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Abstract: We analyze the dynamics of liquidity in Xetra, an electronic open limit order book. We use the Exchange Liquidity Measure (XLM), a measure of the cost of a roundtrip trade of given size *V*. This measure captures the price and the quantity dimension of liquidity. We present descriptive statistics, analyze the cross-sectional determinants of the XLM measure and document its intraday pattern. Our main contribution is an analysis of the dynamics of the XLM measure around liquidity shocks. We use intraday event study methodology to analyze how a shock affects the XLM measure. We consider two sets of liquidity shocks, large transactions (which are endogenous events because they originate in the market) and Bloomberg ticker news items (which are exogenous events because they originate outside of the market). We find that resiliency after large transactions is high, i.e., liquidity quickly reverts to "normal" levels. We further document that large trades take place at times when liquidity is unusually high. We interpret this as evidence that large transactions are timed. The Bloomberg ticker news items do not have a discernible effect on liquidity.

JEL classification: G 10

Keywords: Liquidity, limit order book, resiliency

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1 Introduction

It is a commonplace that liquidity is the most important determinant of market quality. It affects the transaction costs for investors, and it is a decisive factor in the competition for order flow among exchanges, and between exchanges and proprietary trading systems. Over the last decades researchers have gained a thorough understanding of liquidity. There is a wide array of liquidity measures, and the cross-sectional and time-series determinants of liquidity are fairly well understood. However, our understanding of the intraday dynamics of liquidity, and of the motives that govern traders' choices between market orders and limit orders is much less well understood.

Our paper contributes to the literature on liquidity by analyzing the dynamics of liquidity in an electronic open limit order book. The main building block of our analysis is the Exchange Liquidity Measure XLM(V).[1] It measures the cost of a roundtrip trade of size V. We analyze how this measure reacts to liquidity shocks. To do so we employ an intraday event study approach. Using data at 1-minute frequency we analyze how the XLM(V) measure reacts to liquidity shocks. We consider two types of shocks, large transactions and Bloomberg ticker news. The large transactions are endogenous events because they originate in the market. The ticker news, on the other hand, are exogenous.

Our main findings can be summarized as follows. Large transactions (by definition) have an immediate negative impact on liquidity because limit orders in the book are executed. We find that liquidity partially recovers within one or two minutes after the transaction, but does not reach its pre-transaction level. There thus appears to be a permanent effect. The explanation for this pattern is revealed once the XLM measure prior to the transaction is included in the analysis. Liquidity increases prior to the transaction. Thus, transactions take place when li-

[1] See section 2 and Gomber and Schweickert (2002) for a description of the XLM measure.

quidity is unusually high. Immediately after the transaction, liquidity reverts to its normal level. It does not, however, revert to the unusually high level immediately prior to the transaction. The observed pattern suggests that large transactions are timed. This is an important result because it implies that traders initiating large trades, although being arguably less patient than limit order traders, *do* have the patience to delay their transaction until liquidity is high enough. Our results are also consistent with theoretical predictions that market orders are more attractive when liquidity is high (e.g. Foucault 1999, Foucault et al. 2005), and with the intuition that the incentive to split large orders is lower when liquidity is high. The finding that large transactions are timed also suggests that the results of studies treating the timing of large trades as exogenous may be misleading.

We do not find a clear pattern in the XLM measure around the publication of news items on the Bloomberg ticker. This may be because the news items are anticipated[2], because they do not have information content per se, or because Bloomberg is not the first channel through which the information reaches the market. Additional analyses yield support for the second and the third explanation.

Our paper is related to various strands of the microstructure literature. Several authors have proposed theoretical models of dynamic limit order markets (e.g. Parlour 1998, Foucault 1999, Foucault et al. 2005, Goettler et al. 2005, Rosu 2009, Van Achter 2008). A common feature of these models is that they make predictions on the dynamics of liquidity by endogenizing the choice between market orders and limit orders. Theissen and Wuyts (2009) empirically test predictions obtained from these models. The results are somewhat ambiguous,

2 Market participants may know that there will be an information event and withdraw liquidity in anticipation of the release. In such a case there will obviously be an effect on liquidity, but it will be observed prior to the event and not upon publication of the news item.

which may be due to the fact that the models assume symmetric information, an assumption which is unlikely to hold in reality.

The analysis of the impact of large trades on liquidity is related to several previous papers that analyze liquidity dynamics and the resiliency of a limit order book, where resiliency is defined as the speed at which liquidity reverts to "normal" levels after an adverse liquidity shock.[3] Biais et al. (1995) and Hedvall and Niemeyer (1997) investigate into the dynamics of liquidity by cross-tabulating sequences of events in a limit order market. Degryse et al. (2005), De Winne and d'Hondt (2003) and Wuyts (2008) analyze the impact of large trades on depth and the quoted spread. Cummings and Frino (2008, 2010) perform a similar analysis for futures markets. Large (2007) assesses resiliency using a continuous time impulse response function framework while Kempf et al. (2007) use an autoregressive framework. Copejans et al. (2001) used data from a Swedish index futures contract. They found that discretionary traders trade in times of high liquidity, a finding consistent with ours and with the theoretical prediction in Admati and Pfleiderer (1988). They further estimate structural VAR models to investigate the dynamics of a depth-based liquidity measure. Using data from the Swiss Stock Exchange Ranaldo (2004) documents that a trader's order type decision depends on the state of the limit order book, which is consistent with predictions from theoretical models of limit order markets (e.g. Foucault et al. 2005) and with our timing result. Chakravarty et al. (2009) analyze the joint dynamics of quoted prices and quoted depth using error correction models. Cao et al. (2009) analyze the extent to which limit orders beyond the best bid and ask convey information about future returns and future liquidity. Beltran-Lopez et al. (2009) identify commonalities in the order book by analyzing the structure of the order book using principal component analysis. Kempf and Mayston (2008) also analyze commonality in

[3] This definition is in the spirit of Foucault et al. (2005). Alternatively, a market can be said to be resilient when *prices* quickly revert to "normal" levels after a shock (Black 1971, Harris 1990).

the limit order book and find that commonality gets stronger the deeper one looks into the book.

Our analysis of the impact of Bloomberg ticker news on liquidity is related to previous papers that looked into the effect of corporate events such as earnings and dividend announcements on liquidity (e.g. Venkatesh and Chiang 1986, Lee et al. 1993, Krinsky and Lee 1996, Graham et al. 2006). Ranaldo (2006) analyzes prices, volume, volatility, and liquidity around the release of firm-specific news items through Reuters alert. He documents that liquidity is above its normal level around the news release. Finally, Brooks et al. (2003) document the market response to unanticipated negative events (like plane crashes or the death of a CEO). They use a small sample, consisting of 21 events, and document that spreads are higher than normal for about 60 minutes after the event.

Our paper contributes to this literature in several respects. First, it is the only paper analyzing the impact of endogenous and exogenous events in a unified framework. Second, by using the XLM(V) measure for different order sizes we provide a more complete analysis of the execution cost than is obtainable by only considering spread and depth data (as is done in many prior studies of resiliency). In a liquid market there is an almost constant flow of (predominantly small) limit orders. After a liquidity shock a new limit order can quickly restore a small spread. If the new limit order is small, however, the order book remains thin. Consequently, assessing the resiliency of the market by considering the quoted spread may lead to an overstatement of the true liquidity in the market. The XLM measure, in contrast, is a summary measure of the total liquidity in the book and is thus better suited to address the issue of resiliency. A further advantage of the XLM measure is that it allows to assess the liquidity on the bid and the ask side of the market separately. The spread, in contrast, is by definition a symmetric measure.Third, our analysis of the resiliency of the market makes use of an intraday event study approach that allows us to formally test hypotheses relating to the dynamics of liquidity. Finally, our data comes directly from the exchange. We thus do not have to reconstruct the order book. This is important because reconstructing the book with data that is available to researchers may yield results that are less than perfectly accurate.

The remainder of the paper is organized as follows. Section 2 first presents the XLM measure and then describes our data set. In section 3 we present a static analysis of the XLM measure. The main contribution of the paper is in section 4 which presents the design and results of our dynamic analysis. Section 5 concludes.

2 Data set and XLM measure

We use data from Xetra, the most liquid market for German stocks.[4] Xetra is an anonymous electronic limit order book. Trading starts at 9 a.m. with an opening call auction and (during our sample period) ends at 8 p.m. with a closing auction.[5] There are two intraday call auctions at 1 p.m. and 5.30 p.m. Liquidity is supplied by limit order traders. Besides normal limit orders, market participants may submit hidden orders ("iceberg orders"). These orders have a visible part which is displayed on the trading screens and an invisible part. When the visible part is executed it is replaced by a portion of the hidden part that is equal in size to the original visible part. This procedure is repeated until the hidden part is exhausted.

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[4] Besides electronic trading on Xetra there is floor trading on the Frankfurt Stock Exchange and six regional exchanges. Xetra is the dominant market. Its market share is 91.3% (unweighted average for the sample stocks in August 2002, source: Deutsche Börse AG, Kassamarktstatistik August 2002). Due to the introduction of MiFID, market shares have changed since late 2007, however, as of 2011, Xetra is still the dominant market for German shares. A consolidated limit order book or a system similar to the Consolidated Quotation System and the Intermarket Trading System in the US does not exist. A detailed description of Xetra can be found in Kasch-Haroutounian and Theissen (2009).

[5] Since November 2003, the closing auction takes place at 5.30 p.m.

The Exchange Liquidity Measure, XLM, is calculated by Deutsche Börse AG since July 2002. It was introduced in order to consistently and continuously monitor the liquidity of the market.[6] The XLM measure uses the information about all the orders in the book (including the hidden part of iceberg orders[7]) to calculate the weighted average price at which an order of given size could be executed immediately at time *t*. Denote these prices by $P_{B,t}(V)$ and $P_{S,t}(V)$ where the index (B, S) indicates the type of the transaction (buyer-initiated or seller-initiated) and V denotes the order size. Further, let MQ_t be the quote midpoint at time t. The execution cost for a buy and a sell order, measured in basis points, are given by

$$XLM_{B,t}(V) = 10{,}000 \frac{P_{B,t}(V) - MQ_t}{MQ_t}$$
$$XLM_{S,t}(V) = 10{,}000 \frac{MQ_t - P_{S,t}(V)}{MQ_t}$$

They are then added up to obtain the XLM measure as the cost of a roundtrip transaction:

$$XLM_t(V) = XLM_{B,t}(V) + XLM_{S,t}(V)$$

Our data set contains information about 21 stocks (12 of which are included in the blue chip index DAX) and covers the 21 trading days from August 2 through August 31, 2002. Table 1 presents descriptive statistics for the sample stocks. These cover a wide range in both market capitalization and trading volume. The market value of equity of the largest stock, Deutsche Telekom, is 48.7 billion € as compared to 194 million € for the smallest sample stock (Gerry

6 The XLM measure is provided via the Internet for the ten most liquid stocks and Exchange Traded Funds for the previous trading day.

