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Informed trading in hybrid bond markets

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ABSTRACT

I study the impact of pretrade transparency on trading activity in an environment where dealers, informed and uninformed alike, can choose between an electronic limit order book (LOB) and an over-the-counter (OTC) market. By investigating bond dealers' choice in the hybrid Norwegian government bond market, I explore whether they base their trading strategy on the perceived informativeness of their trades. The results imply that bond dealers act strategically to preserve the value of their information by choosing the immediacy of the LOB when trades contain information. This suggests that OTC trades are exposed to a leakage of information to other dealers.

1. Introduction

For years, financial regulators have been calling for increased pretrade and posttrade transparency in previously opaque markets to promote well-functioning markets. Some countries have introduced posttrade transparency in bond markets, the establishment of TRACE in the U.S. is one example.[1] Since the 2008–2009 financial crisis the calls for transparency have intensified. In Europe, the European Securities and Markets Authority (ESMA) has decided to implement pre- and posttrade transparency requirements for bonds, derivatives, and a range of other financial instruments by passing new regulation, known as Markets in Financial Instruments Directive (MiFID II) and Regulation (MiFIR).

While regulators are hoping for a migration of trading to "lit" venues, representatives for financial intermediaries are less hopeful and fear markets instead will become less liquid (Ross, 2014). Which is right, the regulators or the market participants? While the impact of posttrade transparency in bond markets is well documented, little is known about the impact of introducing pretrade transparency in bond markets.

This paper investigates whether increased pretrade transparency will result in a shift in trading activity to the more transparent venues. One natural way to shed light on this issue is to study trading activity in a bond market where traders can choose between an opaque over-the-counter (OTC) market and a transparent electronic limit order book (LOB). Admati and Pfleiderer (1988) show that intraday trading patterns arise endogenously as a result of the strategic behavior by informed and uninformed traders where informed traders choose to trade at times that preserve the value of their information. The Norwegian government bond market is a natural experiment to study whether trading patterns arise endogenously as a result of the strategic behavior by informed and uninformed traders where informed traders choose to trade at venues that preserve the value of their information. In this hybrid interdealer

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[1] The Trade Reporting and Compliance Engine (TRACE) was approved January 23, 2001 by the Securities and Exchange Commission (SEC).

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market dealers can either submit orders in the LOB or trade bilaterally in the OTC market.[2] By studying the complete trading history of five bond dealers on both trading venues for the period 1999 to 2012, it is possible to reveal shifts in trading activity, if any, based on their choice between the two venues.

This paper sits within the intersection of two segments of the empirical finance literature, transparency and choice of venue. The effects of posttrade transparency in bond markets are documented by Goldstein, Hotchkiss, and Sirri (2007), Asquith, Covert, and Pathak (2013), and Li and Schurhoff (2014). This paper differs from the previous literature by focusing on the effects of pretrade transparency. The literature on location of informed trading focus on equity markets and include Reiss and Werner (2005), Kaniel and Liu (2006), and Menkveld, Yueshen, and Zhu (2017). This paper differs by studying bond markets. There are many differences between stock and bond markets; for example, trading frequency can influence the choice of trading venue, necessitating a separate analysis.

The rest of the paper is organized as follows. Section 2 presents the Norwegian government bond market and the data set. Section 3 presents the econometric framework and the results, while Section 4 presents some robustness checks. Section 5 concludes.

2. The Norwegian government bond market

2.1. Market overview

The secondary market in Norwegian government bonds consists of an electronic LOB administered by the Oslo Stock Exchange (OSE) and a bilateral OTC market. OSE members who are authorized to trade bonds have access to the LOB. Authorized dealers include banks and brokerage firms, and are referred to as dealers. Non-exchange members, including institutional investors, leveraged investors, commercial firms, and individual investors (referred to as customers), do not have access to the LOB and have to trade via dealers. The interdealer market is thus a hybrid market where dealers have a choice of trading venue while the customer market is a pure OTC market.

While the same bonds are traded in both venues, an important difference between the LOB and the OTC market is that the former has both pretrade and posttrade transparency while the latter has only posttrade transparency. The pretrade transparency in the LOB contributes to an information asymmetry between dealers and customers. Pretrade transparency includes visible bid and ask quotes, quoted volumes, and the quoting dealers' identities. Posttrade transparency includes trade price, trade size, time of execution, but no identities. Dealers have the possibility to delay the publication of OTC trades until the end of the trading day, which means that the trade will not be visible until 4:00 p.m.[3] Market and limit orders in the LOB are visible in real time. Trading in the OTC market is mainly conducted over the phone and by electronic messaging, and can be time consuming. The initiator will ask for a price and will be given a two-way price unless she indicates the trade direction. If she accepts the price, the two parties will agree on the trade and enter the trade details manually into the OSE trading system within 5 min. If they don't agree, the initiator will normally contact a new dealer.

