Zooming in on Liquidity[*]

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Abstract: In this paper we use the Exchange Liquidity Measure (XLM) to investigate into the time dimension of liquidity. The XLM(V) measures the cost of a roundtrip trade of size V. Besides a descriptive analysis we present the results of intraday event studies. Our objective is to measure how a liquidity shock affects the XLM measure, and how long it takes for the XLM measure to revert to a "normal" level. We analyze two sets of liquidity shocks, namely, large transactions and company-specific Bloomberg ticker news items. Applying the methodology to a sample of German stocks we find that resiliency after large transactions is high, i.e., liquidity quickly reverts to "normal" levels. We further document that large transactions are "timed". The Bloomberg ticker news items do not have a discernible effect on liquidity.

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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.

Though the importance of liquidity is universally recognized, it is much less clear how liquidity is to be defined and measured. A representative definition is "An asset is liquid if it can be bought or sold immediately and without adversely affecting the price". Implicit in this definition are three dimensions of liquidity, execution cost, quantity, and time. The cost dimension measures the cost at which an order of given size can be executed. Similarly, the quantity dimension measures how large an order can be executed at a given price. The most widespread measures for the price and the quantity dimension are the quoted spread and the depth at the best bid and best ask quote. For order sizes exceeding the depth available at the best quotes, the spread does not capture the total cost of executing the order. If a limit order book (or firm market maker quotes beyond the best bid and ask) exists, the information in the book can be used to calculate the weighted average price at which an order of given size can be executed. This results in a measure which Irvine / Benston / Kandel (2000) have termed the Cost of Round Trip, CRT(D), where D indicates the order size. Barclay et al. (1999) have constructed a similar measure for the Nasdaq dealer market.

All these measures essentially ignore the time dimension of liquidity since they measure execution costs by assuming immediate execution of the order. The time dimension - also referred to as the resiliency - measures how fast liquidity reverts to "normal" levels after an adverse liquidity shock (this definition follows Foucault / Kadan / Kandel 2003[1]). The time di-

[1] Alternatively, a market can be said to be resilient when *prices* quickly revert to "normal" levels after a shock (Black 1971, Harris 1990).

mension is important for the overall liquidity of a market, and it is of particular importance for a trader contemplating to split up a large order.

Incorporating the time dimension into a liquidity measure is difficult since a dynamic measure is required. One possible approach is the "price shock approach" introduced by Holthausen / Leftwich / Mayers (1987). They decompose the price impact of large block trades into a transitory and a permanent component. This approach can easily be dynamized by analyzing how long it takes until the price reaches its post-event equilibrium level. There is, however, a problem with this approach. Block trades convey information to the market, and it is thus difficult to determine where the post-event equilibrium price level is. This is particularly true when there is over- or underreaction to the news implicit in the block transaction. Therefore, it is difficult to determine whether transaction prices differ from the true value of the stock.

In the present paper we use a more suitable approach, the "liquidity shock approach". It is based on the Exchange Liquidity Measure (XLM)[2] which is similar to the Cost of Roundtrip [CRT(D)] measure discussed by Irvine / Benston / Kandel (2000). We analyze the time path of the XLM measure after a shock adversely affecting liquidity. Besides a descriptive analysis we present the results of intraday event studies. Our objective is to measure how a liquidity shock affects the XLM measure, and how long it takes for the XLM measure to revert to a "normal" level. We analyze two sets of liquidity shocks, one being endogenous and the other exogenous to the market. The endogenous events are, in the spirit of Holthausen / Leftwich / Mayers (1987), large transactions. We use company-specific news items published by Bloomberg as exogenous events.

Our main findings can be summarized as follows. Large transactions have an immediate negative impact on liquidity as measured by the XLM measure. Within one or two minutes after

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2 See Gomber / Schweickert (2002) for a description of the XLM measure.

the transaction, liquidity partially recovers, but there appears to be a permanent effect. However, this picture changes once the XLM measure *prior to* the transaction is included in the analysis. Liquidity increases prior to the transaction. Thus, transactions take place when liquidity 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 is consistent with timing of large transactions. 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.