7 Comparing the XLM measure with and without inclusion of the hidden part of iceberg orders would be a convenient way to assess the importance of hidden liquidity. Our sample does not comprise the XLM measure without the hidden part of iceberg orders. However, as the focus of our analysis is on the dynamics of liquidity (or, put differently, the resiliency of the market), using a measure that includes the hidden liquidity is appropriate. For an in-depth analysis of hidden orders see Bessembinder et al. (2009).

Weber Int.). Similarly, trading volume in the month of August 2002 ranges from 6.3 billion € for the most active stock (Allianz) to 1.7 million € for the least active stock (again Gerry Weber Int.).

Insert Table 1 about here

Our data set contains the XLM measure (separately for the buy and the sell side) for each minute of the trading day and for different order sizes *V*. The order size grid is not the same for all stocks. Rather, it is differentiated with respect to liquidity. For the most liquid stocks (the constituent stocks of the DAX and the EuroStoxx 50), order sizes range from € 25,000 to € 5,000,000. For all other stocks order sizes range from € 10,000 to € 1,000,000. However, for less liquid stocks the book is not deep enough to accommodate trades of up to € 1,000,000. Therefore, XLM(V) measures for large values of V are not observed for some stocks. The effective order size grids for the sample stocks (i.e., those values of V for which there are data in our sample) are also reported in Table 1.

3 Static analysis

This section provides a detailed analysis of liquidity using the XLM(V) measure. Table 2 presents results for individual stocks. The table shows the half spread and single-sided XLM measures for trading volumes of € 25,000, 100,000, 500,000 and 1,000,000. In the sequel, when referring to a specific XLM(V) measure, we will measure the volume in 1,000 €. XLM(1000) thus corresponds to a volume of € 1,000,000.

The upper entry in each cell of Table 2 reports the average one-sided XLM measure in basis points. Measures for the cost of a round trip trade can be obtained by simply adding the XLM for a purchase and a sale. The lower figure reports the availability, defined as the percentage of cases in which the order book was deep enough to allow immediate execution of an order of the size given in the first row.[8]

Insert Table 2 about here

Panel A shows the results for the DAX stocks, Panel B those for the non-DAX stocks. In both panels, stocks are sorted by market capitalization. For the DAX stocks the availability is always 100%, indicating that the order book for these stocks is always deep enough to allow immediate execution of trades with a volume of up to € 1,000,000. For four of the DAX stocks availability is 100% up to a volume of 5,000,000 € (the maximum *V* in our sample). As one would expect, depth is lower for the non-DAX stocks. Availability decreases with decreasing market capitalization. For the smallest sample stock (in terms of market capitalization), Gerry Weber Int., trades with a volume of € 25,000 can almost always be executed, but € 100,000 trades can only be executed 21.9% of the time.[9]

The large differences with respect to market capitalization and trading volume documented in Table 1 suggest large differences in execution costs. This conjecture is confirmed by the data. The quoted half-spread ranges from 6.1 basis points for DaimlerChrysler to 83.8 basis points for Zapf Creation. Overall, liquidity appears to be reasonably high. For the 8 most liquid sample stocks, the roundtrip cost for a trade with a volume of € 1 million is less than 1%.

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8 Our data set contains values for XLM(V) only if the book is deep enough to allow for a trade of size V on both sides of the market. Therefore, the availability measures for buyer- and seller-initiated trades are equal.

9 In two cases (CON, XLM(1000) for seller-initiated trades and ZPF, XLM(100) also for seller-initiated trades) the XLM measure decreases with trade size. This is explained by a sharp decrease in availability. Take ZPF as an example. Seller-initiated trades of € 25,000 can always be accommodated, and the one-sided transaction cost is 213 basis points. Trades of € 100,000 can only be executed 34.7% of the time. Conditional of the order book being sufficiently thick to accommodate the larger trade, the transaction cost is only 209 basis points. In principle, this might introduce a selection bias into our analysis. However, most of our analysis focuses on order sizes for which availability is 100%. In these cases, the problem does not arise.

There are differences in the slope of the order book. Define, for the DAX stocks, the slope as the ratio of the XLM(1000) and the quoted spread. This ratio is 4.97 for the DAX stock with the highest market capitalization and 12.05 for the stock with the lowest market capitalization. The correlation between the slope measure and the log of market capitalization is -0.86. The picture for the non-DAX stocks is similar. Using the XLM(100) rather than the XLM(1000) to calculate the slope measure, we obtain a correlation of -0.78. These results indicate that stocks with higher spreads also have lower depth.

Execution costs for buyer-initiated and seller-initiated trades are not different from each other. In 33 cases (out of a total of 73 shown in the table), the XLM measure for a purchase is lower, in 40 cases it is higher. A cross-sectional test for the equality of either the mean or the median yields no significant result. This finding is surprising in the light of the existing literature. Irvine et al. (2000) report that depth on the ask side of the limit order book of the Toronto Stock Exchange is higher than the depth on the bid side. Similarly, Chordia et al. (2002) find that, on average, there are more market buy orders than market sell orders on the NYSE. As this imbalance has to be absorbed by the limit order book, their results also suggest higher depth on the ask side of the book.

Table 3 takes a closer look at the determinants of the execution cost measures (the quoted spread, XLM(25), XLM(50) and XLM(100)) in the cross-section. We use the log of market capitalization, the turnover ratio (defined as the ratio of trading volume and market capitalization), the inverse of the price (in order to account for the fixed minimum tick size) and the standard deviation of returns as independent variables. Univariate analysis reveals that all four measures of execution costs are significantly negatively related to market capitalization and turnover, and positively related to the inverse of the price. The correlation with the standard deviation of returns has the expected positive sign in all four cases but is never significant, possibly due to the low number of observations (21 in the cross-section). In a multivariate analysis the four independent variables explain a large part of the cross-sectional differences of the liquidity measures, as is evidenced by R^2's ranging from 0.59 to 0.86.[10]

Insert Table 3 about here

Figure 1 shows the intraday pattern of the quoted spread, the XLM(100) and the XLM(1000) measure for the DAX stocks. In a first step, we average over the 22 daily observations we have for each stock. In the second step, we average over the 12 DAX stocks in our sample. Each point in the figure thus represents an average over 22*12 observations.

The intraday patterns for the three liquidity measures are very similar. This is also evidenced by very high correlations (between 0.954 and 0.991).[11] Overall, there is a very pronounced u-shaped pattern. Liquidity increases during the first hours of the trading day. It then stays more or less constant but decreases sharply after the intraday call auction at 5.30 p.m. The reason for this sharp decrease is that many institutional investors close their books at 5.30 p.m.

Two further points deserve mentioning. First, there appear to be temporary drops in liquidity at 2.30 p.m. and before 4 p.m. This is likely to be due to the start of trading in the US (index futures trading in Chicago starts at 2.20 p.m. and the NYSE opens at 3.30 p.m. Central European Time).[12] Second, liquidity for large trades (i.e., the XLM(1000) measure) is very high immediately after the two intraday auctions at 1 p.m. and 5.30 p.m. This effect is caused by large limit orders that were submitted to the auction but have not been executed because the limit was slightly above or below the resulting market clearing price. The increase in liquidity

[10] We do not report the coefficient estimates of the multivariate regressions because of the presence of severe multicollinearity.

[11] Despite the high correlation between the quoted spread and the XLM measure, it has been documented in previous research that the liquidity beyond the best quotes has additional information content (e.g. Beltran-Lopez et al. 2009, Cao et al. 2009).

[12] For an analysis of the impact of the market opening in the US on trading in Europe, see Harju and Hussain (2011).

is short-lived, however, because these orders are either executed or cancelled. We do not observe a similar pattern for the quoted spread or the XLM(100) measure.

Insert Figure 1 about here

Figure 2 shows the intraday pattern for the non-DAX stocks. Given the lower overall liquidity of these stocks, we choose to depict the quoted spread, the XLM(25) and the XLM(50) measures. Again, there is a pronounced u-shaped pattern and a high degree of similarity between the three liquidity measures (correlations are between 0.972 and 0.988). Apparently the non-DAX stocks are hardly affected by the opening of the US markets, probably because they tend to have a domestic shareholder basis and are not targeted by international investors to the same extent as the DAX stocks. We neither observe a spike at 2:30 p.m., nor do we observe a decrease in liquidity prior to 4 p.m.

Insert Figure 2 about here

4 Dynamic analysis

In this section we investigate into the dynamics of liquidity. To this end, we analyze both the immediate effect and the adjustment path after a shock adversely affecting liquidity. This requires the identification of liquidity shocks. We propose two complementary approaches. First, we analyze the impact of large trades on liquidity. These trades are events that are endogenous, i.e., they originate in the very market we are analyzing. Second, we analyze the impact that company news reported by Bloomberg have on liquidity. Although such news items may occasionally be anticipated by the market, they do not originate in the market. We therefore consider these events to be exogenous.

4.1 Endogenous events: large trades

A large trade consumes liquidity and therefore adversely affects liquidity as measured by the XLM measure. The size of the shock is directly related to the trade size. It is therefore important how we define a "large" transaction. We decided to select the 100 largest trades in each stock with the additional provision that the order triggering the trade must have a volume of at least € 20,000.[13] The latter requirement is a binding restriction only for the three least liquid stocks in the sample. For these stocks, the sample consists of less than 100 observations. The total number of observations is 1,894 (1,200 for the 12 DAX stocks and 694 for the 9 non-DAX stocks).

These large transactions are not evenly distributed over the trading day. Figure 3 shows a kernel density plot of the transaction times. The distribution is double-peaked. The first peak is observed in the morning, at about 10 a.m., the second in the afternoon at about 4:30 p.m.

Insert Figure 3 about here

The number of observations that we include in our analysis is reduced by additional requirements. We require a complete series of XLM(V) observations during an event window which extends from 15 minutes prior to the large trade until 16 minutes after the trade. We therefore exclude transactions that occur in the first 15 minutes and the last 16 minutes of the continuous trading session. We further exclude transactions that occur within 15 minutes before and 16 minutes after the two intraday call auctions.

