdealer order flow. Her long term customer order flows today and yesterday have no explanatory power for today's long term interdealer order flow. Since the long term order flow of Dealer 4 plays an important role in the price discovery for 10 year yields, this indicates that Dealer 4 does not have customer trades as her main source of information. Rather, this points to skill as an important source of information for this dealer. For the other dealers, customer trades can be one source of information, but the link between customer order flow and interdealer order flow is weaker than for Dealer 1. The exception is Dealer 6 who also has a strong link between customer and interdealer orders a the long end of the yield curve.

This could indicate that Dealer 1 and Dealer 6 have a higher share of informed customers than the other dealers. It could also indicate that these dealers are skilled in that they have a better ability to identify their informed customers than the other dealers.

The results in this section show that the order flow of different dealers contribute differently to the price formation process and indicate that dealers are heterogenous. The information content of the interdealer order flow appear to vary between dealers, and the maturity of the most informative order flow also varies. The interdealer order flow of large dealers with a high bond market share appear to contain more information than the order flow of smaller dealers. The extent of interdealer activity does not appear to be important for the information content of individual dealer order flow related to contemporaneous yield changes. The results further indicate that dealers are relying on different sources of information. For some dealers customer trades explain a considerable part of interdealer trades, up to 13 percent, while for other dealers customer trades have no explanatory power for their interdealer trades. This may be due to differences in the size or composition of their customer base, differences in dealer skill, but also in the objectives of the dealer institutions. The information conveyed in aggregate interdealer order flow appear to be based on different sources of dealer information. This indicates that both aggregation of asymmetric information held by market participants and heterogeneous interpretations of public information are types of information imbedded into prices through the process of price discovery.

# 6 Conclusion

This paper explores the price discovery process in government bond markets by employing a new, extensive data set from the Norwegian government bond market. The paper is the first to study price discovery in a two tier market with complete trading records in both markets at the individual dealer level. Previous studies use more limited data sets (Osler, Mende and Menkhoff (2007)), aggregate interdealer order flow only (Brandt and Kavajecz (2004)) or one tier markets (Manaster and Mann (1996), Menkveld, Sarkar and van der Wel (2011) and Anand and Subrahmanyam (2008)).

The results reveal that while aggregate interdealer order flow is highly informative,

aggregate customer order flow is not. A proxy for informed customer trades, delayed publication trades, appear to contain some information relevant for bond yields. This suggests that at least some dealers are able to identify of their informed customers. Some dealers play an important part in the process of price discovery, while others have more limited impact on yield changes. While there is a strong link between the customer order flow and interdealer order flow of some dealers, there is no such link for other dealers, indicating that dealers have different sources of information. While some dealers have informed customer trades as their main source of information, other dealers appear to be actively collecting and aggregating information, pointing to dealer skill as their main source of information.

The findings in this paper suggest that dealers are not mere intermediaries of customer trades, but play an independent role the price discovery process in government bond markets. This supports the conclusion in Osler, Mende and Menkhoff (2007) that price discovery takes place in the interdealer market. Both the currency market and the government bond market are two tier markets, and the findings in this paper indicate that both customer trades and dealer skill could be sources of information in interdealer order flow. These findings are in line with a dealer strategy which implies that a dealer will pass on informed customer trades to the interdealer market as market orders, and pass on uninformed customer trades as limit orders or hold on to them until they are netted by opposite trades.

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**Table 1**
**Benchmark bonds**

The table describes the government bonds that are included in the data set, the number of trades in each bond, the share of interdealer trades in each bond, and the average trade size of interdealer trades and customer trades in each bond. The bonds are all bullet bonds with a remaining time to maturity of ten or eleven years when first issued. The trades included are all trades reported to Oslo Stock Exchange (OSE) during the period September 1999 - September 2005 except repo trades, auction results, and trades with a trade size of less than 1 million NOK. The share of interdealer trades are measured in percent of the total number of trades in each bond.

| **Bond name** | **Coup %** | **Issued date** | **Maturity date** | **Number of trades** | **Share interdealer** | **Avg. trade size (mill.NOK)** | |
|---|---|---|---|---|---|---|---|
| | | | | | | **Interdealer** | **Customer** |
| S463 | 9.5 | 31.10.92 | 31.10.02 | 6 518 | 36 % | 41.6 | 50.6 |
| S465 | 5.75 | 30.11.93 | 30.11.04 | 12 307 | 34 % | 27.3 | 38.8 |
| S467 | 6.75 | 15.01.96 | 15.01.07 | 14 519 | 36 % | 24.1 | 38.8 |
| S468 | 5.50 | 15.05.98 | 15.05.09 | 14 692 | 36 % | 18.6 | 36.5 |
| S469 | 6.00 | 16.05.00 | 16.05.11 | 10 966 | 35 % | 18.9 | 41.1 |
| S470 | 6.50 | 15.05.02 | 15.05.13 | 5 956 | 41 % | 17.6 | 42.3 |
| S471 | 5.00 | 15.05.04 | 15.05.15 | 1 688 | 24 % | 19.0 | 52.2 |
| All | | | | 66 646 | 35 % | 23.6 | 40.5 |