The dealer providing liquidity in the OTC market may infer information from the initiating dealer before they agree on a price; and if private information is revealed, the liquidity provider can adjust her price quote accordingly. As the interdealer market is dominated by a few central dealers who closely monitor market activity, it is difficult to hide OTC trades from the other dealers. This possible leakage of information represents an indirect trading cost in the OTC market. Market orders in the LOB, on the other hand, carry no such risk. The speed of execution eliminates indirect trading costs stemming from information leakage and possible front running by other dealers.

In order to promote a well-functioning and liquid bond market the authorities, represented by the central bank, appoint primary dealers on a yearly basis. Primary dealer obligations include posting firm bid and ask quotes for a minimum trade volume in the LOB when the market is officially open between 9 a.m. and 4 p.m. Primary dealer trading activity accounts for more than half of total trading volume. After the inception of the LOB in 1999 dealers informally agreed to continue quoting bid-ask prices to each other in the OTC market, but around mid-2005 this informal market-maker agreement was terminated. Between 1999 and 2005, six to eight primary dealers were active market participants. Thereafter the number of primary dealers gradually declined to four by the end of 2011.

2.2. Data

The data set contains all trades in both trading venues in the Norwegian government bond market for the period September 1999 to November 2012. The data set includes the identities of the buying and the selling dealers, date, time, price, amount, and whether the trade is OTC or electronic (LOB). Table 1 displays the ten benchmark bonds traded over this period and reveals that new bonds are issued every other year as 11-year bonds. The table also displays the number of trades in each bond and shows that the share of trades executed in the LOB is higher for more recent bond issues. Also, the table displays the average trade size in million NOK for OTC trades and LOB trades. The larger trade size in more recent issues reflects the increase in LOB trading volume, compared to OTC

[2] Foucault, Pagano, and Roell (2013) define a hybrid market as a market design that mixes features of two or more market types. In OTC bond markets, including Request For Quote (RFQ) platforms like Tradeweb, prices must be requested and are subject to negotiations. In LOBs buy- and sell orders are visible to all potential traders until they are matched automatically with market orders.

[3] From 1999 to May 2002 the time of delay was 2 h. Since then delayed trades have been published at 4:00 p.m.

Table 1
Benchmark bonds.

Bond name	Issue year	Maturity year	Number of trades	Share (%) LOB	Avg. trade size OTC	Avg. trade size LOB
S463	1992	2002	6088	14.1	51.6	9.3
S465	1993	2004	14,366	16.7	34.8	13.7
S467	1996	2007	15,993	24.0	36.2	16.0
S468	1998	2009	19,886	19.9	37.1	14.7
S469	2000	2011	17,272	22.5	43.9	16.4
S470	2002	2013	12,776	26.9	60.6	19.4
S471	2004	2015	9031	21.8	57.6	24.1
S472	2006	2017	5730	32.7	59.8	25.0
S473	2008	2019	3577	45.0	65.1	22.3
S474	2010	2021	2581	37.6	58.8	22.4
All			107,300	23.1	48.5	18.3

Notes: The table includes all ordinary trades in benchmark bonds reported to the Oslo Stock Exchange (OSE) from September 6, 1999, to November 8, 2012. The bonds included are all bullet bonds with a remaining time to maturity of ten or eleven years when first issued. The number of ordinary trades in each bond includes both interdealer trades and customer trades; trades in bonds with less than 12 months until maturity are not included. The share of LOB trades is measured as the number of LOB trades as a percentage of the total number of trades in each bond. Average trade size is measured in million Norwegian kroner (NOK).

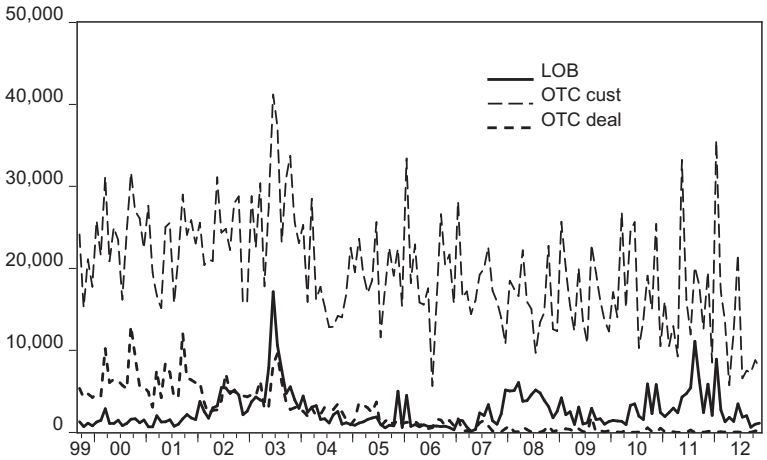

Fig. 1. Trading volume in the electronic limit order book (LOB) and in the over-the-counter (OTC) market in Norwegian government bonds. OTC trading volume is divided into interdealer trading volume (OTC deal) and customer trading volume (OTC cust). Monthly trading volume from September 1999 to November 2012. Million NOK.

trading volume, after the inception of electronic trading in 1999.