[13] These criteria are, admittedly, somewhat arbitrary. At first sight, an alternative is to select the x% largest trades for each stock. However, given the extreme differences in the number of trades for the sample stocks (see the figures on trading volume in Table 1), this would result in very different numbers of observations and, as a consequence, the results would be dominated by the largest sample stocks. We therefore decided to use equal numbers of observations.

The final sample consists of 955 large trades for the DAX stocks (483 buyer-initiated trades with an average order size of € 899,402 and 472 seller-initiated trades with an average order size of € 866,337) and 547 large trades for the non-DAX stocks (258 buyer-initiated trades with an average order size of € 133,949 and 289 seller-initiated trades with an average order size of € 127,920).

In order to analyze the impact of the large trades on liquidity and the resiliency of the market we employ an event study approach. We define t_0 to be the observation immediately prior to the large trade. The impact of the large trade (or, put differently, the size of the liquidity shock) is measured by the change in liquidity from t_0 to t_1. Note that we are likely to understate the size of the liquidity shock. This is because our observation frequency is one minute. If a large trade occurs at 9:50:30 and our next observation for the liquidity measure is at 9:51:00, we understate the impact of the transaction when new limit orders have been submitted during the 30 second delay. Given that there is a constant flow of small limit orders (at least for active stocks), such an understatement is quite likely. Note, however, that these limit orders are unlikely to be submitted in direct response to the liquidity shock because traders will need some time to observe the large trade, decide whether to submit an order and to enter the order into the system[14].

For the DAX stocks we report results for the quoted spread, XLM(100) and XLM(1000). For the less liquid non-DAX stocks we report results for the quoted spread, XLM(25) and XLM(100). For both groups of stocks we report aggregated results for all large transactions and separate results for buyer-initiated and seller-initiated transactions. For buyer-initiated and seller-initiated transactions we report the impact on liquidity separately for both sides of

[14] This obviously has changed due to the increased usage of Algorithmic Trading. However, Algorithmic Trading on Xetra was not existent in 2002 yet and started to become relevant from 2003 (source: Deutsche Börse AG, Preliminary Results Q4 und FY 2007).

the book, e.g., we report $XLM_B(100)$ and $XLM_S(100)$ separately instead of only reporting XLM(100). This allows us to analyze whether large market buy orders affect liquidity only on the ask side or also on the bid side (and vice versa for large market sell orders). The price pressure exerted by a large market buy order decreases the probability that a limit buy order in the book will execute. This is particularly true for limit orders away from the best quote. If such orders are replaced with more aggressively priced limit orders, liquidity on the bid side may improve. If they are replaced with market orders, on the other hand, liquidity on the bid side may decrease.[15]

The results are presented in Table 4. Panel A shows the results for the DAX stocks, Panel B those for the non-DAX stocks. The size of the liquidity shocks and the corresponding t-statistics are depicted in the column labeled “0;1”. The unit of measurement is basis points. All values are positive and statistically different from zero. This is no surprise because, by definition, large trades will negatively affect liquidity.

The increase in the liquidity measure is positively related to the transaction volume *V* the liquidity measure corresponds to. Take, as an example, the DAX stocks in Panel A. The quoted spread increases by 3.45 basis points, the XLM(100) by 5.71 basis points and the XLM(1000) by 21.82 basis points. A similar picture emerges when considering only buyer-initiated or only seller-initiated trades in DAX stocks.

There are two (not mutually exclusive) explanations for this pattern. First, as already noted, there may be a flow of (predominantly small) limit orders that reduce the spread but, because of their small volume, have little impact on the XLM measure for large *V*. The second explanation lies in the shape of the order book. If the slope of the book (i.e., the bid volume and ask

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15 Some limit order traders may need to execute their trade within a specified period. When (due to price pressure) the probability that their limit orders execute decreases, they may choose to use market orders instead (Handa and Schwartz 1996, see also Ahn et al. 2001).

volume at each tick) was constant, the size of the shock should be identical for all three measures. The slope of the book is, however, not constant. Rather, the quantity bid or offered is lower for prices which are further away from the midpoint.[16] Therefore, the size of the liquidity shock as measured by the change in XLM(*V*) is increasing in *V*.

Insert Table 4 about here

In a resilient market, liquidity quickly reverts to its pre-shock levels. We therefore expect to see negative changes in the liquidity measures in the minutes after the large transaction. Table 4 reports the changes from minute 1 to 2, from 2 to 3, from 3 to 4, and from 4 to 5. With only two exceptions, all values until minute 3 are negative, confirming the expectation that liquidity increases in the minutes after the shock.

Resiliency appears to be higher for smaller values of *V*. Define the reversion rate as the fraction of the initial shock that is undone until minute *t*. Considering the DAX stocks first, we find that for the quoted spread and the XLM(100), the reversion rate until minute 3 is about 50%. For the XLM(1000) this reversion rate is only about 15%. The picture for the non-DAX stocks is similar. The reversion rate is about 50% for the quoted spread and the XLM(25), but only about 33% for the XLM(100). This implies that it takes longer to restore large depth than to restore a small spread. It also implies that considering the XLM measure for different trade sizes rather than only the quoted spread adds information.

The results so far suggest that liquidity recovers after a shock. But does it really revert to its pre-shock level? The results in the columns labeled 0;3 and 0;16 suggest that it does not. Figures in these columns measure the cumulative change in liquidity from its pre-shock level

16 The $XLM_s(1000)$ for the DAX stocks (i.e., the cost for a sell order of volume € 1,000,000) is, on average, 39.6 basis points. The additional cost incurred when increasing the transaction size by € one million are 42.0 basis point for the second million, 51.2 for the third, 63.3 for the fourth and 63.9 basis points for the fifth million. Results for buy orders are very similar.

until minute 3 and 16, respectively. In almost all cases there is a significant positive change. When considering buy and sell orders separately, we observe that the cumulative change in liquidity is more pronounced on the side of the book where the trade occurred. Taken at face value, these results would imply that a large trade triggers a permanent liquidity decrease.

However, this interpretation neglects the fact that the timing of a large transaction is not random. Traders may submit their orders in times of unusually high liquidity. In this case, we should not expect liquidity to revert to its pre-shock level. It should instead revert to its "normal" level. We choose liquidity at time -15 (i.e., 15 minutes prior to the large trade) as a representative for the "normal" level of liquidity. The first column in Table 4, labeled -15;0, measures the change in liquidity from time -15 until immediately prior to the large trade. For the DAX stocks this change is significantly negative for all values of *V*. Considering buyer-initiated trades and seller initiated trades separately, we find that liquidity increases predominantly on the side of the market where the trade is to be made. For the non-DAX stocks we also find that liquidity changes are negative for all values of *V*. However, the change is significantly different from zero only for the largest order size, $V = 100$. The result that liquidity increases predominantly on the side of the book where the trade is to be made holds for buyer-initiated trades but not for seller-initiated trades.

These results allow the conclusion that large transactions are timed. They take place when liquidity is unusually high.[17] What is relevant here is, of course, the liquidity for large trades. Therefore, the fact that, for the non-DAX stocks, we only have a significant result for the largest order size category does not contradict our conclusion.

The last column in Table 4 measures the change in liquidity from 15 minutes prior to the large trade until 16 minutes after the event. For the DAX stocks this change is insignificant for all

[17] Degryse et al. (2005) report a similar finding. Their analysis is based on the quoted spread rather than on a XLM(V)-type measure.

values of V. This indicates that liquidity, although not reverting to its pre-shock level, *does* revert to its normal level. For the non-DAX stocks we obtain a similar result for the large order size category, V=100. For the smaller order size categories, particularly for the quoted spread, there appears to be some evidence of a permanent decrease in liquidity. A possible explanation for this result is that the increase in liquidity prior to a large trade extends over more than 15 minutes. In this case, the XLM measure 15 minutes prior to the large trade may not correspond to a "normal" level of liquidity but rather already corresponds to an above-normal degree of liquidity.

Figure 4 provides a graphical representation of the results for V = 100 for the DAX stocks. There is a pronounced increase in liquidity prior to the large trade that lasts about three minutes. The large trade (occurring between t_0 and t_1) has an immediate adverse effect on liquidity. After the shock liquidity recovers and reaches its normal level after about 4 minutes.

Insert Figure 4 about here

Figure 5 presents a similar graph for the non-DAX stocks. Here, the increase in liquidity prior to the event extends over the full 15-minute interval. Also, it takes longer for liquidity to revert to its "normal" level after the event. The differences between the DAX stocks and the non-DAX stocks are likely to be due to the fact that V = 100 represents a rather "normal" order size for DAX stocks but a very large size for the non-DAX stocks.[18]

Insert Figure 5 about here

We interpreted our results as representing evidence of the timing of large trades. However, in section 3 we have documented pronounced intraday patterns. If large trades cluster in times when liquidity is increasing, the results that we have presented may be caused by the general intraday pattern rather than by the timing of large trades. To address this concern, we repeat our analysis with time-of-day adjusted liquidity measures. To obtain these, we calculate, sepa-

[18] In fact, the picture for V = 1,000 for the DAX stocks (not shown) is very similar to Figure 5.

rately for each stock, an average liquidity measure for each minute of the trading day. The average is taken over the 22 trading days in the sample. We next subtract this average from each observation. The result is the deviation of the liquidity measure from its average at the particular minute of the trading day. This normalized measure is independent of the general intraday pattern. We repeat our event study with these normalized liquidity measures. The results are shown in Table 5.

Insert Table 5 about here

They are fully consistent with those presented before. Liquidity is negatively affected by the shock and, in the minutes immediately following the large trade, reverts. It does not, however, revert to the level immediately prior to the shock as is evidenced by the significant positive cumulative change from time 0 to times 3 and 16, respectively. We again find significant increases in liquidity in the 15 minutes preceding the large trade for the DAX stocks. As before, we observe such an increase in liquidity for the non-DAX stocks only for the XLM(100) measure. These results support the conclusion that large trades are timed.

4.2 Exogenous events: ticker news

If new information is released that is considered relevant for the valuation of a stock, the order book may be affected in several ways. First, limit orders standing in the book may be picked off by those who quickly respond to the new information. Second, limit orders may be cancelled in order to prevent being picked off. Third, traders may submit new limit orders. Although the total effect on liquidity is not clear a priori, it is more likely that the immediate effect on liquidity will be negative.

In order to test this prediction we analyze company-specific news items on the Bloomberg ticker. We proceed as follows. First, we select the news items according to the following rules:

- the company name appears in the headline,
- the news item is in either German or English,
- it is neither an obvious repetition of an earlier item, nor is it marked as an update of an earlier item,
- the news is not related to stock price movements[19] and
- the news is published during the trading hours and not within 15 minutes of an (opening, intradaily or closing) call auction.

