With or Without You: Market Quality of Floor Trading when Screen Trading Closes Early*

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Current Draft: August, 2006

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Most stock markets are characterized by a number of parallel operating trading systems which interact intensively with each other. Usually, smaller trading platforms take the leading domestic main market as a benchmark in the price discovery process and for closing open trading positions. But what happens if the smaller trading systems suddenly have to act without this benchmark platform?

We examine the effects of the reduction of the daily business hours of a screen based main trading system while a parallel floor based trading system keeps on operating. We provide evidence that liquidity improves while informed trading and informational efficiency of prices decrease at the floor based trading system as a result of the no longer operating main market. While prior research on parallel trading focuses on changes due to a growing number of trading venues, we present first evidence on market effects when the main trading platform reduces trading hours.

JEL Classification: G14

Keywords: parallel trading, liquidity, information based trading, market efficiency

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* We thank the Deutsche Börse AG for providing the data. We are grateful to Alexandra Hachmeister, António Cerqueirathe, participants of the 4th PFN International Conference 2006 Porto, Portugal and participants of the 34th Annual Meeting of the Academy of Economics and Finance 2007, Jacksonville, USA.

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1. Introduction

Even most highly developed stock markets are characterized by a number of parallel operating trading systems or stock exchanges. Despite strong arguments for consolidation markets are fragmented and remain so for long periods of time. Madhavan (2000) describes this phenomenon as "network externalities puzzle". On the one hand, advocates of parallel trading markets name positive effects such as decreasing monopolistic rents due to increased competition.[3] On the other hand, opponents point out that consolidation leads to higher liquidity externalities. [4]

Another string of literature concentrates on the changes in market quality by the closing of the main trading system and the beginning of after market trading or the ongoing trading on ECNs or regional stock exchanges and find that trading during after hours is mostly illiquid. The price discovery is lower than during the regular trading day and consequently price efficiency is comparably poor. [5] The results are driven by two factors. Firstly, the main stock exchange does not operate during after hours. Secondly, results are influenced by the intraday pattern of trading.[6]

All these studies either analyze event oriented the entrance of a new trading platform or over a long time period the co-existence of established markets. In both cases, the number of trading alternatives is stable or even growing. Market participants here decide whether to stay or go. But we hardly had ever the opportunity to analyze an event where market participants suddenly had to switch because the main market reduced its trading hours. This happened in Germany in 2003[7] and offers the opportunity to study how traders changed their behavior in respond to this reduction. Traders have three alternatives: (a) to finish their activities earlier, (b) to wait until next trading day or (c) to switch to another trading platform. The screen based trading platform Xetra is the main trading system in Germany, concentrating more than 90 % of the overall trading volume on this platform. This huge market share brings us to the assumption that the early closing must have some impact on traders' activities in other trading systems.

Given the ongoing discussion about the consolidation of trading venues across Europe, it is important to examine the behavior of investors when an existing main trading system stops to operate and investors have to adapt. The effects of reducing the operating hours of a main trading system are expected to be much stronger than of a small trading

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[3] See Boehmer and Boehmer (2003), Battalio (1997), Wahal (1997), Mayhew (2002), Fong, Madhavan and Swan (2001), DeFontnouvelle, Fishe and Harris (2000), Conrad, Johnson and Wahal (2003), Biais (1993) or Chowdhry and Nanda (1991).

[4] See Bernhardt and Hughson (1997), Amihud, Lauterbach and Mendelson (2003), Arnold, Hersch, Mulherin and Netter (1999), Madhavan (1995), Jain (2002), Pagano (1989a), Pagano (1989b).

[5] See Barclay and Hendershott (2003), Barclay and Hendershott (2004) and McInish, van Ness and van Ness (2002).

[6] Numerous studies provide evidence that trading activities display intraday pattern, such as: Wood, McInish and Ord (1985), Jain and Joh (1988), McInish and Wood (1992), Abhyankar, Ghosh, Levin and Limmack (1997) and Chan, Chung and Johnson (1995).

[7] The trading system Xetra of Deutsche Börse AG opened every business day from 9:00 a.m. to 8:00 p.m. in the past. Since Nov. 3rd, 2003 Xetra operates every business day only until 5:30 p.m. For further details see Section 2 and 3.

platform. The major differences are liquidity externalities, which could be destroyed by this event, while it is unclear how much of the pre-event conditions have to be contributed to positive liquidity externalities. If liquidity externalities are a major contributor to trading, it is possible that the floor based trading platform is significantly negatively affected. This again could start up a viscous circle, which might force the floor based trading venue to stop operating during the evening as well.