We do not find a clear pattern in the XLM measure around the publication of news items on the Bloomberg ticker. Neither does liquidity decrease immediately after the publication, nor does it improve in the minutes following the publication. We do, however, find weak evidence of a *de*crease in liquidity prior to publication. A possible explanation is that some of the news items may be anticipated. If it is known, for example, that a company will publish an earnings announcement at a pre-specified time, then liquidity may well decrease prior to the announcement. Alternatively, Bloomberg may not be the first channel through which the information reaches the market.

Our work is related to several recent papers. Copejans / Domowitz / Madhavan (2001) use data from a Swedish index futures contract. They find that discretionary traders trade in times of high liquidity, a finding consistent with ours. They further estimate structural VAR models to investigate the dynamics of a depth-based liquidity measure. Giot / Grammig (2002) use a CRT(D) measure to incorporate liquidity risk into Value at Risk estimates. Both Biais / Hillion / Spatt (1995) and Hedvall / Niemeyer (1997) investigate into the dynamics of liquidity by cross-tabulating sequences of events in a limit order market.

The most closely related papers are Degryse et al. (2003) and De Winne / d'Hondt (2003). Both use an approach similar to our liquidity shock approach to analyze the impact of large trades on depth and the quoted spread. Ellul (2002) investigates into the impact that large trades in foreign stocks on London's market maker market have on the home markets (France, Germany and Italy). However, he only analyzes price effects, not the impact on liquidity.

These papers all analyze the effect of large trades which, in our terminology, are endogenous events. Graham / Koski / Loewenstein (2003) build on the literature that analyzes liquidity changes around earnings and dividend announcements (e.g. Venkatesh / Chiang 1986, Lee / Mucklow / Ready 1993, Krinsky / Lee 1996). They consider anticipated and non-anticipated dividend announcements. The latter category is represented by a sample of dividend initiations, i.e., firms that announce a dividend payment for the first time in their history. Graham / Koski / Loewenstein (2003) find that liquidity (measured over 30-minute intervals) deteriorates prior to the anticipated announcements but stays at a normal level prior to surprise announcements. After the announcement the pattern is reversed. There is little decrease in liquidity after anticipated events (except for those announcements with the largest price impact). After unanticipated events, however, liquidity decreases.

Ranaldo (2003) 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. In a recent paper, Brooks / Patel / Su (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 measure for different order sizes we provide a more complete analysis of the execution cost than is obtainable by only considering spread data (as is done by Brooks / Patel / Su 2003 and Ranaldo 2003). Third, we introduce 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 usually yields 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.[3] 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.[4] There are two intraday call auctions at 1 p.m. and 5.30 p.m. Liquidity is supplied by limit order traders. For continuously traded stocks outside the blue chip index DAX, additional liquidity is supplied by designated sponsors.

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

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[3] Besides Xetra, there are the Frankfurt Stock Exchange (organized in a way similar to the NYSE) and several regional exchanges. A consolidated limit order book or a sytem similar to the Consolidated Quotation System and the Intermarket Trading System in the US does not exist.

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

equal in size to the original visible part. This procedure is repeated until the hidden part is exhausted.

The Exchange Liquidity Measure, XLM, is calculated by Deutsche Börse AG. It uses the information about all the orders in the book (including the hidden part of iceberg orders) 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 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 thick 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 provided 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(1,000) 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 buy and a sale. The lower figure reports the availability, defined as the percentage of cases in which the order book was thick enough to allow immediate execution of an order of the size given in the first row.[5]

Insert Table 2 about here

[5] Our data set contains values for XLM(V) only if the book is thick 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.

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 thick enough to always 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.

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 point for Zapf Creation.

It also appears that there are differences in the slope of the order book. Define, for the DAX stocks, the slope as the ratio of the XLM(1,000) 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(1,000) to calculate the slope measure, we obtain a correlation of -0.78. These results indicates 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.