Interdealer trades are identified by applying the identity of the buying and the selling dealer. Trades with different buying and selling dealers are defined as interdealer trades and trades with the same dealer as customer trades. Interdealer trades are separated into LOB trades and OTC trades. Fig. 1 displays total monthly trading volume divided into LOB trades (solid curve), interdealer OTC trades (dotted curve), and customer OTC trades (dashed curve), measured in million NOK. The figure reveals that the share of interdealer trading volume in the OTC market has declined steadily since the inception of the LOB in 1999. In the period 1999 to 2001 about 80% of total interdealer trading volume was executed in the OTC market. This share declined over the next years. After the termination of the informal quoting agreement in 2005, interdealer trading activity in the OTC market remained very low. Fig. 1 reveals that trading volume in the LOB has varied substantially over the period, with peaks in 2003, 2008, and 2011. These peaks are related to expansionary monetary policy in 2003, the financial crisis in 2008–2009, and the European debt crisis in 2010–2011.

In order to investigate the choice of venue when dealers have informative trades, I study the interdealer trades of five dealers representing more than 80% of total interdealer trading volume.[4] The trades of each dealer in each venue are aggregated into dealer-specific and venue-specific order flows. Daily order flows are the sum of signed trades during a day, where buyer-initiated trades have a positive sign and seller-initiated trades have a negative sign.[5] LOB trades include information on the initiating dealer. OTC trades do

[4] This paper employs the same raw data (from Oslo Stock Exchange) as Valseth (2013), updated to November 2012. However, while this paper studies the effect of pretrade transparency on bond trading by studying the choice of trading venue by bond dealers, Valseth (2013) studies the role of dealers and their customers in the price discovery process in the market as a whole.

[5] I also calculate order flows on the basis of signed trading volume for each dealer. The results are robust to the use of order flows based on

Table 2
Descriptive statistics for short-, medium-, and long-term individual dealer order flow and bond excess returns.

Dealer	Order flow	Mean	Std.dev.	Minimum	Maximum	AR(1)
1	Short	0.018	1.033	−8.0	11.0	0.106
	Medium	0.066	1.056	−11.5	15.0	0.068
	Long	−0.017	1.091	−10.0	10.0	0.059
2	Short	−0.083	0.787	−10.0	6.5	0.095
	Medium	−0.050	0.719	−6.0	7.0	0.073
	Long	−0.066	0.731	−6.0	7.0	0.149
3	Short	−0.038	0.784	−15.0	6.0	0.105
	Medium	0.027	0.668	−7.5	7.0	0.059
	Long	−0.017	0.796	−9.0	12.0	0.057
4	Short	0.013	0.729	−7.0	12.0	0.075
	Medium	0.040	0.739	−7.0	8.0	0.058
	Long	−0.016	0.819	−7.0	9.0	0.052
5	Short	−0.079	0.843	−25.0	7.0	0.157
	Medium	−0.015	0.722	−13.0	6.0	0.035
	Long	−0.040	0.604	−7.0	8.0	0.035

Notes: The table presents the descriptive statistics for the five dealers' interdealer order flow in 3-, 5-, and 10-year zero coupon bonds from September 1999 to November 2012. There are 3310 daily observations. The last column displays the first-order autocorrelation.

not include this information and are signed according to the method of Lee and Ready (1991).[6]

The LOB and OTC order flows of each dealer are divided into maturity segments. As the maturity of a bond changes over its life, so do its characteristics. Order flows are therefore divided into short-, medium-, and long-term order flows. Short-term order flow includes trades in bonds with a remaining time to maturity from 1 up to 4 years, medium-term order flow includes trades in bonds with a remaining time to maturity from 4 years up to 7 years, and long-term order flow includes trades in bonds with a remaining time to maturity from 7 up to 10 years. The analysis includes separate LOB and OTC order flows for each dealer over the period 1999 to mid-2005. After that, from mid-2005 to 2012, only LOB order flows are included, as interdealer trading in the OTC market fell to very low levels. Table 2 displays descriptive statistics for the combined short-term, medium-term, and long-term order flows for each of the five dealers. The mean daily order flow is close to zero for all dealers.