**Table 2**

**Descriptives for yield changes, interdealer and customer order flow**

The table displays descriptive statistics for yield changes and interdealer and customer order flows in the period September 1999 to September 2005. The table includes data for the whole sample and two sub-samples; no-news days and news days. News days are defined as the days of CPI announcements and MPC announcements and the two days surrounding the announcements, in total 361 days. Yield changes are daily changes in synthetic 3, 5 and 10 year government bond yields based on the benchmark bonds in Table 1. Yield changes are measured in basis points (0.01 percentage points). Order flow is divided into groups according to the remaining time to maturity of the bonds that are included. Short term order flow, $OF^S$ and $COF^S$, reflects bonds with maturity between 1 and 4 years, medium term order flow, $OF^M$ and $COF^M$, reflects bonds with maturity greater than 4 years up to 7 years and long term order flow, $OF^L$ and $COF^L$, reflects bonds with maturity greater than 7 years up to 11 years. Numbers in parenthesis are standard deviations.

| | All days | | No-news days | | News days | |
|---|---|---|---|---|---|---|
| | Mean | Min/Max | Mean | Min/Max | Mean | Min/Max |
| **Yield changes (bp)** | | | | | | |
| $dY_t^{3\ y}$ | −0.17 (5.07) | -39.7/+24.8 | −0.01 (4.59) | -26/+24.8 | −0.74 (6.32) | -39.7/+21.6 |
| $dY_t^{5\ y}$ | −0.17 (4.88) | -38.4/+25.0 | −0.01 (4.56) | -23.6/+25.0 | −0.71 (5.76) | -38.4/+18.1 |
| $dY_t^{10\ y}$ | −0.16 (4.46) | -23.8/+21.1 | −0.02 (4.40) | -22.5/+21.1 | −0.60 (4.60) | -23.8/+14.9 |
| **OF (interdealer)** | | | | | | |
| $OF^S$ 1-4 years | −0.75 (3.77) | -27/+22 | −0.66 (3.64) | -27/+22 | −1.04 (4.16) | -25/+15 |
| $OF^M$ 4-7 years | −0.17 (3.69) | -26/+28 | −0.19 (3.44) | -19/+19 | −0.10 (4.38) | -26/+28 |
| $OF^L$ 7-11 years | −1.30 (4.46) | -34/+20 | −1.29 (4.46) | -34/+20 | −1.31 (4.47) | -24/+14 |
| **COF (customer)** | | | | | | |
| $COF^S$ 1-4 years | −0.32 (4.08) | -21/+15 | −0.33 (3.94) | -21/+15 | −0.32 (4.50) | -17/+13 |
| $COF^M$ 4-7 years | 0.05 (3.49) | -16/+14 | 0.02 (3.39) | -16/+13 | 0.15 (3.80) | -14/+14 |
| $COF^L$ 7-11 years | −0.80 (4.20) | -20/+14 | −0.84 (4.15) | -20/+14 | −0.68 (4.34) | -13/+14 |

**Table 3**
**Descriptive statistics informed customer order flow and orthogonal interdealer order flow**

The table presents the descriptive statistics for short, medium and long term informed customer order flow (delayed publication customer order flow) and interdealer order flow orthogonal to informed customer order flow. The statistics are based on all days in the sample.

| Series | obs | mean | std.err | minimum | maximum | AR(1) |
|---|---|---|---|---|---|---|
| $\text{HCOF}^S$ | 1504 | -0.09 | 3.07 | -18 | 13 | 0.105 |
| $\text{HCOF}^M$ | 1504 | 0.17 | 2.37 | -12 | 14 | 0.068 |
| $\text{HCOF}^L$ | 1504 | -0.19 | 2.72 | -15 | 14 | 0.058 |
| $\text{resOF}^S$ | 1504 | 0.00 | 3.75 | -26 | 23 | 0.144 |
| $\text{resOF}^M$ | 1504 | 0.00 | 3.67 | -25 | 27 | 0.053 |
| $\text{resOF}^L$ | 1504 | 0.00 | 4.39 | -28 | 21 | 0.097 |

**Table 4**

**Correlations**

The table shows the unconditional correlations between yield changes, aggregate interdealer order flow and customer order flow for the period September 1999 – September 2005. Yield changes are daily changes in synthetic 3, 5 and 10 year government bond yields based on the benchmark bonds in Table 1. The order flow variables are divided into short ($OF^S$and $COF^S$), medium ($OF^M$and $COF^M$) and long term ($OF^L$ and $COF^L$) according to the remaining time to maturity of the bonds included. Numbers in parenthesis are p-values.

| | $OF^S$ | $OF^M$ | $OF^L$ | $COF^S$ | $COF^M$ | $COF^L$ | $dY_t^{3\ y}$ | $dY_t^{5\ y}$ | $dY_t^{10\ y}$ |
|---|---|---|---|---|---|---|---|---|---|
| $OF^S$ | 1 | | | | | | | | |
| $OF^M$ | 0.24 (0.00) | 1 | | | | | | | |
| $OF^L$ | 0.19 (0.00) | 0.23 (0.00) | 1 | | | | | | |
| $COF^S$ | 0.10 (0.00) | 0.01 (0.73) | −0.05 (0.04) | 1 | | | | | |
| $COF^M$ | 0.08 (0.00) | 0.16 (0.00) | −0.02 (0.35) | 0.15 (0.00) | 1 | | | | |
| $COF^L$ | 0.06 (0.03) | 0.05 (0.05) | 0.14 (0.00) | 0.04 (0.13) | 0.08 (0.00) | 1 | | | |
| $dY_t^{3\ y}$ | −0.35 (0.00) | −0.34 (0.00) | −0.30 (0.00) | 0.00 (0.96) | −0.04 (0.13) | −0.04 (0.08) | 1 | | |
| $dY_t^{5\ y}$ | −0.30 (0.00) | −0.37 (0.00) | −0.34 (0.00) | 0.02 (0.39) | −0.06 (0.02) | −0.05 (0.03) | 0.90 (0.00) | 1 | |
| $dY_t^{10\ y}$ | −0.23 (0.00) | −0.30 (0.00) | −0.41 (0.00) | 0.00 (0.89) | 0.01 (0.71) | −0.11 (0.00) | 0.76 (0.00) | 0.85 (0.00) | 1 |