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 (defined as the ratio of trading volume and market capitalization), the inverse of the price and the standard deviation of returns as independent variables. Univariate analyses reveal that all four measures of execution costs are 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.[6]

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 21 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 21*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). 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.[7]

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

[7] Deutsche Börse AG has reacted to the low liquidity in the evening hours by shortening the trading hours. Since November 3, 2003, trading in Xetra ends 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). Second, liquidity for large trades (i.e., the XLM(1000) measure) is very high immediately after the two intradaily 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 price was slightly above or below the resulting market clearing price. The increase in liquidity is very short-lived, however, because these orders are either executed or cancelled.

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. 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 resiliency of the market. 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. In the sequel we use two definitions. 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.

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.[8] The latter requirement is only a binding restriction 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 want to have a complete series of 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 16 minutes before and 15 minutes after the two intraday call auctions.

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8 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.

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 alternatively, 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 trades 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.

The results are presented in Table 4. Panel A shows the results for the DAX stocks, Panel B those for the non-DAX stocks. For the former group we report results for the quoted spread, XLM(100) and XLM(1000). For the latter group which consists of less liquid stocks we report results for the quoted spread, XLM(25) and XLM(100).

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 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. 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 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.[9] 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 one exception, all values until minute 4 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 liquidity premium 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 liquidity premium and the XLM(25), but only about 33% for the XLM(100).

These results 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 until

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[9] 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

minute 3 and 16, respectively. In each single case there is a significant positive change. Taken at face value, these results 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. The picture is slightly different for the non-DAX stocks. Here, figures are negative for all values of V but significantly so only for the largest order size, $V = 100$. These results allow the conclusion that large transactions are timed. They take place when liquidity is unusually high. 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 15 minutes after the event. For the DAX stocks this change is insignificant for all values of V. This indicates that liquidity, although it does not revert 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 there is some evidence of a permanent decrease in 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 min-

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basis point for the second million, 51.2 for the third, 63.3 for the fourth and 63.9 basis points for the fifth utes. 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.[10]

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. First, we calculate, separately for each firm, an average liquidity measure for each minute of the trading day. The average is taken over the 21 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

million. Results for buy orders are very similar.

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

They are consistent with those presented before. Liquidity is negatively affected by the shock and, in the minutes immediately following the large trades, reverts. It does not revert, however, 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 our conclusion that large trades are timed. The finding that there appears to be a permanent decrease in liquidity for the non-DAX stocks (at least for small values of *V*) also extends to the time-of-day adjusted analysis.

<u>Exogenous events: ticker news</u>

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 by submitting market orders. 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 seems more likely that the immediate effect on liquidity is negative.

In order to test this prediction we analyze company-specific news items on the Bloomberg ticker. We proceed as follows. First, we selected 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[11] 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). 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.[12]

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 not a single significant change in liquidity between minute 1 and minute 5, and the cumulated effects from minute 1 to minute 3 and 16, respectively, are also insignificant.

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. Although we do not want to overemphasize this result, there are two possible explanations. First, some of the news items may be anticipated. If it is known, for example, that a company will publish an earnings announcement at a pre-specified time, then liquidity may well decrease prior to the announcement. Second, Bloomberg may not be the first channel through which the information reaches the market.

Insert Figure 6 and Figure 7 about here

[11] 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.

5 Summary and Conclusions

In this paper we present a static and dynamic analysis of the liquidity in the German stock market based on the Exchange Liquidity Measure, XLM(V). The calculation of the XLM is based on all orders in the limit order book (including hidden orders). 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 mid-point of the spread.

We obtain intraday data for August 2002 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.

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).

Our most important result is 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.

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

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 after publication. What we do observe, however, is a weak tendency for liquidity to decrease prior to publication. This may be either because some of the news items are anticipated (e.g., because it is known that an announcement will be made), or because the Bloomberg ticker is not the first channel through which the information reaches the market.

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Table 1: Sample Stocks

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, and 750,000 (up to the stock specific maximum size given in the table).

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

Table 2: Descriptive Statistics for the XLM Measure

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 thick 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).