3. Identification of informative trades and choice of venue

To investigate whether dealers endogenously choose trading venues according to the informativeness of their trades, I define and identify informative trades without loss of generality. I take as informative trades those that contain private information about future excess returns. Such information is valuable to a dealer, especially if she is the only one who possesses this information. To profit from this she wants to execute the informative trade before its content becomes available to other dealers.

To identify informative trades I perform predictive regressions of order flows on bond excess returns. The excess returns are based on zero-coupon bond prices and I focus on 3-, 5-, and 10-year excess returns.[7] Order flows with significant power to predict next-period excess returns are defined as informative. I include short-, medium-, and long-term order flows in all regressions, as order flows for all maturity segments can potentially contain private information about future returns. This is because the yield curve often make parallel shifts and bond trades often are linked. Indeed, many trading strategies (for example in trading strategies like bullets, barbells, and ladders) require trading at different points along the yield curve.

Fig. 2 displays the changes in 3-, 5-, and 10-year synthetic government bond yields over the sample period.[8] The figure shows that bond yields move in parallel much of the time.

I include both LOB and OTC order flows for each dealer for the period with substantial interdealer trading volumes in both venues, from September 1999 to mid-2005. If there are differences in the predictive power of trades executed in the two separate trading venues, it suggests that dealers make conscious choices about where to trade. The one-day ahead predictions are based on the following model:

(*footnote continued*)
number of trades versus order flows based on trade volume.

[6] Lee and Ready (1991) classify trades that are executed at a price less than the midprice as seller-initiated, and trades that are executed at a price higher than the midprice as buyer-initiated. For trades executed at the midprice, the tick rule is used. This rule implies that if the price is higher than the previous transaction price (an uptick) it is classified as a buy. If the price is lower (a downtick) it is classified as a sell. If it is unchanged the rule is applied to the price that preceded it.

[7] Zero coupon prices are kindly provided by Nordea Markets.

[8] Fixed duration (synthetic) bond yields are calculated by the central bank, Norges Bank.

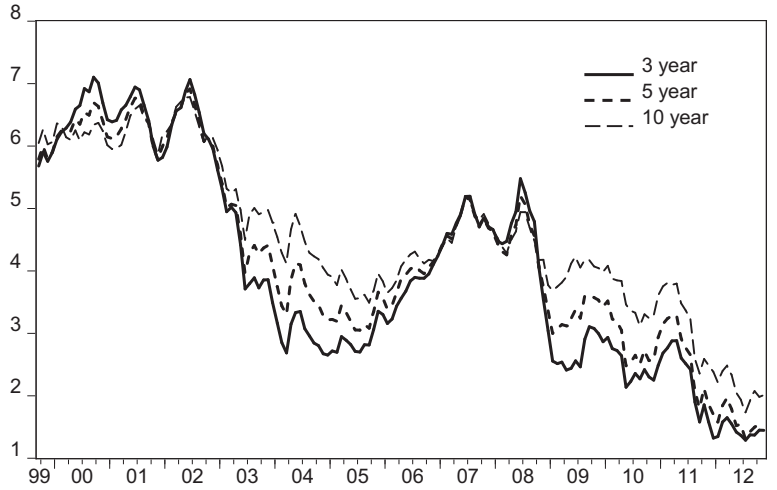

Fig. 2. Yield to maturity for 3-year solid curve, 5-year dotted curve, and 10-year dashed curve Norwegian government bonds. Monthly averages. September 1999 to November 2012.

$$exr_{t+1}^{(N)} = \beta_0 + \sum_{k=1}^{3} \beta_2^k F_t^k + \sum_{i=1}^{5} \sum_{d=S}^{L} (\beta_3^i OFB_{i,t}^d) + \sum_{i=1}^{5} \sum_{d=S}^{L} (\beta_4^i OFO_{i,t}^d) + \varepsilon_{t+1}, \quad (1)$$

where $exr_{t+1}^{(N)}$ is the excess return on a zero coupon bond with N years to maturity on day t + 1, β_0 is a constant, and F_t^k is the kth principal component of bond yields where k = 1,2,3. The model includes lagged values of the three first principal components of bond yields to control for the information reflected in the current yield curve.[9] This accords with Litterman and Scheinkman's (1991) finding that the first three principal components of the yield curve explain most of the variation in yields. The principal components are based on zero coupon yields up to ten years on Norwegian government bonds. Including lagged principal components of yields also controls for autocorrelation in bond yields. $OFB_{i,\,t}^{\,d}$ and $OFO_{i,\,t}^{\,d}$ represent order flows in the LOB and the OTCmarket, respectively, for Dealer i, where i = 1,2,3,4,5, and for the three maturity groups d = S,M,L. For example, $OFB_{1,\,t}^{\,S}$ is the short term LOB order flow of Dealer 1, and $OFO_{2,\,t}^{\,L}$ is the long term OTC order flow of Dealer 2 on day t. ε_{t+1} is the error term. I correct for autocorrelation and heteroscedasticity by applying the Newey-West method to the regression coefficients.