**Table 5**

**Principal components of yields and order flow**

The table presents the factor structures of yields and order flow. The table shows the loadings of the three orthogonal factors extracted from the correlation matrix of yields, short, medium and long term interdealer order flow, and short, medium and long term customer order flow. The principal components analysis is based on data including all days during the period September 1999 to September 2005. The factors are ordered according to how much they explain of the total variation.

| | F1 | F2 | F3 |
|---|---|---|---|
| Yields | | | |
| 3 year | 0.577 | -0.653 | 0.491 |
| 5 year | 0.580 | -0.096 | -0.809 |
| 10 year | 0.575 | 0.751 | 0.323 |
| % explained | 0.990 | 0.010 | 0.000 |
| OF (interdealer) | | | |
| 1-4 years | 0.567 | -0.679 | 0.467 |
| 4-7 years | 0.604 | -0.043 | -0.796 |
| 7-11 years | 0.561 | 0.733 | 0.385 |
| % explained | 0.482 | 0.270 | 0.248 |
| COF (customer) | | | |
| 1-4 years | 0.616 | -0.454 | 0.644 |
| 4-7 years | 0.668 | -0.134 | -0.732 |
| 7-11 years | 0.418 | 0.881 | 0.221 |
| % explained | 0.396 | 0.322 | 0.282 |

## Table 6

**Response of daily yield changes to aggregate order flow**

The table presents the results of regressing 3, 5 and 10 year yield changes, $dY_t^{3\ y}$, $dY_t^{5\ y}$and $dY_t^{10\ y}$, on day t on short, medium and long term interdealer order flow, $OF^S$, $OF^M$ and $OF^L$, and short, medium and long term customer order flow, $COF^S$, $COF^M$ and $COF^L$, between time t-1 and time t, and the first yield factor at time t-1. The regressions are based on data for all days and include a constant, but the coefficients for the constant are dropped here. The coefficients are corrected for autocorrelation and heteroscedasticity by the Newey-West method. Coefficients are multiplied with 100 and in bold when significant at the 10 percent level and starred when significant at the 5 percent level or better. T-statisics are in parenthesis.

| | $dY_t^{3\ y}$ | $dY_t^{5\ y}$ | $dY_t^{10\ y}$ |
|---|---|---|---|
| $F1_{t-1}$ | −0.06 | −0.06 | −0.04 |
| | (−1.19) | (−1.22) | (−0.98) |
| $OF_t^S$ | **−0.35*** | **−0.26*** | **−0.15*** |
| | (−6.92) | (−5.57) | (−3.87) |
| $OF_t^M$ | **−0.32*** | **−0.34*** | **−0.24*** |
| | (−7.04) | (−7.26) | (−6.07) |
| $OF_t^L$ | **−0.22*** | **−0.26*** | **−0.33*** |
| | (−6.46) | (−7.46) | (−11.35) |
| $COF_t^S$ | 0.03 | 0.04 | −0.00 |
| | (0.66) | (1.32) | (0.06) |
| $COF_t^M$ | 0.02 | −0.02 | **0.06*** |
| | (0.02) | (−0.46) | (1.99) |
| $COF_t^L$ | 0.01 | 0.00 | **−0.05*** |
| | (0.27) | (−0.07) | (−2.00) |
| $Adj.R^2$ | 0.223 | 0.235 | 0.226 |

**Table 7**

**Response of daily yield changes to informed customer order flow and interdealer order flow orthogonal to informed customer order flow**

The table presents the results of regressing daily yield changes on aggregate interdealer order flow orthogonal to informed customer order flow, $resOF_t^S$, $resOF_t^M$ and $resOF_t^L$, and on informed customer order flow, $HCOF_t^S, HCOF_t^M$ and $HCOF_t^L$. The regressions are based on data for the whole period 1999-2005, and for the two sub-periods 1999-2002 and 2002-2005. The first principal component of yields at time t-1 and a constant are included in the regressions, but the coefficients are dropped here. The coefficients are corrected for autocorrelation and heteroscedasticity by the Newey-West method. Coefficients are multiplied with 100 and in bold when significant at the 10 percent level and starred when significant at the 5 percent level or better. T-statisics are in parenthesis.