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

Table 3: Determinants of the XLM Measure

The table shows sign and significance of 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. The entries in columns 2-5 indicate:

0 no significant correlation

+ [-] positive [negative] correlation, significant at the 5% level

(+) [(-)] positive [negative] correlation, significant at the 10% level

	log(cap)	turnover	1 / price	Standard deviation	adjusted R^2 of multi-variate regression
LP	-	-	+	0	0.86
XLM(25)	-	-	+	0	0.67
XLM(50)	-	-	+	0	0.59
XLM(100)	-	-	+	0	0.79

Table 4: Event study results - large transactions

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. Panel A presents results for the DAX stocks, Panel B those for the non-DAX stocks.

Panel A: DAX stocks

	-15;0	0;1	1;2	2;3	3;4	4;5	0,3	0,16	-15,16
quoted spread	-1.089 2.51	3.454 8.08	-1.329 3.22	-0.485 1.37	-0.084 0.25	-0.425 1.28	1.640 4.00	0.781 1.94	-0.308 0.75
100	-2.679 5.28	5.712 11.50	-2.13 4.32	-0.700 1.59	0.064 0.16	-0.657 1.70	2.880 5.92	2.196 4.403	-0.482 1.03
1,000	-15.26 9.20	21.82 14.08	-2.387 1.98	-0.863 0.83	-1.450 1.52	-0.813 0.90	18.57 11.34	14.02 8.44	-1.232 0.70

Panel B: Non-DAX stocks

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

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

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.

Panel A: DAX stocks

	-15;0	0;1	1;2	2;3	3;4	4;5	0,3	0,16	-15,16
quoted spread	-0.712 1.73	3.477 8.37	-1.422 3.56	-0.391 1.16	-0.095 0.29	-0.311 0.96	1.663 4.19	1.098 2.83	0.386 0.96
100	-1.899 3.86	5.583 11.56	-2.085 4.41	-0.707 1.67	0.092 0.23	-0.490 1.29	2.791 5.88	2.649 5.56	0.750 1.67
1,000	-12.20 7.67	20.87 14.06	-2.277 1.95	-0.933 0.93	-1.234 1.32	-0.515 0.59	17.66 11.21	14.64 9.52	2.443 1.48

Panel B: Non-DAX stocks

	-15;0	0;1	1;2	2;3	3;4	4;5	0,3	0,16	-15,16
quoted spread	1.37 0.51	19.13 8.31	-6.545 2.89	-2.543 2.80	-2.267 3.23	0.321 0.41	10.04 4.30	6.794 2.37	8.182 2.98
25	-0.052 0.01	37.08 5.29	-15.05 2.53	3.258 2.37	-1.128 1.29	0.887 0.50	18.77 3.27	15.07 2.54	15.01 2.91
100	-10.37 2.99	38.51 9.99	-8.135 3.85	-4.526 1.93	-1.126 0.88	-2.449 2.23	25.85 7.43	17.52 5.24	7.15 1.58

Table 6: Event study results - ticker news

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.

Panel A: DAX stocks

	-15;0	0;1	1;2	2;3	3;4	4;5	0,3	0,16	-15,16
quoted spread	1.042 1.51	-0.890 1.60	0.157 0.29	0.115 0.22	-0.314 0.61	0.261 0.48	-0.618 0.94	-0.602 0.90	0.440 0.68
100	0.287 0.39	-0.263 0.40	-0.494 0.78	0.121 0.19	0.617 0.98	0.757 1.27	-0.636 0.86	0.373 0.46	0.660 0.75
1,000	0.353 0.19	1.446 0.71	-0.574 0.38	-0.843 0.73	-0.991 0.87	-0.016 0.02	0.029 0.02	-1.053 0.53	-0.701 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 spread	7.692 1.55	-1.848 1.41	2.622 0.85	2.205 0.70	-1.333 0.53	-0.723 0.36	2.979 0.75	-6.785 1.28	0.907 0.18
25	14.43 1.88	-1.807 1.15	2.644 0.87	3.548 1.04	-2.724 0.97	2.621 0.85	4.386 1.09	-6.810 1.05	7.621 1.38
100	10.46 1.45	0.381 0.15	3.125 1.176	1.034 0.49	-2.939 1.08	-1.404 0.66	4.539 1.19	-6.074 0.64	4.386 0.58

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).