The results of the model presented in Eq. (1), for the years 1999 to 2005, are displayed in Table 3. The table shows the power of the two types of order flows to predict 3-, 5-, and 10-year excess returns. All dealers except Dealer 1 have LOB order flow with significant predictive power for the next day's excess returns, while only one has OTC order flow with predictive power. This suggests that dealers choose to execute informative trades as market orders in the LOB. This is in line with Hombert, Foucault, and Rosu's (2016) finding that trading speed is more important when trade informativeness is high. While market orders in the LOB are executed immediately, market orders in the OTC-market are time-consuming, as they require contacting at least one dealer to request a quote. The bilateral negotiation process in OTC markets exposes informed traders to a costly leakage of information. Table 3 also shows that for some dealers, long-term order flow has predictive power, while for others, short- and medium-term order flow have predictive power. This suggests that dealers specialize in trading in different segments of the yield curve. The results reveal that informative order flow in one maturity segment affects bond returns in several maturity segments. This shows that information contained in trades can be relevant for the whole yield curve and supports the finding of Litterman and Scheinkman (1991) that the "level" factor explains most of the variability in yields.

In all, Table 3 suggests that dealers differentiate between informative trades and noninformative trades and form their trading strategies accordingly. Similarly, Bessembinder and Venkataraman (2004), who investigate large (block) trades in the OTC market (upstairs market) and LOB (downstairs market) on the Paris Bourse for the period 1987–1988, find that both execution costs and information content are lower in OTC trades than in LOB trades. Dealers prefer to execute informative trades in the LOB because it is difficult to hide them and preserve their value in OTC markets. The preference for executing informative trades as market orders in the anonymous LOB exposes liquidity providers in lit venues to high adverse selection risk. The preference for executing non-informative trades in the nonanonymous OTC market limits adverse selection risk substantially. The result of this trading strategy among dealers implies higher bid-ask spreads on the lit venue. Fig. 3, which displays relative spreads in the LOB and the OTC market for medium-term bonds, clearly confirms this.[10]

[9] The first principal component of the yield curve is often referred to as the level factor, the second principal component as the slope factor, and the third principal component as the curvature factor.

[10] Relative spreads in the LOB are measured as the quoted spread in percent of the midquote, while relative spreads in the OTC market are measured as twice the spread between the OTC transactions price and the midquote in the LOB at the same time.

Table 3
Response of 3-, 5-, and 10-year bond excess returns to lagged interdealer order flows for five dealers in the LOB and OTC market, September 1999–June 2005.

Dealer	Venue	Order flow	3-year	5-year	10-year
1	LOB	Short	−0.03	−0.63	−1.52
			(−0.06)	(−0.73)	(−1.09)
	LOB	Medium	0.83	0.91	2.54
			(1.47)	(0.97)	(1.51)
	LOB	Long	−0.20	0.22	1.22
			(−0.41)	(0.25)	(0.67)
	OTC	Short	0.13	0.11	−0.31
			(0.22)	(0.12)	(−0.18)
	OTC	Medium	−0.52	−0.09	−1.65
			(−0.73)	(−0.08)	(−0.71)
	OTC	Long	−0.64	−1.08	−2.62
			(−0.95)	(−0.99)	(−1.28)
2	LOB	Short	0.44	0.18	−0.00
			(0.63)	(1.47)	(1.47)
	LOB	Medium	0.30	0.95	2.71
			(0.48)	(0.91)	(1.27)
	LOB	Long	**1.52***	**2.21***	**5.17***
			(2.79)	(2.26)	(2.32)
	OTC	Short	0.40	1.29	2.89
			(0.36)	(0.78)	(1.05)
	OTC	Medium	**1.93**	**2.91**	2.57
			(1.88)	(1.80)	(0.81)
	OTC	Long	**−1.29**	−1.71	−2.35
			(−1.81)	(−1.49)	(−1.06)
3	LOB	Short	0.82	1.56	1.18
			(1.37)	(1.62)	(0.70)
	LOB	Medium	**1.48***	**1.86**	1.34
			(2.24)	(1.89)	(0.74)
	LOB	Long	0.07	0.18	0.08
			(0.13)	(0.21)	(0.04)
	OTC	Short	−0.14	−0.77	−2.55
			(−0.19)	(−0.63)	(−1.10)
	OTC	Medium	0.73	0.11	0.36
			(0.72)	(0.07)	(0.12)
	OTC	Long	−0.36	0.02	0.64
			(−0.56)	(0.02)	(0.30)
4	LOB	Short	**1.27**	1.19	−0.52
			(1.74)	(0.98)	(−0.20)
	LOB	Medium	0.49	1.01	1.46
			(0.69)	(0.85)	(0.68)
	LOB	Long	0.99	**1.67**	**4.11***
			(0.61)	(1.89)	(2.43)
	OTC	Short	−0.27	−0.28	1.58
			(−0.28)	(−0.20)	(0.64)
	OTC	Medium	0.09	0.23	−1.17
			(0.10)	(0.17)	(−0.47)
	OTC	Long	0.68	2.27	3.54
			(0.60)	(1.33)	(1.36)
5	LOB	Short	**0.74**	**1.22***	1.61
			(1.92)	(2.01)	(1.26)
	LOB	Medium	**1.00**	**2.04***	2.86
			(1.86)	(2.04)	(1.33)
	LOB	Long	−0.98	−1.97	−4.32
			(−0.84)	(−1.03)	(−1.57)