| | $dY_t^{3\ y}$ | | | $dY_t^{5\ y}$ | | | $dY_t^{10\ y}$ | | |
|---|---|---|---|---|---|---|---|---|---|
| *period* | $99-05$ | $99-02$ | $02-05$ | $99-05$ | $99-02$ | $02-05$ | $99-05$ | $99-02$ | $02-05$ |
| $resOF_t^S$ | $\mathbf{-0.36}^*$ | $\mathbf{-0.31}^*$ | $\mathbf{-0.38}^*$ | $\mathbf{-0.26}^*$ | $\mathbf{-0.18}^*$ | $\mathbf{-0.33}^*$ | $\mathbf{-0.15}^*$ | $-0.03$ | $\mathbf{-0.25}^*$ |
| | $(-7.13)$ | $(-6.24)$ | $(-4.73)$ | $(-5.71)$ | $(-3.99)$ | $(-4.62)$ | $(-4.03)$ | $(-0.90)$ | $(-4.75)$ |
| $resOF_t^M$ | $\mathbf{-0.32}^*$ | $\mathbf{-0.25}^*$ | $\mathbf{-0.37}^*$ | $\mathbf{-0.34}^*$ | $\mathbf{-0.28}^*$ | $\mathbf{-0.41}^*$ | $\mathbf{-0.23}^*$ | $\mathbf{-0.17}^*$ | $\mathbf{-0.29}^*$ |
| | $(-7.11)$ | $(-4.79)$ | $(-5.67)$ | $(-7.38)$ | $(-4.82)$ | $(-6.08)$ | $(-5.91)$ | $(-3.45)$ | $(-5.10)$ |
| $resOF_t^L$ | $\mathbf{-0.21}^*$ | $\mathbf{-0.13}^*$ | $\mathbf{-0.29}^*$ | $\mathbf{-0.26}^*$ | $\mathbf{-0.19}^*$ | $\mathbf{-0.32}^*$ | $\mathbf{-0.33}^*$ | $\mathbf{-0.33}^*$ | $\mathbf{-0.35}^*$ |
| | $(-6.33)$ | $(-3.23)$ | $(-5.72)$ | $(-7.40)$ | $(-4.35)$ | $(-6.49)$ | $(-11.45)$ | $(-8.66)$ | $(-8.22)$ |
| $HCOF_t^S$ | $0.01$ | $-0.13$ | $0.05$ | $0.04$ | $-0.13$ | $0.08$ | $0.02$ | $\mathbf{-0.16}^*$ | $0.06$ |
| | $(0.23)$ | $(-1.26)$ | $(0.72)$ | $(0.81)$ | $(-1.44)$ | $(1.36)$ | $(0.55)$ | $(-2.14)$ | $(1.28)$ |
| $HCOF_t^M$ | $-0.06$ | $-0.13$ | $-0.04$ | $-0.08$ | $-0.02$ | $-0.09$ | $-0.01$ | $-0.06$ | $-0.00$ |
| | $(-0.98)$ | $(-1.06)$ | $(-0.56)$ | $(-1.36)$ | $(0.14)$ | $(-1.37)$ | $(-0.29)$ | $(-0.59)$ | $(-0.06)$ |
| $HCOF_t^L$ | $\mathbf{-0.12}^*$ | $\mathbf{-0.23}^*$ | $-0.10$ | $\mathbf{-0.10}^*$ | $-0.15$ | $-0.10$ | $\mathbf{-0.18}^*$ | $\mathbf{-0.20}^*$ | $\mathbf{-0.18}^*$ |
| | $(-2.37)$ | $(-2.62)$ | $(-1.60)$ | $(-2.13)$ | $(-1.85)$ | $(-1.71)$ | $(-4.67)$ | $(-2.53)$ | $(-4.02)$ |
| $Adj.R^2$ | $0.225$ | $0.230$ | $0.236$ | $0.236$ | $0.212$ | $0.268$ | $0.227$ | $0.205$ | $0.264$ |

**Table 8**

**Response of daily yield changes to aggregate customer order flow and informed customer order flow**

The table presents the results of regressing daily yield changes on aggregate customer order flow, $COF_t^S, COF_t^M$ and $COF_t^L$, and on informed customer order flow, proxied by delayed publication customer order flow, $HCOF_t^S, HCOF_t^M$ and $HCOF_t^L$. The regressions are based on data for the whole period 1999-2005 and the two sub-periods 1999-2002 and 2002-2005. The coefficients are corrected for autocorrelation and heteroscedasticity by the Newey-West method. Coefficients are multiplied with 100 and in bold when significant at the 10 percent level and starred when significant at the 5 percent level or better. T-statisics are in parenthesis.