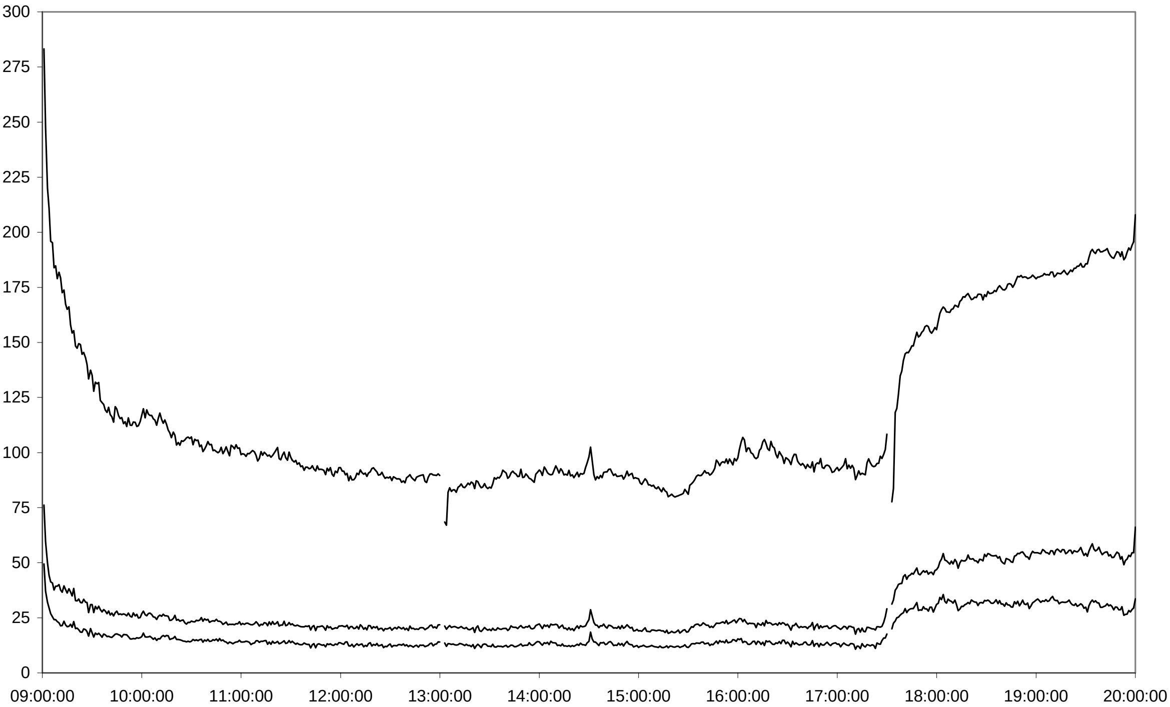

Figure 2: Intraday patterns, non-DAX stocks

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).