(*continued on next page*)

Table 3 (*continued*)

Dealer	Venue	Order flow	3-year	5-year	10-year
	OTC	Short	0.17	0.32	−0.98
			(0.15)	(0.19)	(−0.32)
	OTC	Medium	−0.41	0.88	2.66
			(−0.34)	(0.48)	(0.86)
	OTC	Long	−0.79	−1.44	−3.07
			(−0.69)	(−0.72)	(−0.78)
Adj. R^2			0.0214	0.0193	0.0119

Notes: Coefficients are corrected for autocorrelation and heteroscedasticity by the Newey-West method. Coefficients are multiplied by 10^4 for readability, and in bold when significant at the 10% level or better, and marked with an asterisk when significant at the 5% level or better. T-statistics are in parentheses.

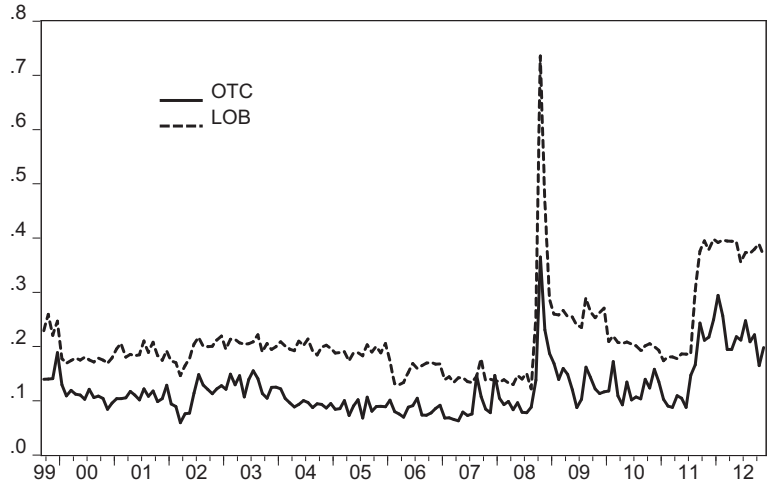

Fig. 3. Relative bid-ask spreads in the over-the-counter (OTC) market and in the electronic limit order book (LOB) for medium-term bonds with a remaining time to maturity between 4 and 7 years. Monthly averages. September 1999 to November 2012.

Bid-ask spreads in Norwegian government bonds are substantially higher in the LOB than in the OTC market.[11] The lower bid-ask spreads in the OTC market for Norwegian government bonds support the conclusion of Bessembinder and Venkataraman (2004) that trading costs are lower in the upstairs (OTC) market because traders are credibly signaling that their orders do not reflect private information. The results accord with Menkveld et al. (2017) finding that the choice of trading venue depends on the trade-off between direct trading costs (spreads) and the urgency to trade. It is reasonable to assume that the more informative a trade is, the higher is a dealer's urgency to trade.

However, if liquidity providers on lit venues are partly compensated for their risk, spreads could come down and attract uninformative trades as well. This will contribute to higher trading activity and better liquidity on lit venues, in line with the intentions of financial regulators. The findings in this paper thus imply that financial regulation promoting pretrade transparency in bond markets should be accompanied by incentives for liquidity provision to have the intended effect. One way to compensate liquidity providers is to pay them regularly for market-making services. Such payment could be covered by bond issuers, regulators, or both.