The number of news items differs across firms. The highest number is observed for Allianz (60), the lowest for Gerry Weber Int. (1).[20] For each item we obtain the publishing time. We then proceed by applying the event study methodology described in the previous section. The results are presented in Table 6 and in Figure 6 and Figure 7.[21]

Insert Table 6 about here

Apparently, the news items do not cause a shock to the liquidity of the market. The immediate effect (shown in the column labeled 0;1) is never significant and is even negative in four cases. Given that there is no shock in the first place, it is not surprising that we do not observe an increase in liquidity after the event. There is no significant change in liquidity between minute

[19] There are frequent news items like "German stocks rise, led by Bayer, BASF ...". These items do not represent new information to traders monitoring the market and are therefore excluded.

[20] Some of the news items (e.g., earnings announcements) are scheduled. Market participants thus know that an announcement will be made, but do not know the exact contents of the announcement. The number of scheduled announcements in our sample is not sufficiently large to allow for a separate analysis.

[21] We only present the results without time-of-day adjustment. The results with adjustment are very similar.

1 and minute 5, and the cumulated effects from minute 0 to minutes 3 and 16, respectively, are also insignificant.[22]

Insert Figure 6 and Figure 7 about here

The result that the ticker news items do not have a significant impact on liquidity is surprising. In order to assess the information content of the news items, we analyze their price impact. We obtain time-stamped data on all Xetra transactions in our sample stocks. We then calculate the return over varying intervals extending from 15 minutes prior to the event until 15 minutes after the event. The analysis is complicated by the fact that we do not know whether any given news item represents positive or negative news. However, new information, be it positive or negative, will cause prices to change. We therefore analyze *absolute* log returns to test whether the Bloomberg news items are informative. A significant result indicates that the news item causes prices to change and thus contains information about the stock value. The results are shown in Table 7.

It appears that the information content of the news items is rather limited. The average absolute return from the last trade prior to the event until the first trade after the event is 0.09%. Allowing 5 [15] more minutes for prices to adjust results in an average absolute return of 0.24% [0.43%]. To put this into perspective, we also calculate absolute average returns over 5 and 15 minute periods prior to the event. They amount to 0.27% and 0.44%, respectively, and are thus *larger* than the post-event returns.

Insert Table 7 about here

These results are consistent with the Bloomberg ticker news items not having informational content. They are, however, also consistent with information reaching the market prior to the news release on Bloomberg. In this case, both the absolute returns prior to and those after the

[22] There is, however, weak evidence for a decrease in liquidity prior to the event. The cumulative change in liquidity from t_{-15} to t_0 is always positive and is significant at the 10% level in one case.

event may be above their normal levels. To shed some light on this issue we test whether the absolute returns over the event window are significantly larger than average absolute returns in non-event periods. We obtain critical values from a simple bootstrap analysis. We randomly select (with replacement) a sample of exogenous events that is equal in size to our actual sample. We retain the stock id and the exact time of day of the randomly chosen sample. However, we replace the event day by randomly choosing one of the 22 sample days. This procedure provides us with a random sample of "event" times such that the distribution of stocks and the distribution of event times are identical to those in the actual sample. We then calculate the average absolute price changes for the random sample. This procedure is repeated 1,000 times. The critical values are the 95% quantiles of the resulting distribution of average absolute returns.

Using these critical values we find that the immediate price impact (i.e., the return from the last price prior to the news release to the first transaction after the release) is not significantly different from its normal level. Absolute returns measured over 5 and 15 minute intervals prior to the publication of the Bloomberg ticker news items, however, are statistically significant. The post-event 15 minute average absolute returns are also significant whereas the post-event 5 minute returns are not.

Two conclusions follow from these results. First, the finding that pre-event average absolute returns are above their normal levels indicates that Bloomberg is not (or at least not always) the first channel through which the information reaches the market. Second, the low value of the average absolute returns implies that they are, in spite of their statistical significance, economically insignificant. This, in turn, indicates that the information content of the average Bloomberg ticker news item is small.

What do these conclusions imply for our analysis of liquidity? The finding that Bloomberg is not the first channel through which the information reaches the market indicates that the publication time is not the accurate event time. The result that the information content of the news items appears to be generally low implies that the "true" abnormal returns (i.e., those that would obtain if the exact event time was known) are also low. In the light of this it is not surprising that we did not find pronounced liquidity patterns around the publication of the news items.

5 Summary and conclusions

In this paper we present a static and dynamic analysis of the liquidity in the Xetra order book based on the Exchange Liquidity Measure, XLM(V). The calculation of the XLM is based on all orders in the limit order book. It relates the price at which a buy order, a sell order or a round trip trade of size V could be executed to the midpoint of the spread.

We obtain intraday data with a frequency of one minute for 21 stocks. As one would expect, we find pronounced cross-sectional differences. The XLM measure decreases (and liquidity thus increases) with market capitalization, trading volume and the price level. We further document a pronounced u-shaped intraday pattern. We do not find differences in the liquidity on the bid side and the ask side of the book. This is in contrast to the extant literature (e.g. Irvine et al. 2000, Chordia et al. 2002) that suggests a deeper book on the ask side.

In our dynamic analysis we investigate how liquidity reacts to shocks, and whether and how it reverts to “normal” levels after the shock. To this end we analyze two distinct sets of events: large trades (endogenous events) and Bloomberg ticker news items (exogenous events).

We find that large trades are timed. They occur when liquidity in the market is unusually high. This is evidenced by the fact that liquidity increases significantly prior to the transaction. The large trade triggers an immediate decrease in liquidity. Within 2 to 3 minutes (depending on the characteristics of the stock) liquidity reverts to its normal level. It does not, however, revert to the unusually high level immediately prior to the large trade.

The observation that large trades are timed may not appear very surprising at first sight. It does, however, have an important implication. It implies that traders initiating large trades, although being arguably less patient than limit order traders, do have the patience to delay their transaction until liquidity is high enough. Our evidence that large trades are timed also suggests that studies treating the timing of large transactions as exogenous may be misleading.

The Bloomberg ticker news items do not affect liquidity in a systematic way. Liquidity does not decrease immediately after the publication, nor does it increase in the minutes following publication. In order to shed more light on this surprising result we analyze the price impact of the news releases. The results suggest that the news items indeed have low information content and that Bloomberg is not always the first channel through which the information reaches the market. It is thus not surprising that the Bloomberg ticker news items do not have a discernible impact on liquidity.

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Table 1: Sample Stocks

name	ticker symbol	market capitalization (€ million, July 31, 2002)	trading volume (Xetra, € million, Aug. 2002)	XLM range 1,000 €
Deutsche Telekom	DTE	48,747	4,795.6	25 - 5,000
Siemens	SIE	44,961	5,616.5	25 - 5,000
DaimlerChrysler	DCX	44,417	4,740.4	25 - 5,000
Deutsche Bank	DBK	36,126	5,695.1	25 - 5,000
Allianz	ALV	35,306	6,327.4	25 - 5,000
E.ON	EOA	34,565	3,229.9	25 - 5,000
Münchener Rückversicherung	MUV2	34,541	4,046.9	25 - 5,000
BASF	BAS	22,753	2,681.8	25 - 5,000
RWE	RWE	18,832	1,438.3	25 - 5,000
Bayer	BAY	18,405	1,969.2	25 - 5,000
Volkswagen	VOW	16,569	1,792.7	25 - 5,000
Bayerische Hypo- und Vereinsbank	HVM	10,913	1,008.9	25 - 5,000
Altana	ALT	7,065	313.0	10 - 1,000
Merck	MRK	3,371	43.3	10 - 750
Karstadt	KAR	2,756	122.7	10 - 1,000
Continental	CON	2,285	95.2	10 - 1,000
Fraport	FRA	1,940	31.0	10 - 250
Hugo Boss Vz.	BOS3	728	32.0	10 - 250
Gildemeister	GIL	235	3.3	10 - 150
Zapf Creation	ZPF	200	3.6	10 - 150
Gerry Weber Int.	GWI	194	1.7	10 - 100

The table shows descriptive statistics for the stocks in the sample. The last column indicates the smallest and the largest order sizes for which our data set contains the XLM measure. Intermediate order sizes are

- for stocks with range 25,000 - 5,000,000: 50,000, 100,000, 250,000, 500,000, 1,000,000, 2,000,000, 3,000,000 and 4,000,000
- for all other stocks: 25,000, 50,000, 75,000, 100,000, 150,000, 250,000, 500,000, 750,000 and 1,000,000 (up to the stock specific maximum size given in the table).

Table 2: Descriptive Statistics for the XLM Measure

Panel A: DAX stocks

Stock	LP (half spread)	€ 25,000		€ 100,000		€ 500,000		€ 1,000,000	
		buy	sell	buy	sell	buy	sell	buy	sell
DTE	8.64	9.99 100	10.15 100	13.48 100	13.23 100	27.95 100	27.04 100	43.51 100	42.40 100
SIE	7.64	8.60 100	8.74 100	11.19 100	11.31 100	23.18 100	22.43 100	36.81 100	35.13 100
DCX	6.07	6.91 100	7.98 100	9.31 100	11.29 100	21.07 100	21.99 100	34.66 100	34.35 100
DBK	7.19	7.88 100	7.85 100	10.07 100	9.78 100	19.90 100	18.16 100	30.36 100	28.13 100
ALV	8.59	9.51 100	9.87 100	12.14 100	12.98 100	24.94 100	26.07 100	40.08 100	41.76 100
EOA	7.85	8.71 100	8.58 100	11.10 100	10.93 100	22.86 100	21.94 100	36.12 100	35.26 100
MUV2	8.81	9.66 100	9.83 100	14.75 100	12.58 100	28.40 100	24.48 100	44.28 100	40.67 100
BAS	8.24	9.51 100	9.48 100	12.91 100	12.98 100	28.72 100	29.58 100	47.42 100	50.52 100
RWE	9.61	11.16 100	11.00 100	16.01 100	15.32 100	41.85 100	39.65 100	71.29 100	66.50 100
BAY	10.67	12.76 100	13.33 100	18.89 100	19.96 100	47.24 100	49.03 100	81.48 100	86.47 100
VOW	9.65	11.21 100	11.31 100	15.73 100	15.56 100	36.83 100	37.86 100	60.51 100	66.84 100
HVM	14.02	18.17 100	18.34 100	29.55 100	29.17 100	91.93 100	88.84 100	174.42 100	163.39 100