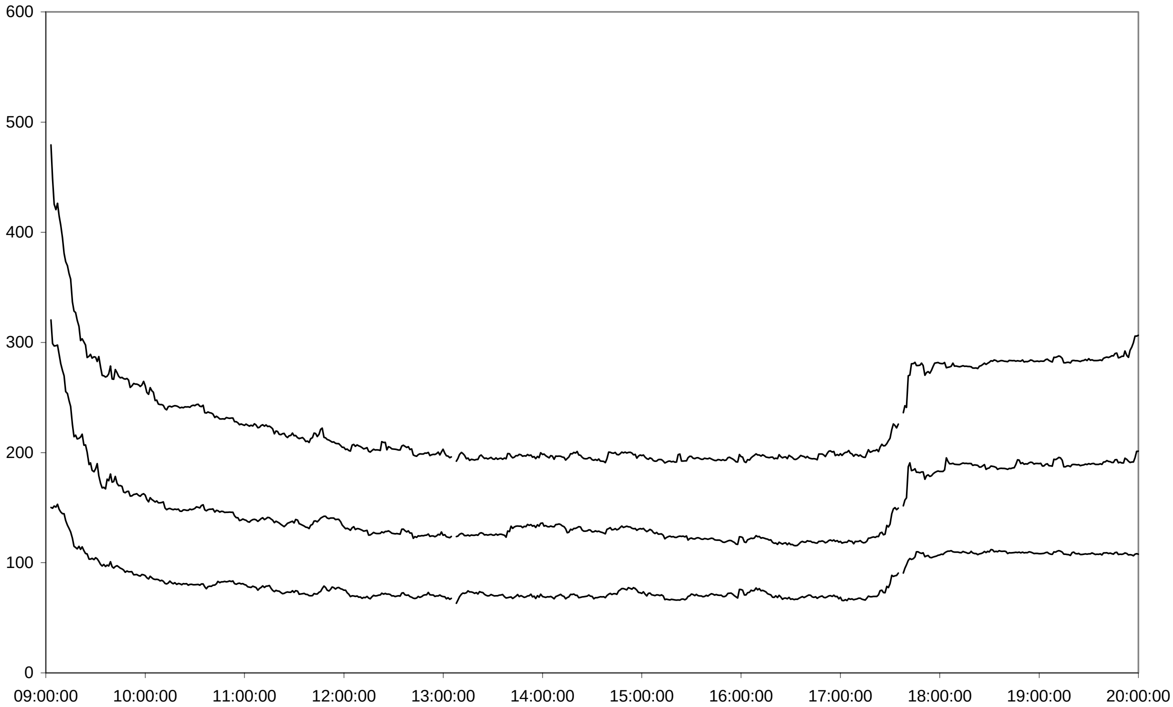

Figure 3: Distribution of the large transactions

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.

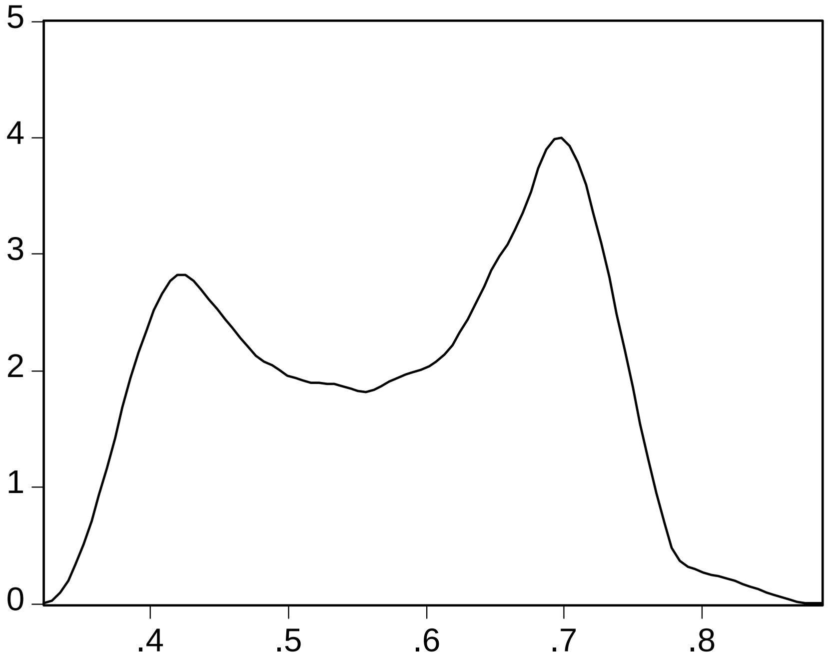

Figure 4: Event study results - large transactions, DAX stocks, XLM(100)

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.