| | $dY_t^{3\ y}$ | | | $dY_t^{5\ y}$ | | | $dY_t^{10\ y}$ | | |
|---|---|---|---|---|---|---|---|---|---|
| *period* | $99-05$ | $99-02$ | $02-05$ | $99-05$ | $99-02$ | $02-05$ | $99-05$ | $99-02$ | $02-05$ |
| $COF_t^S$ | 0.01 | −0.00 | 0.03 | −0.04 | 0.02 | 0.07 | 0.01 | −0.02 | 0.03 |
| | (0.24) | (−0.04) | (0.46) | (1.05) | (0.38) | (1.14) | (0.18) | (−0.40) | (0.63) |
| $COF_t^M$ | −0.05 | −0.02 | −0.07 | **−0.08** | −0.04 | −0.11 | 0.02 | 0.07 | −0.00 |
| | (−1.26) | (−0.29) | (−1.01) | (−1.93) | (−0.64) | (−1.63) | (0.65) | (1.42) | (−0.07) |
| $COF_t^L$ | **−0.05** | −0.05 | −0.03 | **−0.06*** | −0.06 | −0.04 | **−0.12*** | **−0.11*** | **−0.11*** |
| | (−1.67) | (−1.29) | (−0.64) | (−1.98) | (−1.46) | (−0.96) | (−4.10) | (−2.66) | (−2.72) |
| $Adj.R^2$ | 0.001 | 0.000 | 0.000 | 0.005 | 0.001 | 0.004 | 0.010 | 0.011 | 0.006 |
| $HCOF_t^S$ | 0.02 | **−0.21** | 0.01 | 0.05 | **−0.21*** | 0.08 | 0.03 | **−0.17*** | 0.05 |
| | (0.23) | (−1.73) | (0.13) | (0.76) | (−2.02) | (1.25) | (0.55) | (−2.03) | (1.03) |
| $HCOF_t^M$ | −0.07 | −0.21 | **−0.12** | −0.08 | −0.07 | −0.07 | −0.00 | −0.01 | 0.01 |
| | (−0.97) | (−1.43) | (−1.78) | (−1.19) | (−0.43) | (−0.96) | (−0.01) | (−0.06) | (0.19) |
| $HCOF_t^L$ | **−0.13*** | **−0.25*** | −0.04 | **−0.11*** | **−0.20** | −0.06 | **−0.19*** | **−0.28*** | **−0.14*** |
| | (−2.18) | (−2.29) | (−0.58) | (−2.01) | (−1.94) | (−1.00) | (−4.01) | (−3.06) | (−2.67) |
| $Adj.R^2$ | 0.004 | 0.022 | 0.001 | 0.004 | 0.012 | 0.002 | 0.011 | 0.020 | 0.008 |

**Table 9**
**Characteristics of individual dealers**

The table describes the seven dealers who were active in the government bond market during the period 1999 to 2005. They are characterized by size, size of customer base and their activity in the interdealer market. Size is measured as total market share, calculated as the gross value of customer trades and initiated interdealer trades by the dealer as a percentage of the total value of both markets combined. Customer base is measured as the market share in the customer market, calculated as the gross value of a dealers's customer trades as a percentage of total customer trades. Interdealer activity is measured as the value of a dealer's initiated interdealer trades over the value of her customer trades.

| Dealer | Size | Customer base | Interdealer activity |
|---|---|---|---|
| | Total | Customer | *Interdealer trades* |
| | market share | market share | *Customer trades* |
| 1 | 24 % | 24 % | 31 |
| 2 | 23 % | 25 % | 19 |
| 3 | 21 % | 19 % | 42 |
| 4 | 17 % | 18 % | 28 |
| 5 | 9 % | 9 % | 33 |
| 6 | 4 % | 4 % | 30 |
| 7 | 2 % | 1 % | 435 |

## Table 10

**Response of daily yield changes to interdealer order flow of individual dealers**

The table presents the results of regressing daily yield changes on individual dealer interdealer order flow, $OF^S_{i,t}, OF^M_{i,t}$ and $OF^L_{i,t}$. The regressions are based on the period 1999-2005. The coefficients are corrected for autocorrelation and heteroscedasticity by the Newey-West method. Coefficients are multiplied with 100 and in bold when significant at the 10 percent level and starred when significant at the 5 percent level or better. T-statisics are in parenthesis.

| Dealer | | $dY_t^{3\ y}$ | $Adj.R^2$ | $dY_t^{5\ y}$ | $Adj.R^2$ | $dY_t^{10\ y}$ | $Adj.R^2$ |
|---|---|---|---|---|---|---|---|
| 1 | $OF_1^S$ | **−0.88*** | | **−0.60*** | | **−0.35*** | |
| | | (−6.34) | | (−4.01) | | (−2.92) | |
| | $OF_1^M$ | **−0.90*** | 0.095 | **−0.87*** | 0.073 | **−0.70*** | 0.068 |
| | | (−4.76) | | (−4.46) | | (−4.23) | |
| | $OF_1^L$ | **−0.23*** | | **−0.29*** | | **−0.45*** | |
| | | (−2.38) | | (−3.24) | | (−5.07) | |
| 2 | $OF_2^S$ | **−0.40*** | | **−0.33*** | | **−0.31*** | |
| | | (−2.55) | | (−2.26) | | (−2.48) | |
| | $OF_2^M$ | **−0.44*** | 0.055 | **−0.50*** | 0.063 | **−0.45*** | 0.058 |
| | | (−3.02) | | (−3.19) | | (−3.06) | |
| | $OF_2^L$ | **−0.86*** | | **−0.92*** | | **−0.79*** | |
| | | (−5.27) | | (−5.97) | | (−5.86) | |
| 3 | $OF_3^S$ | **−0.47*** | | **−0.35*** | | **−0.25*** | |
| | | (−2.45) | | (−2.09) | | (−1.97) | |
| | $OF_3^M$ | **−0.38*** | 0.041 | **−0.45*** | 0.039 | **−0.31*** | 0.042 |
| | | (−2.75) | | (−3.29) | | (−2.65) | |
| | $OF_3^L$ | **−0.41*** | | **−0.39*** | | **−0.48*** | |
| | | (−3.95) | | (−3.64) | | (−4.69) | |
| 4 | $OF_4^S$ | **−0.33*** | | **−0.23** | | **−0.24** | |
| | | (−2.15) | | (−1.68) | | (−1.88) | |
| | $OF_4^M$ | **−0.40*** | 0.032 | **−0.62*** | 0.056 | **−0.44*** | 0.073 |
| | | (−2.97) | | (−4.95) | | (−4.14) | |
| | $OF_4^L$ | **−0.51*** | | **−0.64*** | | **−0.77*** | |
| | | (−4.48) | | (−5.50) | | (−8.00) | |
| 5 | $OF_5^S$ | **−0.34*** | | **−0.29*** | | −0.14 | |
| | | (−3.07) | | (−3.18) | | (−1.61) | |
| | $OF_5^M$ | **−0.66*** | 0.053 | **−0.59*** | 0.050 | **−0.49*** | 0.041 |
| | | (−4.01) | | (−3.91) | | (−3.78) | |
| | $OF_5^L$ | **−0.52*** | | **−0.55*** | | **−0.53*** | |
| | | (−3.27) | | (−3.44) | | (−3.85) | |
| 6 | $OF_6^S$ | **−0.94*** | | **−0.86*** | | **−0.65*** | |
| | | (−3.07) | | (−3.24) | | (−2.65) | |
| | $OF_6^M$ | **−0.68*** | 0.054 | **−0.67*** | 0.052 | −0.41 | 0.038 |
| | | (−2.45) | | (−2.20) | | (−1.54) | |
| | $OF_6^L$ | **−0.91*** | | **−0.86*** | | **−0.80*** | |
| | | (−2.57) | | (−2.51) | | (−2.66) | |
| 7 | $OF_7^S$ | **−0.41*** | | **−0.37*** | | **−0.24*** | |
| | | (−2.80) | | (−2.70) | | (−2.68) | |
| | $OF_7^M$ | **−0.21*** | 0.029 | **−0.23*** | 0.032 | −0.13 | 0.022 |
| | | (−2.24) | | (−2.29) | | (−1.41) | |
| | $OF_7^L$ | **−0.21*** | | **−0.25*** | | **−0.26*** | |
| | | (−2.26) | | (−2.68) | | (−3.28) | |