Panel B: Non-DAX stocks

Stock	LP (half spread)	€ 25,000		€ 100,000		€ 500,000		€ 1,000,000	
		buy	sell	buy	sell	buy	sell	buy	sell
ALT	17.22	20.07 100	21.24 100	29.18 100	31.57 100	73.86 100	101.85 100	145.20 98.7	297.15 98.7
MRK	30.61	38.10 100	39.02 100	64.70 100	67.26 100	421.78 99.8	467.79 99.8	na	na
KAR	26.12	31.19 100	31.55 100	48.55 100	47.23 100	206.73 99.5	152.54 99.5	508.78 68.9	244.10 68.9
CON	24.12	29.83 100	29.65 100	49.06 100	49.47 100	169.51 75.0	157.06 75.0	395.95 20.5	145.37 20.5
FRA	31.86	41.18 100	39.54 100	64.21 99.9	59.45 100	na	na	na	na
BOS3	32.23	44.24 100	43.64 100	90.82 99.1	76.95 99.1	na	na	na	na
GIL	56.19	110.20 99.5	110.99 99.5	494.97 96.8	328.4 96.8	na	na	na	na
ZPF	83.78	240.62 100	213.32 100	371.96 34.7	208.66 34.7	na	na	na	na
GWI	74.13	128.53 99.2	129.58 99.2	514.73 21.9	159.82 21.9	na	na	na	na

The table shows descriptive statistics for the XLM measure. The first column identifies the stock. The second column reports the liquidity premium (= the average quoted half-spread). The remaining columns report the XLM measure, separately for buyer- and seller-initiated transactions, for the order size reported in the first row. There are two entries in each cell. The upper figure reports the average XLM measure in basis points. The lower figure reports the availability, defined as the percentage of cases in which the order book was deep enough to allow immediate execution of an order of the size given in the first line. “na” indicates that our data set does not contain the XLM measure for the respective order size (see the description of the order size grids in Table 1).

Table 3: Determinants of the XLM Measure

	log(cap)	turnover ratio	1 / price	Standard deviation	adjusted R^2 of multi-variate regression
Quoted spread	-0.935*	-0.755*	0.680*	0.111	0.86
XLM(25)	-0.834*	-0.625*	0.549*	0.131	0.67
XLM(50)	-0.788*	-0.572*	0.503*	0.134	0.59
XLM(100)	-0.857*	-0.639*	0.780*	0.078	0.79

The table shows bivariate correlations between the variables in the first column and the first row. The log of market capitalization and turnover are calculated from the data provided in Table 1. The inverse of the price and the standard deviation of returns are calculated from daily closing prices for the period December 31, 2001 through July 31, 2002. An asterisk indicates significance at the 5% level. The last column shows the R^2 of a cross-sectional regression of the liquidity measure indicated in the first column on the independent variables listed in the first row.

Table 4: Event study results - large transactions

Panel A: DAX stocks

	-15;0	0;1	1;2	2;3	3;4	4;5	0;3	0;16	-15;16
all trades									
quoted spread	-1.089*	3.454*	-1.329*	-0.485	-0.084	-0.425	1.640*	0.781	-0.308
	2.51	8.08	3.22	1.37	0.25	1.28	4.00	1.94	0.75
XLM(100)	-2.679*	5.712*	-2.132*	-0.700	0.064	-0.657	2.880*	2.196*	-0.482
	5.28	11.50	4.32	1.59	0.16	1.70	5.92	4.403	1.03
XLM(1000)	-15.26*	21.82*	-2.387*	-0.863	-1.450	-0.813	18.57*	14.02*	-1.232
	9.20	14.08	1.98	0.83	1.52	0.90	11.34	8.44	0.70
buyer-initiated trades	-15;0	0;1	1;2	2;3	3;4	4;5	0;3	0;16	-15;16
half spread	-0.627*	1.606*	-0.719*	-0.047	0.095	-0.047	1.841*	0.383	-0.244
	2.24	5.57	2.54	0.20	0.39	0.21	3.22	1.41	0.83
XLM_B(100)	-2.728*	3.034*	-0.860*	-0.410	0.608	-0.381	1.764*	1.696*	-1.032*
	6.73	7.42	2.15	1.16	1.75	1.08	4.36	4.10	2.39
XLM_S(100)	-0.396	2.371*	-1.345*	-0.322	-0.090	0.140	0.705	0.967*	0.571
	1.01	5.47	3.20	0.95	0.25	0.42	1.89	2.26	1.38
XLM_B(1000)	-16.13*	14.144*	-0.272	-1.576	1.142	0.639	12.296*	13.730*	-2.395
	10.34	8.72	0.22	1.46	1.33	0.66	6.55	7.90	1.49
XLM_S(1000)	-3.671*	5.693*	-0.891	-0.217	-1.634	-0.875	4.585*	4.125*	0.454
	2.01	5.08	0.89	0.26	1.47	0.97	3.64	2.56	0.26
seller-initiated trades	-15;0	0;1	1;2	2;3	3;4	4;5	0;3	0;16	-15;16
half spread	-0.461	1.851*	-0.608*	-0.444	-0.182	-0.382	0.799*	0.399	-0.062
	1.39	5.85	2.02	1.66	0.75	1.54	2.52	1.334	0.21
XLM_B(100)	-0.591	2.766*	-0.964*	-0.634	-0.456	-0.145	1.168*	-0.032	-0.624
	1.18	6.54	2.02	1.26	1.09	0.37	2.44	0.07	1.50
XLM_S(100)	-1.633*	3.258*	-1.093*	-0.033	0.056	-0.938*	2.132*	1.753*	0.120
	3.81	7.19	2.51	0.09	0.16	2.84	5.29	4.12	0.28
XLM_S(1000)	0.217	8.045*	-1.112	-0.313	-1.135	0.716	6.620*	0.497	0.715
	0.13	6.33	0.97	0.36	1.27	0.88	4.31	0.33	0.46
XLM_S(1000)	-10.84*	15.806*	-2.525*	0.399	-1.294	-2.118*	13.680*	9.614*	-1.222
	6.59	9.79	2.23	0.33	1.17	2.30	9.01	6.00	0.70

Table 4 (contd.)

Panel B: Non-DAX stocks

all trades

	-15;0	0;1	1;2	2;3	3;4	4;5	0;3	0;16	-15;16
quoted spread	-0.897	19.72*	-6.848*	-2.927*	-2.487*	0.328	9.945*	7.057*	6.160*
	0.34	8.15	2.86	3.06	3.30	0.40	4.02	2.29	2.20
XLM(25)	-4.981	38.61*	-15.98*	-3.379*	-1.686	1.113	19.25*	14.41*	9.431
	1.14	5.236	2.55	2.36	1.80	0.601	3.13	2.31	1.75
XLM(100)	-17.43*	40.82*	-8.639*	-4.960*	-1.293	-2.355*	27.22*	18.10*	0.665
	4.46	9.89	3.94	2.03	0.96	2.06	7.37	5.13	0.14

buyer-initiated trades

	-15;0	0;1	1;2	2;3	3;4	4;5	0;3	0;16	-15;16
half spread	-1.490	9.229*	-2.004*	-1.601*	-1.571*	-0.103	5.624*	3.621*	2.131
	1.29	7.12	2.38	2.32	2.75	0.18	4.24	2.62	1.64
$XLM_B(25)$	-4.416*	21.391*	-3.611*	-2.242	-0.862	0.096	15.538*	10.964*	6.548
	2.50	4.02	2.39	1.85	0.69	0.15	3.55	2.56	1.58
$XLM_S(25)$	-3.098*	7.691*	-2.083*	-0.617	-0.709	-0.763	4.991*	2.234	-0.864
	1.97	4.01	2.3	0.77	0.87	1.16	2.52	1.13	0.50
$XLM_B(100)$	-9.655*	32.852*	-6.628*	1.033	-3.120	-0.791	27.257*	17.320*	7.665
	2.40	5.90	2.83	0.33	1.70	0.58	4.74	3.60	1.65
$XLM_S(100)$	-2.933	10.765*	-2.005	-1.288	0.243	-1.074	7.472*	2.671	-0.262
	1.50	5.74	1.58	1.10	0.18	1.30	4.16	1.28	0.12

seller-initiated trades

	-15;0	0;1	1;2	2;3	3;4	4;5	0;3	0;16	-15;16
half spread	0.481	10.423*	-4.692*	-1.340*	-0.951	0.403	4.391*	3.446	3.927
	0.21	5.27	2.19	2.02	1.91	0.67	2.17	1.31	1.65
$XLM_B(25)$	-2.113	16.367*	-7.318*	-1.041	-0.500	0.229	8.008	8.771	6.658
	0.78	3.08	2.30	1.12	0.80	0.36	1.81	1.82	1.28
$XLM_S(25)$	-0.571	30.686*	-17.772	-2.784	-1.278	2.439	10.130	6.849	6.278
	0.09	2.97	1.89	1.63	1.84	0.83	1.15	0.82	1.02
$XLM_B(100)$	-11.96*	13.854*	-3.670	-6.345*	1.311	-0.269	3.839*	4.869	-7.093
	2.59	4.24	1.59	2.76	1.60	0.26	1.98	1.78	1.16
$XLM_S(100)$	-10.17*	24.261*	-4.975*	-3.171	-1.069	-2.561*	16.115*	11.399*	1.234
	4.76	7.88	2.56	1.86	1.16	2.75	6.86	4.45	0.44

The table shows the results of an intraday event study. For each stock we identify the 100 largest transactions during the sample period. As a second criterion, we only include transactions triggered by orders of a size exceeding € 20,000. The second criterion is only a binding restriction for three of the non-DAX stocks. The upper entry in each cell shows the (cumulated) change in the liquidity measure denoted in the first row over the period given in the first line. Time is measured in minutes, time 0 is the observation immediately prior to the large transaction. The lower entry in each cell shows the t-statistic. An asterisk indicates significance at the 5% level. Panel A presents results for the DAX stocks, Panel B those for the non-DAX stocks.