To our knowledge, this situation has hardly ever been subject of any research. One exception is a recent analysis by Hendershott and Jones (2005) on the market of three exchange-traded-funds when the Island electronic communication network stopped displaying its limit order book, while it was the dominant venue. The study documents that trading activity and price discovery decreases, leading to overall worsening of market quality. After one year of non-display, Island redisplays quotes again. Hendershott and Jones (2005) show that the second event is much more modest and does not simply reverse the effects. In contrast to our study, Island did not stop to operate but only denied displaying quotes to “any” market participant. In our German case the screen based trading venue completely stops operating during the evening.

The focus of this paper is to analyze the impact of this event on the leading floor based exchange in Germany, when the main screen trading platform reduced its operating hours. In the study we illustrate the changes of liquidity, informed trading and market efficiency as a direct result of the event. The results offer additional insight in the dynamic behavior of investors on changes in market structure.

Our findings suggest that the earlier closing of the screen based trading system is mostly beneficial for the floor based stock exchanges. This finding is important for several reasons. Firstly, it provides evidence that those floor based stock exchanges are able to profit from this event by gaining additional liquidity. Secondly, it shows that market structure has an impact on the behavior of investors, by documenting that especially uninformed traders willing to trade in highly liquid stocks make the transfer. Thirdly, despite a decrease of market efficiency an increased number of traders are still willing to trade during evening hours. This implies that obviously waiting cost until next day are much higher for them. Thus, evening hour trading yields added value, despite less favorable market conditions.

The rest of the paper is structured as follows: Section 2 provides an overview of the institutional setting of the examined stock exchange and the German equity market. In Section 3 we review the related literature and derive our testable hypotheses. Section 4 presents a descriptive statistic of the employed data sample. Section 5 analyzes the change in level of liquidity at the FSE. Section 6 examines the level of informed trading and the corresponding changes subsequent the event. In Section 7 we determine the informational efficiency of prices. Finally, in Section 8 we conclude.

2. The Structure of the German Equity Markets

As described by Theissen (2003a), the German equity[8] market is horizontally and vertically fragmented. In the vertical dimension the market is divided into three segments, namely "*Freiverkehr*", "*General Standard*" and "*Prime Standard*". The unregulated "*Freiverkehr*" is the least regulated segment, followed by the "*General Standard*". It is designed for smaller companies with a domestic focus. The "*Prime Standard*" is the highest regulated segment, aiming at internationally visible companies. Among many other requirements, those companies have to be included in one of the indices calculated and published by the Deutsche Börse AG.[9] The structure of the most important German indices is shown in Figure I. The DAX is the blue chip index, including the 30 most liquid stocks. Next, 50 MDAX securities and 50 SDAX securities are following each representing the "old economy". The TecDAX comprises the 30 most liquid high tech firms, thus representing the "new economy". Table I shows the market capitalization of the indices and all domestic securities. Obviously, the DAX index is dominating all other indices and represents nearly half of the total market capitalization.

< insert Figure I about here >
< insert Table I about here >

In the horizontal dimension, the German equity market is fragmented between seven floor-based stock exchanges and one electronic trading system. The Deutsche Börse AG is hugely dominating the equity market by operating electronic trading system Xetra and the floor based trading platform Frankfurt Stock Exchange (FSE). Additionally, there are six other stock exchanges located in Berlin-Bremen, Düsseldorf, Hamburg, Hannover, Munich, and Stuttgart, with only small market shares ranging between 0.87 percent and 5.75 percent depending on the index. (See Table II)

< insert Table II about here >

The electronic trading system Xetra, introduced in 1997, is fully automated, based on open limit order book providing continuous trading.[10] The computerized order book manages all incoming market and limit orders. Orders are automatically matched by the system based on price and time priority. The operating hours before Nov. 3rd, 2003 were 9:00 a.m. to 8:00 p.m. and after Oct. 31st, 2003 are 9:00 a.m. to 5:30 p.m. [11] Every trading session starts, ends and is twice interrupted by call auctions. All securities traded at the market are ranked according to their liquidity. Securities belonging to the low-liquidity category are only traded when they have at least one "*Designated Sponsor*". Those "*Designated Sponsor*" are required to quote bid and ask prices and participate in call auctions. They are responsible for providing the minimum requirements of liquidity. For quality assurance all "*Designated Sponsor*" are regularly rated by the exchange and the results are made public.

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[8] For further information on the microstructure of German equity markets see Demarchi and Foucault (2000) and Commerton-Forde and Rydge (2004).