## Table 11

**Response of interdealer order flow to customer order flow**

The table presents the results of regressing the short, medium and long term interdealer order flow, measured as net volume (in Norwegian kroner) on day t on the short, medium and long term customer order flow on time t and t-1 for individual dealers. Coefficients are multiplied with 100 and in bold when significant at the 10 percent level and starred when significant at the 5 percent level or better. T-statisics are in parenthesis. The coefficients are corrected for autocorrelation and heteroscedasticity by the Newey-West method.

| Dealer | | $COF_t^S$ | $COF_{t-1}^S$ | $COF_t^M$ | $COF_{t-1}^M$ | $COF_t^L$ | $COF_{t-1}^L$ | Adj.$R^2$ |
|---|---|---|---|---|---|---|---|---|
| 1 | $OF_t^S$ | **19.83**∗ (5.59) | **5.86**∗ (3.01) | | | | | 0.129 |
| | $OF_t^M$ | | | **4.71**∗ (4.80) | **2.19**∗ (2.51) | | | 0.038 |
| | $OF_t^L$ | | | | | **5.79**∗ (2.41) | 1.02 (1.26) | 0.040 |
| 2 | $OF_t^S$ | **7.13**∗ (4.26) | 0.96 (0.88) | | | | | 0.027 |
| | $OF_t^M$ | | | **2.97**∗ (3.40) | **1.28**∗ (2.28) | | | 0.016 |
| | $OF_t^L$ | | | | | **2.79**∗ (2.36) | 2.54 (1.19) | 0.020 |
| 3 | $OF_t^S$ | **10.80**∗ (4.78) | 1.10 (0.77) | | | | | 0.032 |
| | $OF_t^M$ | | | **5.49**∗ (3.35) | 2.43 (1.84) | | | 0.029 |
| | $OF_t^L$ | | | | | **8.89**∗ (4.75) | 1.75 (1.41) | 0.046 |
| 4 | $OF_t^S$ | **11.98**∗ (3.20) | **4.16**∗ (2.50) | | | | | 0.046 |
| | $OF_t^M$ | | | **2.68**∗ (2.17) | 1.80 (1.49) | | | 0.011 |
| | $OF_t^L$ | | | | | 1.15 (1.56) | 0.78 (1.34) | 0.007 |
| 5 | $OF_t^S$ | **7.87**∗ (2.99) | 2.02 (1.28) | | | | | 0.041 |
| | $OF_t^M$ | | | **4.58**∗ (2.05) | −0.46 (−0.12) | | | 0.012 |
| | $OF_t^L$ | | | | | **4.06**∗ (2.78) | **1.91**∗ (1.96) | 0.015 |
| 6 | $OF_t^S$ | 5.28 (1.10) | 1.98 (1.54) | | | | | 0.012 |
| | $OF_t^M$ | | | **7.13**∗ (2.51) | **2.88** (1.83) | | | 0.043 |
| | $OF_t^L$ | | | | | **7.35** (1.91) | **1.98**∗ (2.48) | 0.046 |
| 7 | $OF_t^S$ | **38.28**∗ (2.51) | −0.60 (−0.30) | | | | | 0.027 |
| | $OF_t^M$ | | | **27.71**∗ (2.92) | 4.18 (0.26) | | | 0.007 |
| | $OF_t^L$ | | | | | 15.05 (0.92) | −32.77 (−1.34) | 0.011 |