Table 5: Event study results - large transactions, time-of-day adjustment

Panel A: DAX stocks

all trades

	-15;0	0;1	1;2	2;3	3;4	4;5	0;3	0;16	-15;16
quoted spread	-0.712	3.477*	-1.422*	-0.391	-0.095	-0.311	1.663*	1.098*	0.386
	1.73	8.37	3.56	1.16	0.29	0.96	4.19	2.83	0.96
XLM(100)	-1.899*	5.583*	-2.085*	-0.707	0.092	-0.490	2.791*	2.649*	0.750
	3.86	11.56	4.41	1.67	0.23	1.29	5.88	5.56	1.67
XLM(1000)	-12.20*	20.87*	-2.277	-0.933	-1.234	-0.515	17.66*	14.64*	2.443
	7.67	14.06	1.95	0.93	1.32	0.59	11.21	9.52	1.48

buyer-initiated trades

	-15;0	0;1	1;2	2;3	3;4	4;5	0;3	0;16	-15;16
quoted spread	-0.464	1.672*	-0.793*	0.013	0.059	0.011	0.892*	0.538*	0.074
	1.68	6.01	2.86	0.06	0.25	0.05	3.52	2.05	0.25
$XLM_B(100)$	-2.175*	3.015*	-0.966*	-0.386	0.597	-0.331	1.663*	1.761*	-0.414
	5.57	7.66	2.47	1.12	1.77	0.97	4.19	4.43	0.98
$XLM_S(100)$	-0.396	2.371*	-1.345*	-0.322	-0.090	0.140	0.705	0.967*	0.571
	1.01	5.47	3.20	0.95	0.25	0.42	1.89	2.26	1.38
$XLM_B(1000)$	-13.94*	13.631*	-0.434	-1.723	1.148	0.605	11.474*	13.257*	-0.681
	9.31	8.71	0.37	1.64	1.35	0.66	6.35	7.89	0.41
$XLM_S(1000)$	-3.671*	5.693*	-0.891	-0.217	-1.634	-0.875	4.585*	4.125*	0.454
	2.01	5.08	0.89	0.26	1.47	0.97	3.64	2.56	0.26

seller-initiated trades

	-15;0	0;1	1;2	2;3	3;4	4;5	0;3	0;16	-15;16
quoted spread	-0.245	1.806*	-0.627*	-0.408	-0.156	-0.325	0.770*	0.560	0.315
	0.80	5.84	2.17	1.61	0.67	1.35	2.51	1.95	1.15
$XLM_B(100)$	-0.189	2.757*	-1.028*	-0.576	-0.432	-0.023	1.152*	0.319	0.130
	0.38	6.62	2.23	1.18	1.04	0.06	2.49	0.72	0.32
$XLM_S(100)$	-1.633*	3.258*	-1.093*	-0.033	0.056	-0.938*	2.132*	1.753*	0.120
	3.81	7.19	2.51	0.09	0.16	2.84	5.29	4.12	0.28
$XLM_B(1000)$	1.820	7.663*	-1.223	-0.272	-0.843	0.668	6.168*	1.434	3.254*
	1.12	6.34	1.12	0.31	0.97	0.84	4.14	0.97	2.09
$XLM_S(1000)$	-10.84*	15.806*	-2.525*	0.399	-1.294	-2.118*	13.680*	9.614*	-1.222
	6.59	9.79	2.23	0.33	1.17	2.30	9.01	6.00	0.70

Table 5 (contd.)

Panel B: Non-DAX stocks

all trades

	-15;0	0;1	1;2	2;3	3;4	4;5	0;3	0;16	-15;16
quoted spread	1.387	19.13*	-6.545*	-2.543*	-2.267*	0.321	10.04*	6.794*	8.182*
	0.51	8.31	2.89	2.80	3.23	0.41	4.30	2.37	2.98
XLM(25)	-0.052	37.08*	-15.05*	3.258*	-1.128	0.887	18.77*	15.07*	15.01*
	0.01	5.29	2.53	2.37	1.29	0.50	3.27	2.54	2.91
XLM(100)	-10.37*	38.51*	-8.135*	-4.526	-1.126	-2.449*	25.85*	17.52*	7.151
	2.99	9.99	3.85	1.93	0.88	2.23	7.43	5.24	1.58

buyer-initiated trades

	-15;0	0;1	1;2	2;3	3;4	4;5	0;3	0;16	-15;16
quoted spread	-0.032	8.803*	-2.069*	-1.377*	-1.493*	0.020	5.357*	3.735*	3.703*
	0.03	7.19	2.59	2.12	2.74	0.04	4.29	2.84	2.70
$XLM_B(25)$	-1.387	20.360*	-3.437*	-1.974	-0.594	0.076	14.948*	11.252*	9.865*
	0.74	4.01	2.38	1.70	0.49	0.12	3.59	2.75	2.27
$XLM_S(25)$	-3.098*	7.691*	-2.083*	-0.617	-0.709	-0.763	4.991*	2.234	-0.864
	1.97	4.01	2.30	0.77	0.87	1.16	2.52	1.13	0.50
$XLM_B(100)$	-4.907	30.564*	-6.241*	1.009	-3.014	-0.863	25.332*	15.917*	11.010*
	1.28	6.01	2.92	0.34	1.73	0.66	4.82	3.65	2.14
$XLM_S(100)$	-2.933	10.765*	-2.005	-1.288	0.243	-1.074	7.472*	2.671*	-0.262
	1.50	5.74	1.58	1.10	0.18	1.30	4.16	1.28	0.12

seller-initiated trades

	-15;0	0;1	1;2	2;3	3;4	4;5	0;3	0;16	-15;16
quoted spread	1.344	10.250*	-4.352*	-1.176	-0.811	0.286	4.721*	3.094	4.438
	0.56	5.43	2.15	1.85	1.79	0.50	2.47	1.26	1.93
$XLM_B(25)$	0.350	16.135*	-6.843*	-1.484	-0.243	-0.045	7.807	8.510	8.860
	0.12	3.17	2.25	1.60	0.41	0.07	1.86	1.87	1.78
$XLM_S(25)$	-0.571	30.686*	-17.772	-2.784	-1.278	2.439	10.130	6.849	6.278
	0.09	2.97	1.89	1.63	1.84	0.83	1.15	0.82	1.02
$XLM_B(100)$	-8.709*	13.471*	-3.159	-6.033*	1.396	-0.328	4.279*	5.706*	-3.004
	2.25	4.33	1.45	2.7	1.73	0.32	2.25	2.07	0.57
$XLM_S(100)$	-10.17*	24.261*	-4.975*	-3.171	-1.069	-2.561*	16.115*	11.399*	1.234
	4.76	7.88	2.56	1.86	1.16	2.75	6.86	4.45	0.44

This table is similar to Table 4. The only difference is that the upper entry in each cell shows the (cumulated) change in the time-of-day adjusted liquidity measures. The adjusted measure is the difference between the liquidity measure for a given minute and the average liquidity measure for that minute. Please see the legend of Table 4 for further details.

Table 6: Event study results - ticker news

Panel A: DAX stocks

	-15;0	0;1	1;2	2;3	3;4	4;5	0;3	0;16	-15;16
quoted	1.042	-0.890	0.157	0.115	-0.314	0.261	-0.618	-0.602	0.440
spread	1.51	1.60	0.29	0.22	0.61	0.48	0.94	0.90	0.68
XLM(100)	0.287	-0.263	-0.494	0.121	0.617	0.757	-0.636	0.373	0.660
	0.39	0.40	0.78	0.19	0.98	1.27	0.86	0.46	0.75
XLM(1000)	0.353	1.446	-0.574	-0.843	-0.991	-0.016	0.029	-1.053	-0.701
	0.19	0.71	0.38	0.73	0.87	0.02	0.02	0.53	0.33

Panel B: Non-DAX stocks

	-15;0	0;1	1;2	2;3	3;4	4;5	0;3	0;16	-15;16
quoted	7.692	-1.848	2.622	2.205	-1.333	-0.723	2.979	-6.785	0.907
spread	1.55	1.41	0.85	0.70	0.53	0.36	0.75	1.28	0.18
XLM(25)	14.43	-1.807	2.644	3.548	-2.724	2.621	4.386	-6.810	7.621
	1.88	1.15	0.87	1.04	0.97	0.85	1.09	1.05	1.38
XLM(100)	10.46	0.381	3.125	1.034	-2.939	-1.404	4.539	-6.074	4.386
	1.45	0.15	1.176	0.49	1.08	0.66	1.19	0.64	0.58

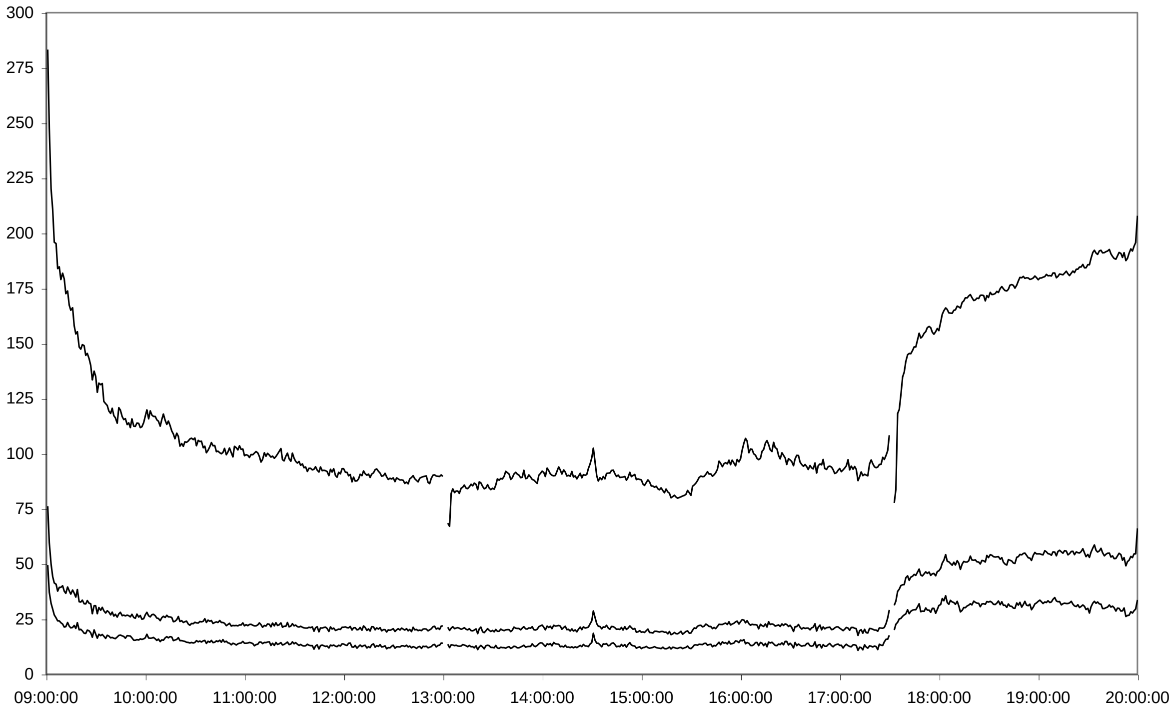
The table shows the results of an intraday event study. For each stock we identified (according to the rules outlined in the main text) company-specific news items published on the Bloomberg ticker. The upper entry in each cell shows the (cumulated) change in the liquidity measure denoted in the first row over the period given in the first line. Time is measured in minutes, time 0 is the observation immediately prior to the publishing time. The lower entry in each cell shows the t-statistic. Panel A presents results for the DAX stocks, Panel B those for the non-DAX stocks.