4. Robustness

In this section I present some robustness checks on the results in the previous section. As Fig. 1 shows, interdealer OTC trading activity declined to very low levels for many dealers in the second half of 2005. I therefore investigate the predictive power of market orders in the LOB for the whole 1999–2012 period and for the second subperiod separately. For this purpose I modify the model to include LOB order flow only:

$$exr_{t+1}^{(N)} = \beta_0 + \sum_{k=1}^{3} \beta_2^k F_t^k + \sum_{i=1}^{5} \sum_{d=S}^{L} (\beta_3^i OFB_{i,t}^d) + \epsilon_{t+1} \tag{2}$$

[11] Fig. 3 shows relative bid-ask spreads in the LOB and the OTC market which includes both interdealer trades and customer trades. When OTC spreads are separated into interdealer spreads and customer spreads, interdealer spreads are lower for all maturity groups.

Table 4
Response of 3-, 5-, and 10-year bond excess returns to lagged interdealer order flows for five dealers in the LOB, September 1999–November 2012 and July 2005–November 2012.

		Sep.99–Nov. 12			Jul.05–Nov.12		
Dealer	Order flow	3-year	5-year	10-year	3-year	5-year	10-year
1	Short	0.25	−0.10	−1.00	0.47	0.05	−0.84
		(0.86)	(−0.16)	(−0.84)	(0.99)	(0.06)	(−0.52)
	Medium	**0.73***	**1.67***	**2.62***	0.62	**2.12***	**2.68***
		(2.29)	(2.87)	(2.64)	(1.58)	(2.85)	(2.12)
	Long	0.41	0.89	**2.01**	0.61	0.05	**2.33**
		(1.25)	(1.64)	(1.90)	(1.50)	(1.31)	(1.75)
2	Short	0.62	0.68	1.20	0.88	1.68	3.73
		(1.15)	(0.79)	(0.78)	(1.01)	(1.13)	(1.60)
	Medium	0.21	0.55	1.57	0.22	0.31	0.47
		(0.48)	(0.79)	(1.16)	(0.32)	(0.33)	(0.26)
	Long	**0.95***	**2.09***	**4.34***	0.67	**1.84**	**3.77***
		(2.31)	(2.91)	(3.16)	(1.20)	(1.96)	(2.28)
3	Short	0.65	0.86	−0.74	0.22	−0.06	−2.74
		(1.29)	(1.04)	(−0.05)	(0.21)	(−0.39)	(−1.09)
	Medium	**1.43***	**2.36***	2.26	1.14	2.95	3.02
		(2.56)	(2.36)	(1.46)	(1.16)	(1.49)	(1.09)
	Long	0.36	0.83	1.33	1.17	**2.37**	**4.72**
		(0.87)	(1.18)	(0.88)	(1.52)	(1.76)	(1.81)
4	Short	**1.31***	1.16	0.39	**1.19**	0.82	0.43
		(2.83)	(1.59)	(0.25)	(1.87)	(0.89)	(0.24)
	Medium	0.16	1.14	1.87	0.13	1.56	2.53
		(0.38)	(1.53)	(1.50)	(0.24)	(1.55)	(1.52)
	Long	0.29	0.69	**3.12***	−0.26	−0.25	2.02
		(0.81)	(1.06)	(2.60)	(−0.53)	(−0.25)	(1.17)
5	Short	**0.66***	**1.08***	1.41	0.59	0.81	1.45
		(1.97)	(2.02)	(1.27)	(0.66)	(0.54)	(0.60)
	Medium	0.25	0.61	0.57	−0.58	−1.15	−2.14
		(0.51)	(0.73)	(0.34)	(−0.68)	(−0.81)	(−0.78)
	Long	0.04	−0.38	−1.21	**1.45**	1.91	3.68
		(0.05)	(−0.29)	(−0.69)	(1.65)	(1.31)	(1.59)
Adj. R^2		0.0181	0.0209	0.0191	0.0137	0.0232	0.0249

Notes: Coefficients are corrected for autocorrelation and heteroscedasticity by the Newey-West method. Coefficients are multiplied by 10^4, and in bold when significant at the 10% level or better, and marked with an asterisk when significant at the 5% level or better. T-statistics are in parentheses.

The model presented in Eq. (2) is first applied for the whole period from September 1999 to November 2012 and then for the period July 2005 to November 2012. Table 4 displays the results. They show that all dealers have LOB order flows with predictive ability for bond excess returns, and that these flows are in line with the findings in Table 3. Some LOB order flows have significant predictive power in the second period as well. The results for the second period reflect changes in dealers' market shares over time and include the reduction in the number of primary dealers from five to four in 2011.