Figure 1: Trading in the secondary market for government bonds in Norway

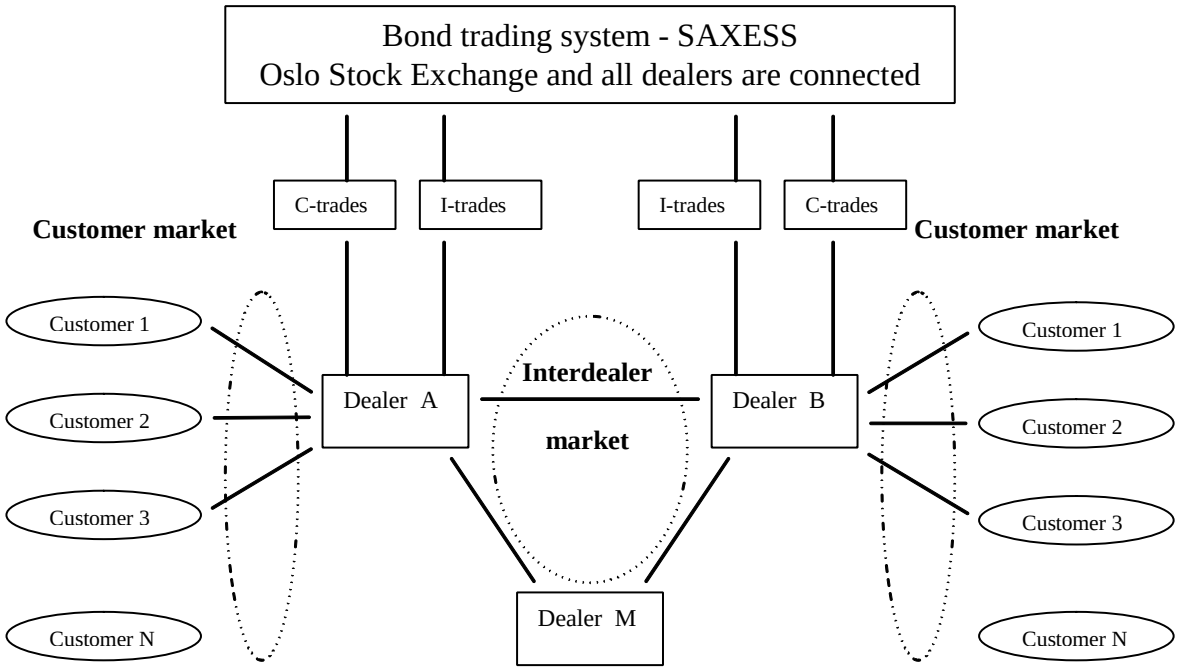

Figure 2: Possible dealer strategy in the government bond market when dealers can identify their informed customers.