Table 7: Price impact of ticker news

	-15 until pre-event	-5 until pre-event	immediate (pre-event until post-event)	pre-event until +5	pre-event until +15
absolute return	0.4380	0.2688	0.0917	0.2433	0.4274
5% critical value	0.4295	0.2548	0.1116	0.2786	0.4215

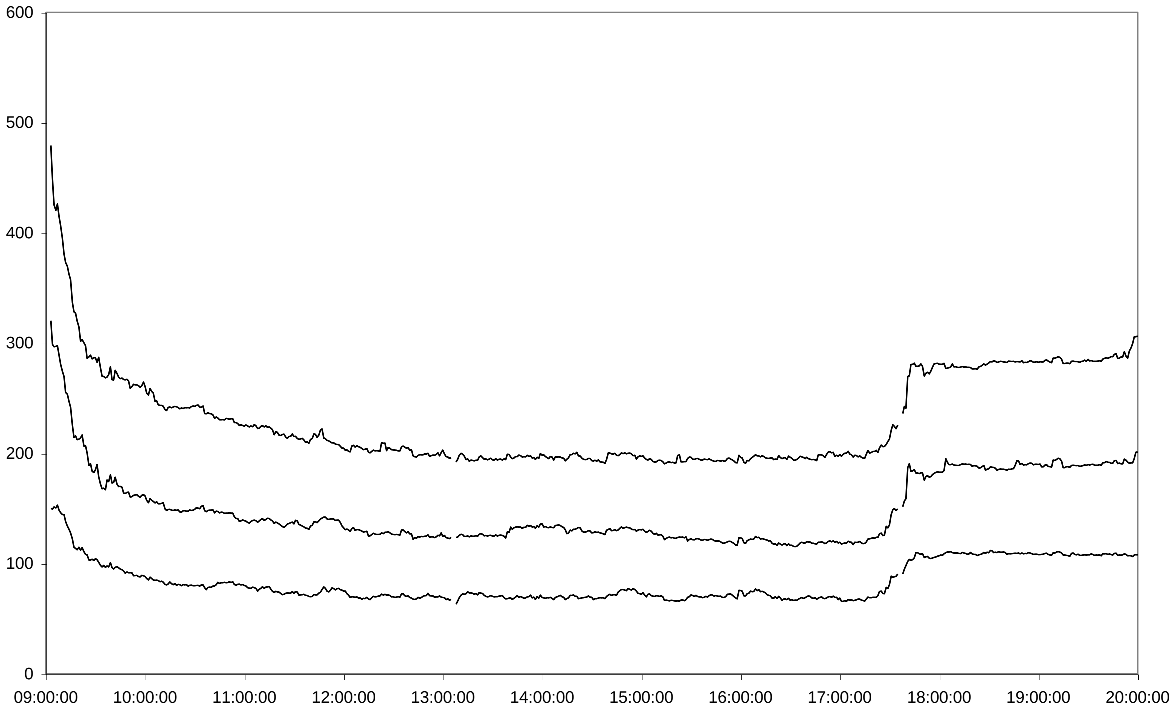
The table shows the price effect of the Bloomberg ticker news. The sample comprises 407 events. The first line shows the average absolute log return (measured in percent) for the period indicated in the headline. "Pre-event" and "post-event" refer to the last transaction prior to and the first transaction after the news event, respectively. "-15", "-5", "+5" and "+15" refer to the last transaction at least 5 [15] minutes prior to the news event and the first transaction at least 5 [15] minutes after the event, respectively. The second line shows 5% critical values (one-sided test) from the bootstrap analysis described in the text.

Figure 1: Intraday patterns, DAX stocks



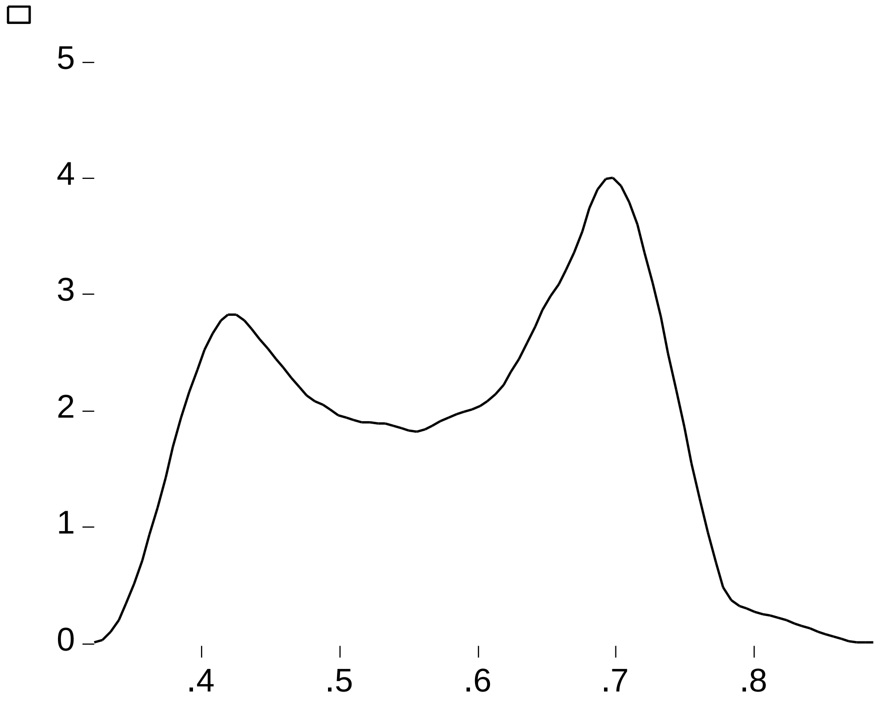
The figure reports averages of the roundtrip transaction costs at different times of the day. The averages are calculated over the 21 trading days in our sample and the 12 DAX stocks. The transaction cost measures are the liquidity premium multiplied by 2 (= the quoted spread), the XLM(100,000) and the XLM(1,000,000).

Figure 2: Intraday patterns, non-DAX stocks



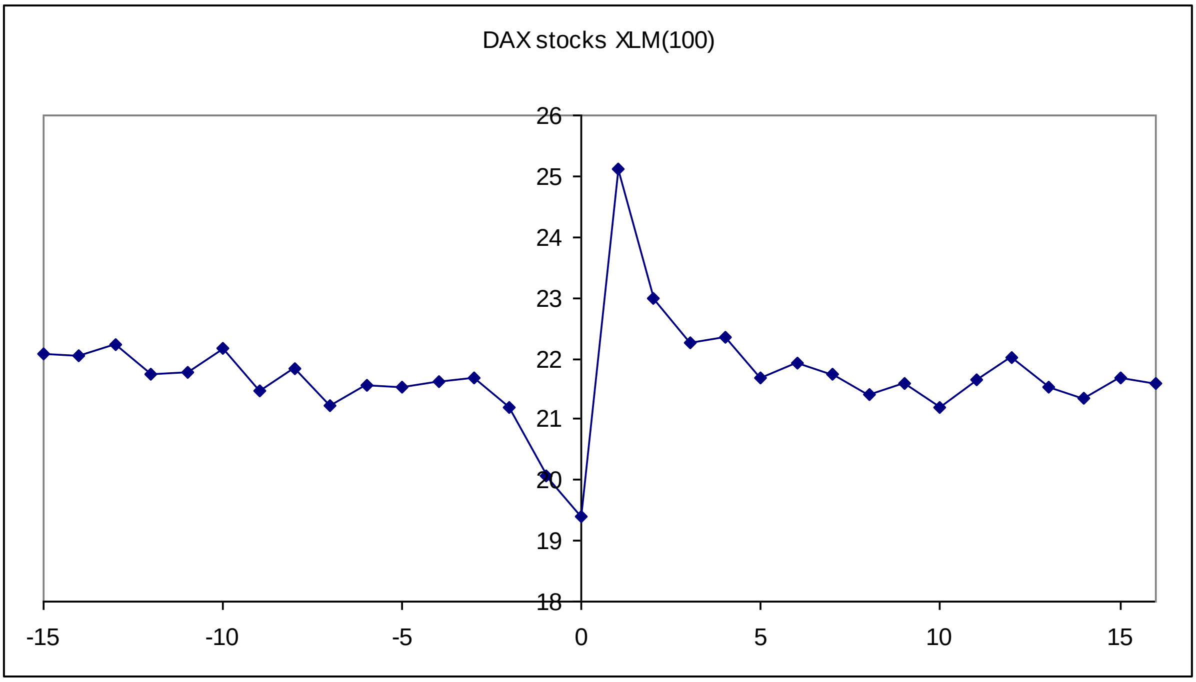
The figure reports averages of the roundtrip transaction costs at different times of the day. The averages are calculated over the 21 trading days in our sample and the 9 non-DAX stocks. The transaction cost measures are the liquidity premium multiplied by 2 (= the quoted spread), the XLM(25,000) and the XLM(50,000).