[9] The membership of the security in the CDAX does not qualify for "Prime Standard", given that this index includes all listed companies.

[10] See Reck (2001) and Theissen (2003a) for a description of the trading system Xetra

[11] The first day with the new Xetra operating hours was Monday Nov. 3rd, 2003. The last day of trading with the old operating hours was Friday Oct. 31st, 2003.

Trading at FSE is organized similar to the NYSE.[12] A "*Kursmarkler*" (similar to the specialist) conducts trading, and has exclusive access to the information in the limit order book. Contrary to the NYSE the "*Kursmarkler*" may trade on his own account in addition, but is not obliged to do so. He quotes continuously bid and ask prices (called "*Taxen*"), which represent either limit orders in the order book or the Kursmakler's own willingness to trade. The operating hours are between 9:00 a.m. and 8:00 p.m. The Kursmarkler conducts at 9:00 a.m. an opening call auction goes on to a continuous trading session and finally ends with a closing call auction. [13]

3. Related Literature and Testable Hypotheses

The screen trading system Xetra opened every business day from 9:00 a.m. to 8:00 p.m. in the past. Since Nov. 3rd, 2003 Xetra operates every business day only until 5:30 p.m. This change in operating hours has consequences for all market participants willing to trade after 5:30 p.m. During regular business hours (9:00 a.m. – 5:30 p.m.) investors have a wide choice of screen-based and floor-based trading platforms. But trading during evening hours (between 5:30 p.m. and 8:00 p.m.) is limited to all but Xetra.

Investors which used to trade on the most liquid trading platform Xetra in the evening now have three alternatives for adjusting their trading activities. Either they choose to trade earlier, or they choose to wait until the next trading day, or they switch to one of the less liquid floor-based stock exchanges. As those particular investors choose to trade on Xetra beforehand, obviously they view all the alternatives as inferior compared to Xetra. Therefore, investors wanting to trade on Xetra during evening hours face a trade-off between trading at a sub-optimal point in time (before or next day) and an inferior transaction process at a different market. We expect that at least some investors will switch from Xetra to FSE. This change in trading activities will improve the liquidity on the floor to some extent. We do not expect that all investors transfer to the FSE, because some investors are more affected by the changes than other and consequently are less prone to switch. We test these predictions in hypothesis H1:

H1: *The liquidity at the FSE increased significantly after the change in opening times at Xetra.*

For the British stock market Jain, Siang, McInish and Taechapiroontong (2003) show that informed traders prefer the anonymous SETS, while the non-anonymous voluntary dealer market is able to compete effectively for uninformed order flow. Barclay, Hendershott and McCormick (2003) show that informed traders are more willing to trade at ECNs, due to a greater degree of anonymity. Consistently, Grammig, Schiereck and Theissen (2001) provide evidence for stock trading in Germany that the probability of informed trading is higher at the anonymous screen trading compared to the floor of FSE. They point out that at the FSE the Kursmarkler knows the identity of his counter-

[12] See Theissen (2003a) and Theissen (2003b) for an overview on the trading system of the floor of the FSE.

[13] A larger number of securities (none included in the sample) is too illiquid for continues trading. Thus, only daily call auctions are conducted. The same applies for Xetra.

party. Informed traders prefer an anonymous electronic trading system, where they can trade longer undetected on their information. Thus, informed traders are less likely to transfer to non-anonymous floor trading and more likely to trade earlier or wait until the next trading day, as they are preferring anonymity stronger. Hence, we estimate the probability of informed trading by employing the methodology proposed by Easley, Kiefer, O'Hara and Paperman (1996) for trading at the FSE. We expect to observe that the arrival rate of uninformed traders increases stronger than the rate for informed traders, resulting in a decrease in the probability of informed trading. We test whether hypothesis H2 holds.

H2: *The arrival rate of uninformed traders increased stronger than the arrival rate of informed traders after the change in opening times at Xetra.*

The abolishment of trading during evening hours does not only yield potentially positive effects for the floor-based stock exchanges, when a decreased liquidity, informed trading and pre-trade transparency leads to a decline in market efficiency. Hasbrouck (1995) analyzes the proportional contribution to the innovation in the common efficient price for homogeneous or closely-linked securities of multiple markets. He provides evidence that the price discovery takes mainly place at the New York Stock Exchange (NYSE) and not at the US regional stock exchanges. For the price discovery in Xetra and FSE Theissen (2001) finds that both markets contribute to price discovery. The contributions of the two trading systems to the process of price discovery are almost equal, but show tendencies for higher contributions of Xetra. Thus, the FSE profited from the price discovery at Xetra during evening hours before the event. Now Xetra closes early and price discovery has to be produced solely by FSE. If FSE is not able to provide additional price discovery stock prices become less efficient and overall market quality decreases.