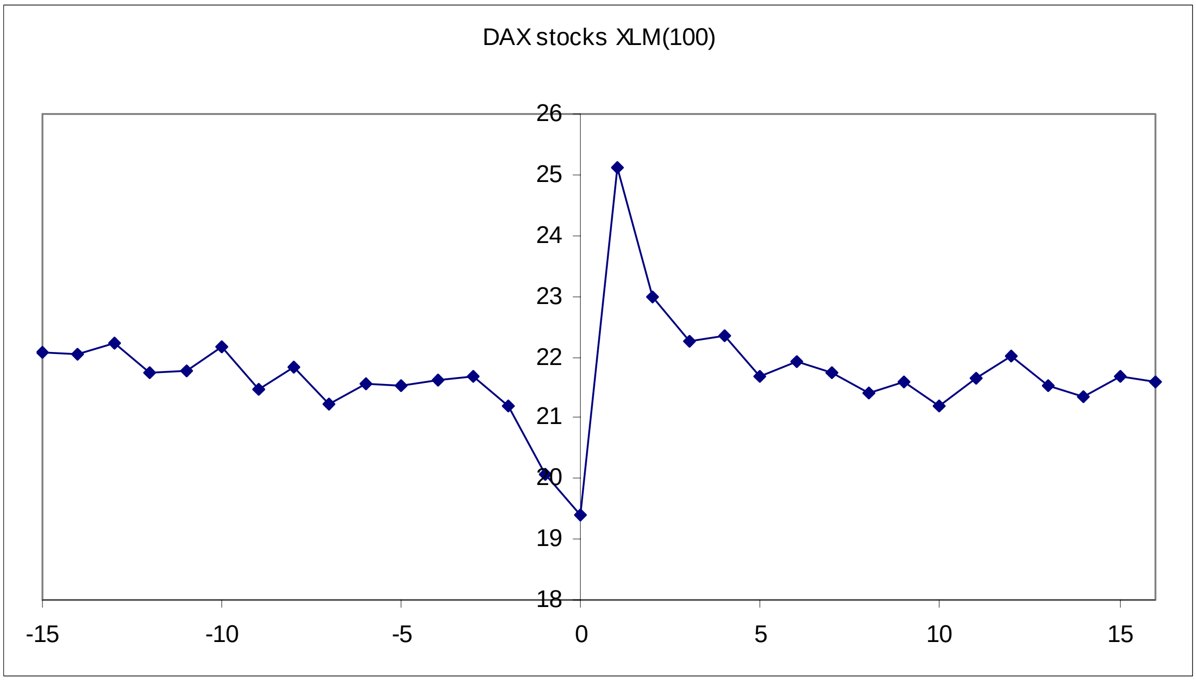

Figure 5: Event study results - large transactions, non-DAX stocks, XLM(100)

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.