Figure 3: Distribution of the large transactions



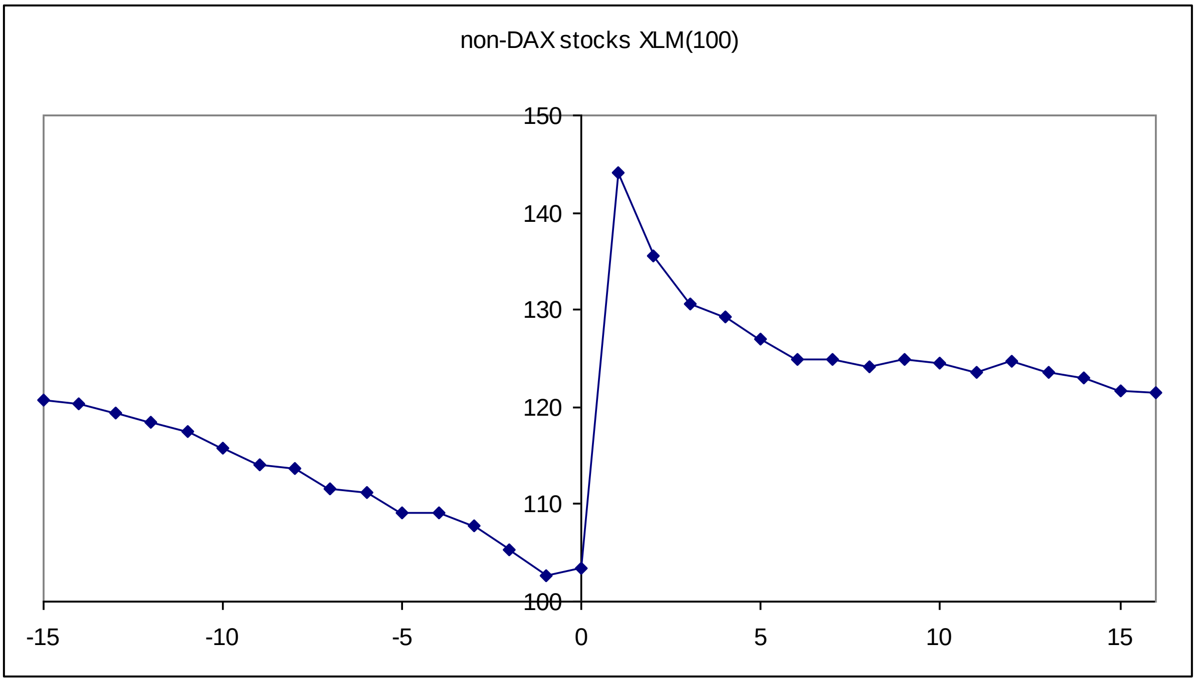
The figure presents a kernel density plot (Epanechnikov kernel, bandwidth 0.05) of the distribution of the transaction times. The horizontal axis measures the time of day. 0.4 corresponds to 9.36 a.m., 0.7 to 4.48 p.m.

Figure 4: Event study results - large transactions, DAX stocks, XLM(100)



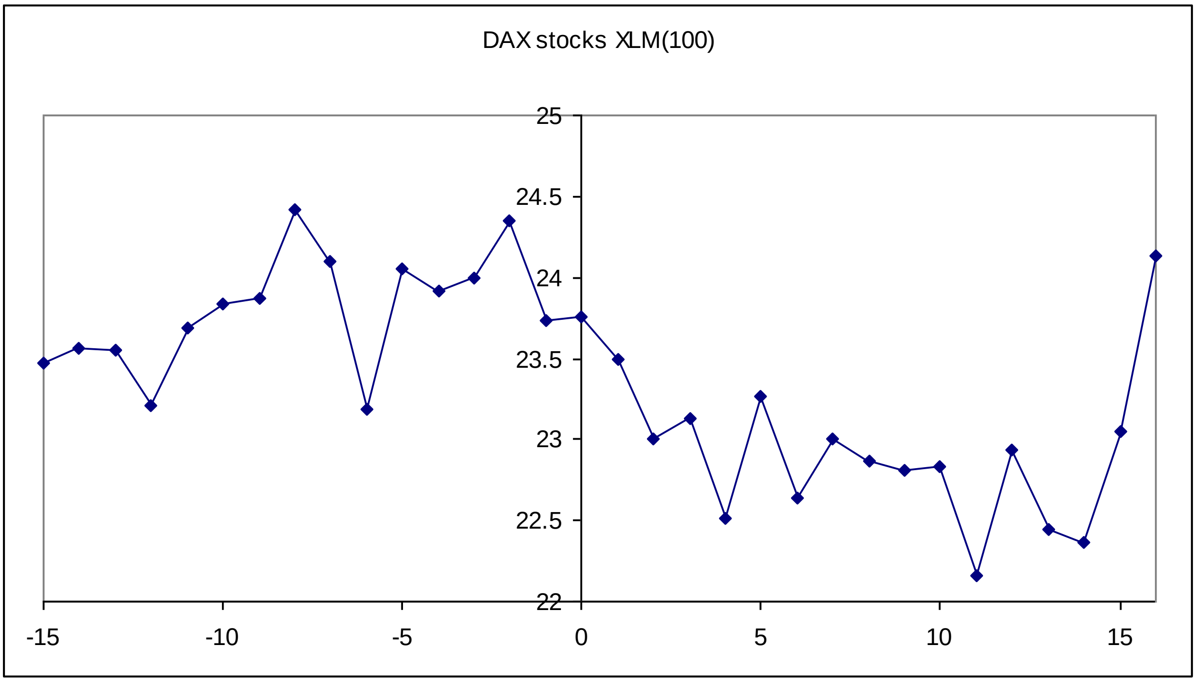
The figure presents the results of the intraday event study for the DAX stocks and the XLM(100) measure. The horizontal axis measures the time, relative to the time of the large transaction (t = 0), in minutes.

Figure 5: Event study results - large transactions, non-DAX stocks, XLM(100)



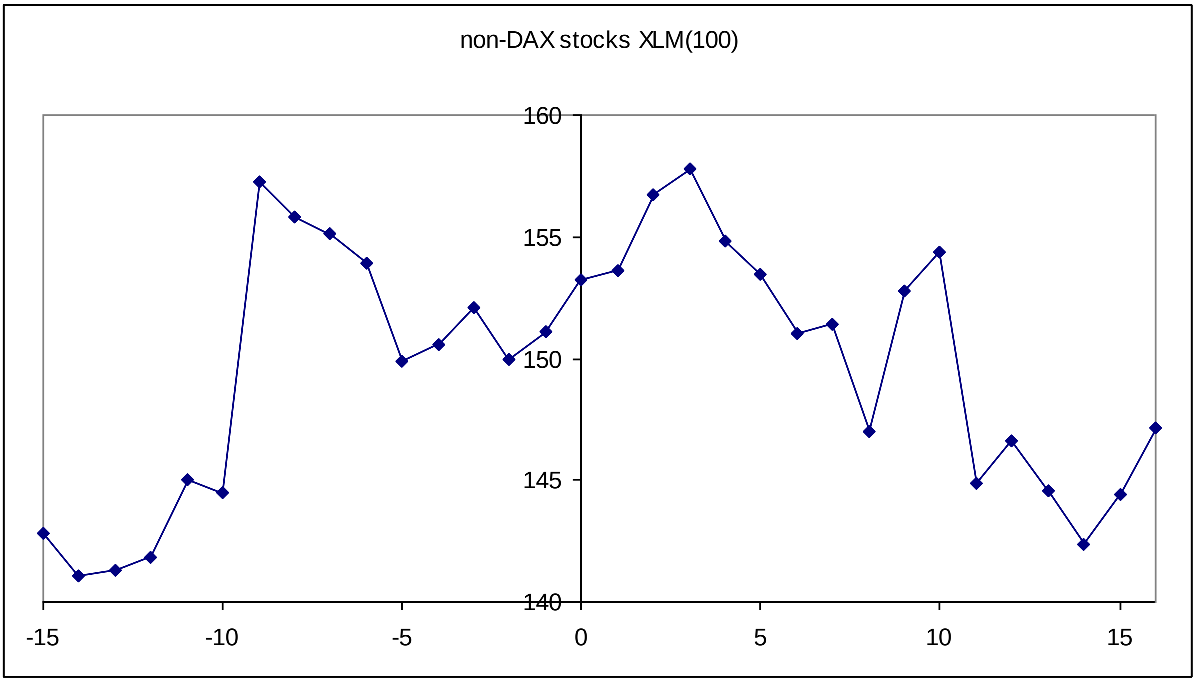
The figure presents the results of the intraday event study for the non-DAX stocks and the XLM(100) measure. The horizontal axis measures the time, relative to the time of the large transaction (t = 0), in minutes.

Figure 6: Event study results - ticker news, DAX stocks, XLM(100)



The figure presents the results of the intraday event study for the DAX stocks and the XLM(100) measure. The horizontal axis measures the time, relative to the publishing time of the news item (t = 0), in minutes.

Figure 7: Event study results - ticker news, non-DAX stocks, XLM(100)



The figure presents the results of the intraday event study for the non-DAX stocks and the XLM(100) measure. The horizontal axis measures the time, relative to the publishing time of the news item (t = 0), in minutes.

Executive Summary

It is universally recognized, both among market practitioners and among researchers, that liquidity is the most important aspect of market quality. However, liquidity definitions and measurement concepts widely differ. Moreover, the dynamics of liquidity in electronic order books are hardly investigated.

In this paper, we address the analysis of these dynamics by applying a liquidity measure, the Exchange Liquidity Measure (XLM), that is measured continuously since 2002 by Deutsche Börse AG and that was provided directly by the exchange for the analysis. XLM is based on the concept of measuring the round trip costs of a trade of a specific size relative to the current midpoint of the spread and thereby considers both spread and depth of the order book. Specifically, we investigate the impact of liquidity shocks, i.e. large trades and ticker news, on the XLM and its dynamics by applying intraday event study analysis. The paper is the first one to investigate the impact of market endogenous (large trades) and market exogenous events (ticker news) based on a unified framework. The analysis of the liquidity structure, i.e. the static analysis of the liquidity in the Xetra order book, and the analysis of the liquidity dynamics is of high relevance for traders that are responsible for order execution in agent and proprietary trading as the insights into the ability of the order book to recover and to revert to a normal level of liquidity after a shock is a key input for the decisions on order splitting and order timing.

Concerning the structure of liquidity, we find pronounced cross-sectional differences and, as expected, liquidity decreases with market cap, trading volume and price level. Although we find a distinct u-shaped intraday pattern in liquidity, differences between the depth on the bid and the ask side of the order book were not identified which is in contrast to the existing literature that identifies a deeper order book on the ask side.

Concerning the dynamics of liquidity after shocks triggered by large trades, we analyze the immediate effect and the adjustment path after the shock that consumes significant liquidity

by matching multiple limits in the order book. We find that although liquidity recovers within the first minutes of the shock to its normal level, it does not revert to the level that exists immediately before the large trade occurs. This can be explained by an unusually high level of liquidity immediately before the large trade and implies that large trades are timed. They are executed deliberately when the currently available liquidity is high relative to the average level of liquidity in that stock. This result is in contrast to the common view that aggressive orders are placed by impatient traders.

Concerning the dynamics of liquidity after shocks triggered by news (news items on the Bloomberg ticker), we test whether the net effect of (i) the execution of standing limit orders, (ii) the cancellation of standing limit orders and (iii) the insertion of new limit orders, i.e. the three possible effects after a news item release, is resulting in lower liquidity levels relative to the pre-news liquidity. We do not find news items to cause a shock to market liquidity nor does liquidity increase after the publication as no clear pattern in the applied liquidity measure can be observed. The analysis provides support that the investigated news items do have no or only low information content per se and that the analyzed news channel is not the first way the information is released to market participants.

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