A decrease of the informational efficiency of prices during evening hours is expected for the following reasons: If some investors are less likely to transfer than others, all those who decide to trade at a different point of time are lost to the evening hours trading across all stock exchanges in Germany. Chordia, Roll and Subrahmanyam (2005) show that the liquidity in stock trading is positively related to market efficiency. They argue that market efficiency is not immune to frictions such as illiquidity and higher liquidity is associated with more trading on private information, which increases price efficiency. Thus informational efficiency is expected to decrease. Boehmer, Kelley and Pirinsky (2005) support the idea that there is a positive relationship between the fraction of informed trading and efficient prices, arguing that institutional investors are better informed and thus increase informational efficiency. While we argued earlier, that the arrival rate of uninformed traders will increase stronger than the rate for informed traders, we expect that a decrease of price efficiency.

Additionally, Xetra functions as an open limit order book, providing detailed information on depth and liquidity of the market to potential investors, while floor trading does not. Thus, pre-trade transparency of German stock markets hugely decreases in German stock markets after 5:30 p.m. Glosten (1999) and Baruch (2005) predict that an improvement of transparency leads to an increase of informational efficiency of prices. Boehmer, Saar and Yu (2005) show for the introduction of NYSE’s open book service which provides limit order book information to traders off the exchange floor, that an increase in pre-trade transparency improves informational efficiency of prices. The early closing of Xetra represents a decrease of pre-trade transparency. Therefore, we expect that decreased liquidity, informed trading and pre-trade transparency cause a reduction of informational efficiency. We test our expectations in hypothesis H3:

H3: *The informational efficiency of prices decreased after the change in opening times at Xetra.*

Theissen (2002) compares floor-based and screen-based trading in Germany. He shows that both trading systems have their advantages. While the electronic screen trading system displays lower bid-ask spreads for more liquid stocks, transaction costs appear lower for less liquid stocks at the floor trading. Theissen (2002) explains those differences with a trade-off between operational costs (electronic stock exchanges are more efficient) and adverse selection costs (market structure of floor trading reduces adverse selection component of bid-ask spread). Thus, investors willing to trade more in liquid stocks are less likely to transfer to one of the other stock markets and more likely to wait until the next trading day, as they are stronger preferring a electronic trading system. Therefore, we expect differentiated results according to low and high trading volume. The testable implications that arise are stated in the hypotheses H4a to H4c:

H4a: *Liquid and illiquid stocks respond differently at the change of opening times at Xetra in regard to liquidity.*

H4b: *Liquid and illiquid stocks respond differently at the change of opening times at Xetra in regard to arrival rates of (un)informed traders.*

H4c: *Liquid and illiquid stocks respond differently at the change of opening times at Xetra in regard to market efficiency.*

4. Data

The data sample includes information on 823.362 transactions. Transaction data comprises time-stamped transaction prices, volume data, unique transaction identifier and trade-direction identifier. The time periods 10/01-10/31/2003 (23 trading days); 11/01-11/21/2003 (15 trading days); 01/05-01/23/2004 (15 trading days) and 02/16-02/27/2004 (10 trading days). Thus, we are able to analyze 23 trading days prior and 40 trading days after the event. Taken the vertical segmentation of the German stock market, the sample contains all 30 securities of the DAX and another 49 securities selected from the indices MDAX and TecDAX. Table II shows that securities included in DAX and MDAX are traded more actively on Xetra, while securities included in SDAX are comparably more actively traded at FSE. The more a security is traded on Xetra, the more it will be affected by the change in operating hours.

< insert Table III about here >

Descriptive statistics are given in Table III. Apparently, the sample covers a wide range of market capitalizations and number of transactions. The less liquid stocks have a median market capitalization of 1.1 billion Euro and a median of 2,500 transactions, while highly liquid stocks show a median market capitalization of 12.1 billion Euro and a median of 12,089 transaction. The average free float for stocks with low trading volume is about 55.00 percent while stocks with high trading volume have a mean of 75.00 percent.