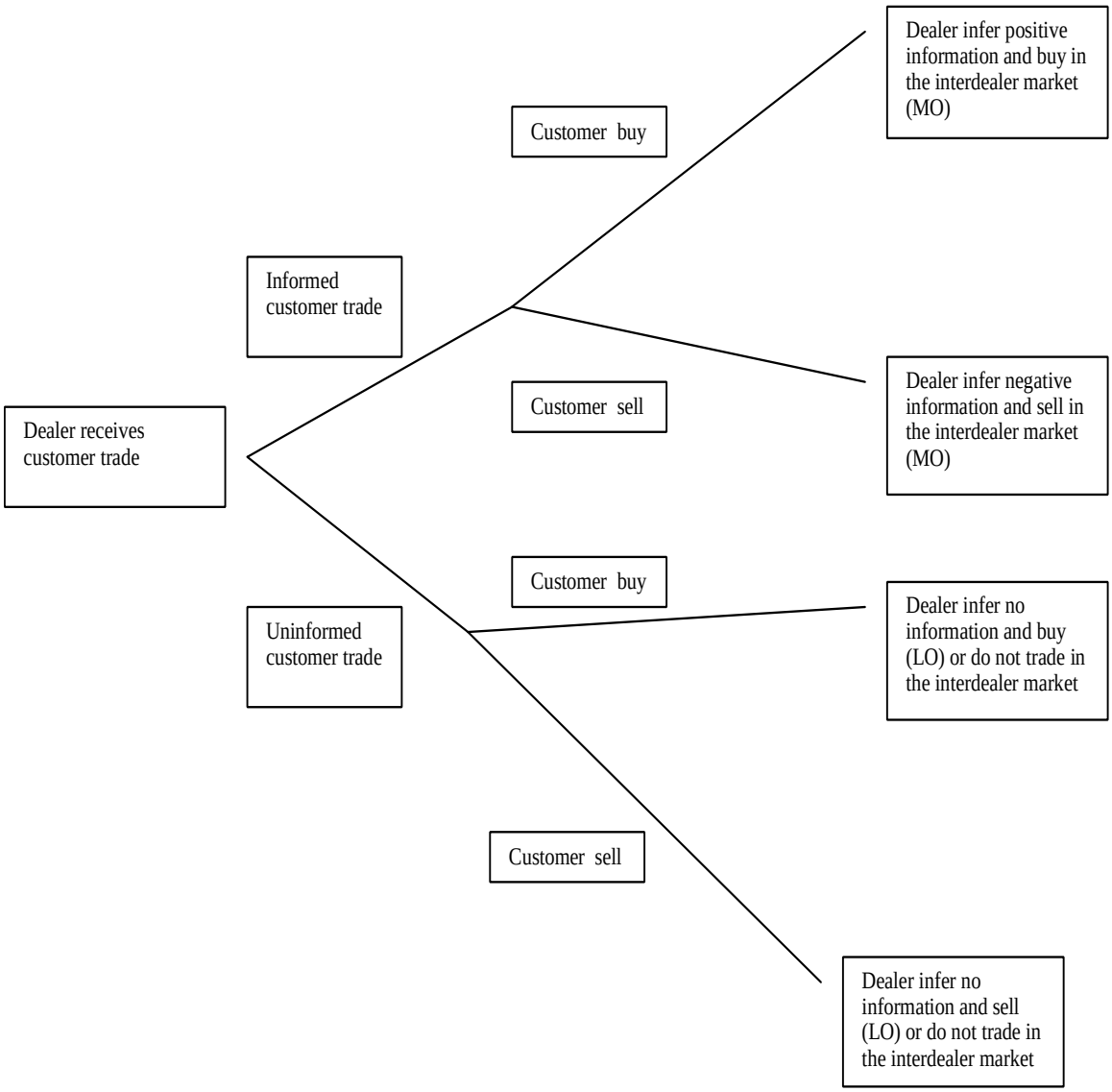

Figure 3: The figure shows the accumulated response of 3 year yield changes to a unit innovation in interdealer order flow. The first picture shows the response to a unit innovation in short term order flow, $OF^S$, the second picture the response to a unit innovation in medium term order flow, $OF^M$, and the third picture the response to a unit innovation in long term order flow, $OF^L$.

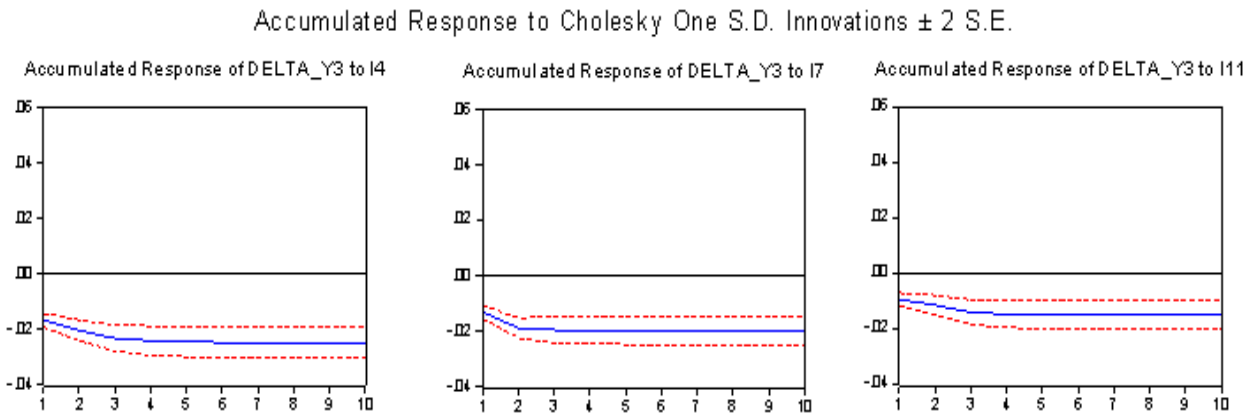

Figure 4: The figure shows the accumulated response of 5 year yield changes to a unit innovation in interdealer order flow. The first picture shows the response to a unit innovation in short term order flow, $\mathrm{OF}^S$, the second picture the response to a unit innovation in medium term order flow, $\mathrm{OF}^M$, and the third picture the response to a unit innovation in long term order flow, $\mathrm{OF}^L$.

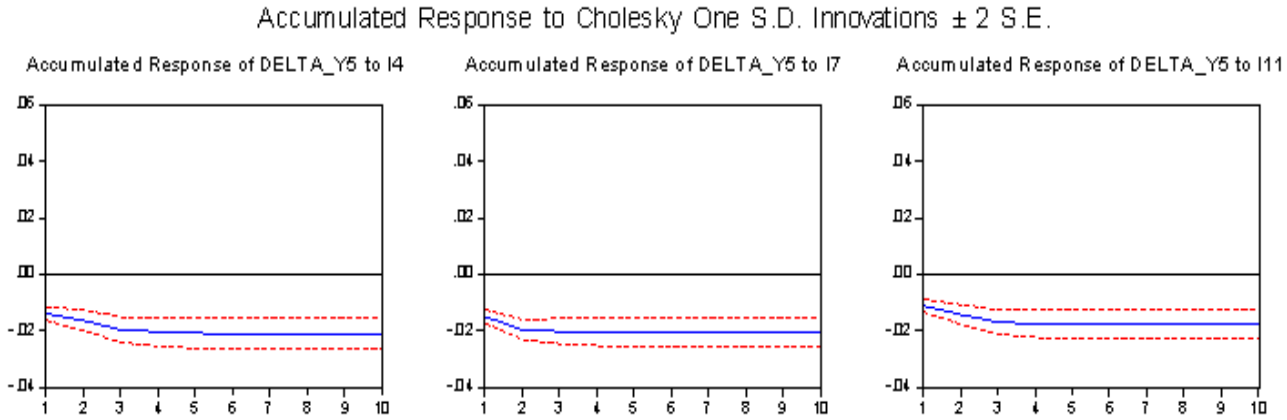

Figure 5: The figure shows the accumulated response of 10 year yield changes to a unit innovation in interdealer order flow. The first picture shows the response to a unit innovation in short term order flow, $\mathrm{OF}^S$, the second picture the response to a unit innovation in medium term order flow, $\mathrm{OF}^M$, and the third picture the response to a unit innovation in long term order flow, $\mathrm{OF}^L$.