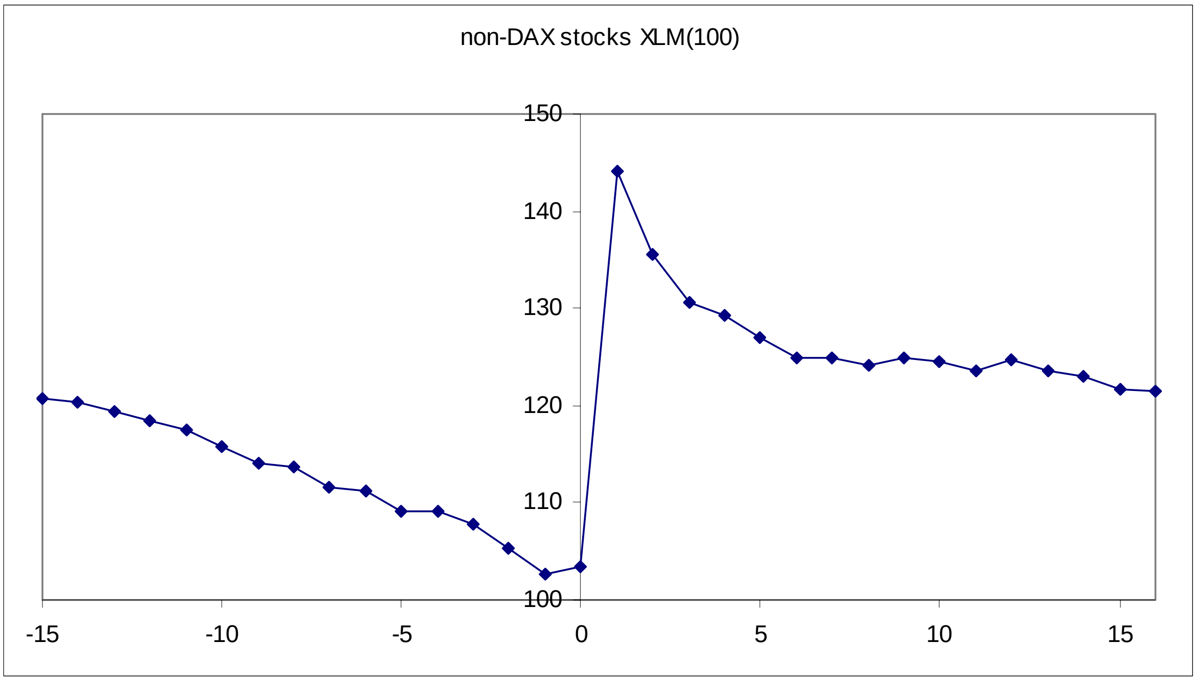

Figure 6: Event study results - ticker news, DAX stocks, XLM(100)

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.

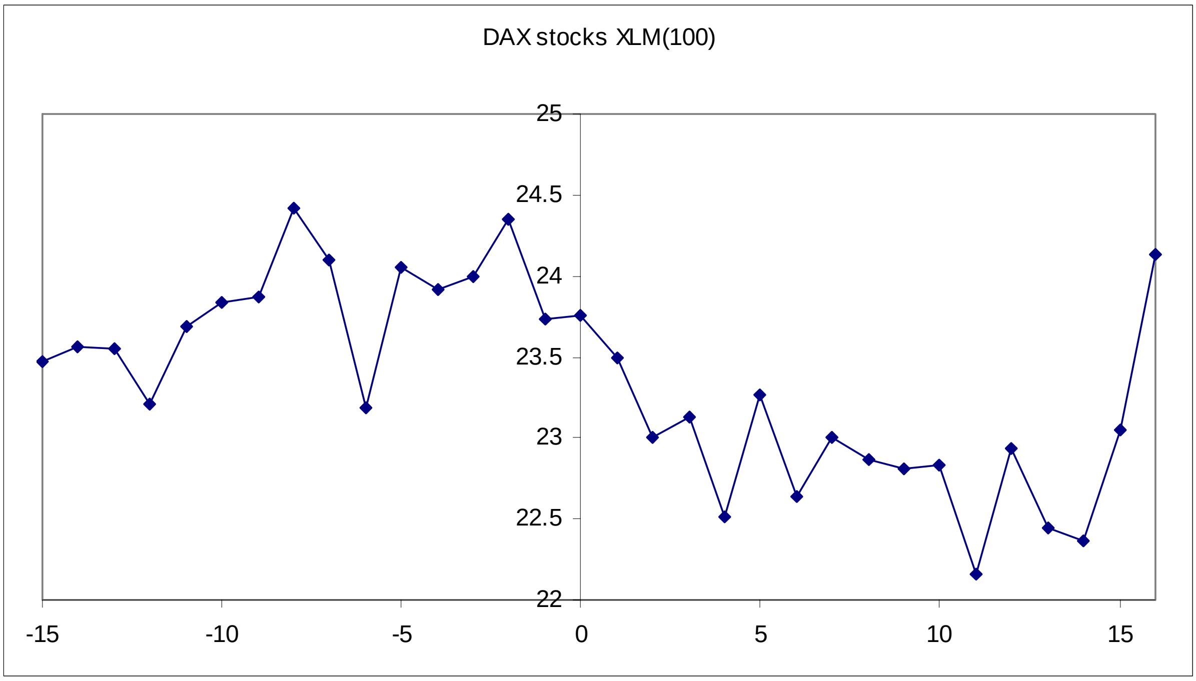

Figure 7: Event study results - ticker news, non-DAX stocks, XLM(100)

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.