As another robustness check I investigate the predictive power of aggregate interdealer order flows over the 1999–2005 period. If many dealers follow the trading strategy of executing informative trades on the lit venue, I expect this to be reflected in aggregate trading variables as well. I aggregate all LOB trades into LOB order flows and all OTC trades into OTC order flows, and separate them into the three maturity groups. I perform one-day-ahead predictive regressions of these order flows on bond excess returns using the following model for the period September 1999 to July 2005:

$$exr_{t+1}^{(N)} = \beta_0 + \sum_{k=1}^{3} \beta_2^k F_t^k + \sum_{d=S}^{L} (\beta_3^i OFB_t^d) + \sum_{d=S}^{L} (\beta_4^i OFO_t^d) + \epsilon_{t+1} \tag{3}$$

where OFB_t^d represents the aggregate order flows in the LOB and OFO_t^d represents the aggregate order flows in the OTC market at time t for the three maturity groups d = S,M,L. The results are presented in Table 5. The table shows that only aggregate LOB order flow has predictive power for bond excess returns. Short- and medium-term LOB order flow have significant predictive power for 3-year returns, while short- and medium-term OTC order flows have no predictive power. Long-term LOB has significant predictive power for both 5- and 10-year returns. These results support the findings above that traders prefer the immediacy of the lit LOB when they have informative trades and the opaque OTC market otherwise.

Finally, I study the predictive power of aggregate order flows at longer horizons. I run predictive regressions of aggregate order

Table 5
Response of bond excess returns to lagged aggregate interdealer order flows in the LOB and OTC market for Norwegian government bonds, September 1999–June 2005.

	Venue	3-year	5-year	10-year
Constant		−0.06	−0.43	−0.50
		(−0.05)	(−0.25)	(−0.16)
PC1		−0.41	0.07	0.07
		(−0.78)	(0.08)	(0.05)
PC2		1.36	4.06	11.59
		(0.45)	(0.86)	(1.36)
PC3		2.94	−15.05	59.73
		(0.14)	(−0.44)	(0.93)
Short	LOB	**1.47***	**1.61**	0.06
		(2.26)	(1.88)	(0.11)
Medium	LOB	**0.33**	0.32	0.34
		(1.75)	(0.98)	(0.54)
Long	LOB	0.29	**0.58***	**1.39***
		(1.64)	(1.99)	(2.47)
Short	OTC	−0.12	−0.09	−0.07
		(−1.21)	(−0.52)	(−0.22)
Medium	OTC	−0.01	0.05	0.39
		(−0.10)	(0.28)	(1.06)
Long	OTC	−0.03	0.03	0.02
		(−0.22)	(0.15)	(0.06)
Adj. R^2		0.0141	0.0069	0.0039

Notes: There are 1446 daily observations. Coefficients are corrected for autocorrelation and heteroscedasticity by the Newey-West method. Coefficients are multiplied by 10^4 for readability, and in bold when significant at the 10% level or better, and marked with an asterisk when significant at the 5% level or better. T statistics are in parentheses.

flow from both trading venues on weekly and monthly yield changes for the period September 1999 to July 2005. The results, which are available on request, show that short-term LOB order flow has predictive power for 3- and 5-year yields at the weekly horizon. Long-term LOB order flow has predictive power for 10-year yields, while short-, medium-, and long-term OTC order flows have no predictive power. At the monthly horizon, which includes only 69 nonoverlapping observations, the results show that short-term LOB order flow has predictive power for 3- and 5-year yield changes. I also perform out-of-sample predictions at the daily horizon with both individual dealer order flows and aggregate order flows, and the results (available upon request) strongly support my findings.

In all, the results in this section support the conclusion that trading patterns arise endogenously as a result of strategic behavior by informed and uninformed dealers wherein informed dealers choose to trade at venues that preserve the value of their information.

5. Conclusion

The complete trading records of five dealers in Norwegian government bonds show that, given the choice between an LOB and an OTC market, dealers shift a portion of their trading activity onto the more transparent venue. This portion includes informative trades, submitted as market orders in the LOB; the remaining portion stays in the opaque OTC market. A possible explanation is that dealers prefer to execute informative trades fast in the LOB because it is difficult to hide and thus benefit from the private information in trades in OTC markets.

The results documented in this paper support the regulators' view that trading activity will migrate from opaque to lit venues. However, it appears that this migration mainly involves a subset, informative trades, as long as there is a viable, opaque alternative venue. The evidence from the Norwegian government bond market also supports the opposing view that pretrade transparency will reduce trading and liquidity. Total interdealer trading activity has slowly declined after the introduction of the transparent LOB, and spreads have remained high even as most of the trading volume has migrated to the LOB.

In order to ease the transition to lit trading venues regulators could incentivize liquidity provision, at least for a transitional period. This is especially important for infrequently traded securities, where liquidity providers face both high adverse selection costs and high waiting costs. In order to secure a fairly liquid market for infrequently traded bonds, the new requirements should therefore be accompanied by an incentive scheme for liquidity suppliers. Such measures could be organized and financed by the issuers or the regulators.

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