5. Liquidity and Trading Activity

As proxy for liquidity we employ the following transaction data based measures: trade size in Euro (*TS*), trade duration (*TD*) and turnover duration (*TOD*). Trade duration as defined by Hautsch (2004) is the time between two consecutive trades. Trade duration accounts for the frequency of trading, but does not measure differences in turnover. Thus, we calculate turnover duration, which describes the time that a stock needs to absorb a certain amount of money. This measure is based on volume duration suggested by Gouriéoux, Jasiak and Le Fog (1999). Volume duration describes the time that a stock needs to absorb a certain number of stocks. We keep in mind that this measure does not allow a comparison across different stocks. Therefore, we extend the measurement by accounting for differences in price levels. Alternatively, turnover duration can be viewed as the reciprocal measure of the turnover measure (total turnover over a certain period) suggested by Chan, Chung and Fong (2002). The threshold for turnover duration is defined as 10,000 Euros. All trade information observed during a trading session and across all securities is aggregated to one trade information, using the equal weighted mean of this trading session.

< insert Table IV about here >

Table IV presents descriptive results for the liquidity at FSE around the change in operating hours at Xetra. The results show that highly liquid and less liquid stocks differ significantly. Trade duration for highly liquid securities ranges between 1 – 8 minutes, while trade duration for less liquid stocks ranges between 11 – 41 minutes. A similar picture evolves considering turnover duration. Stocks with high trading volume range between 1 – 3 minutes and stocks with low trading volume range between 7 – 17 minutes. Trade duration and turnover duration improved in all samples across time. Trade duration and turnover duration increased during regular hours and during evening hours. We attribute the improvement during regular operating hours to a secular trend, which is not driven by the event under examination. But we attribute the stronger growth during the evening hours – beyond the growth rates observed during regular operating hours – to the change of opening hours of Xetra. The effects are stronger for highly liquid stocks compared to less liquid securities.

Comparing turnover duration with trade duration reveals that turnover duration reacts relatively stronger in the evening for stocks with high trading volume. This indicates that not only trading frequency but also trading volume increased during evening hours. Thus, trade size is examined across all samples which stagnates or even slightly decreases over time, except for highly liquid stocks during evening hours. There is a sharp increase from €6.965 up to €12.261 for liquid stocks during the evening. Before the event, trade size is similar (or slightly lower) compared to trading during regular hours. After the event trade size increases strongly and is even larger than in any other subsample of this time period. This implies that trading during evening hours is strongly affected by the event. Two explanations are possible for this effect. Firstly, the already active investors at FSE changed their preferred trade size. Secondly, FSE attracted new investors, which prefer a larger trade size, than the already active investors at those stock exchanges. Because of a higher trading frequency after the event we believe that the second explanation is more convincing.

Summarizing, the frequency of trading at FSE increased after the change of operating hours at Xetra. The increase appears to be stronger during evening hours. This holds especially true for securities with high trading volume. The remarkably strong increase in trade size provides further indication for additional investors. Thus, we conclude that some of the investors decided to transfer their trading activities to FSE. These observations are consistent with Hypotheses 1 and 4a.

6. Probability of Informed Trading

6.1. Methodology

Information-based trades are not directly observable. Therefore, a structural microstructure model is applied to make inferences about it. According to Easley, Hvidkjaer and O'Hara (2002): “microstructure models can be viewed as learning models in which market makers watch market data and draw inferences about the underlying true value of an asset”. Following Easley, Kiefer, O'Hara and Paperman (1996), the trading process and the market maker’s learning process can be modeled and used to make an inference about the probability of information based trading.

For estimating the probability of informed trading the model suggested in Easley, Hvidkjaer and O'Hara (2002) is applied. Trading can be depicted as a game that repeats over $t = 1 \ldots T$ days. Trades occur over the days in discrete time, within each trading day trades take place in continuous time. Between each day nature determines whether a relevant information event occurs or not. Information events are independently distributed and take place with probability α. The events are bad news with probability δ and good news with probability $(1 - \delta)$. Good news imply that the value of the asset increases from V_t^* to V_t^h while bad news imply a decrease in value from V_t^* to V_t^l, respectively. Thus, it is assumed, that $V_t^l < V_t^* < V_t^h$. The orders arrive every day following Poisson processes. The market maker executes orders as they arrive based on the previously quoted bid and ask prices. Uninformed traders trade for liquidity reason. It is assumed that buy as sell orders of uninformed traders arrive at rate ε. informed traders buy if they observe good news and sell if they observe bad news. The arrival rate of orders of informed trades is μ. Every time an order arrives, the market maker updates his expectations. This process is described in Figure II.

< insert Figure II about here >

A number of papers[14] show how to use this structural model to work backwards and provide specific estimates for the risk of information based trading. The structural microstructure model can be estimated using a maximum likelihood function. The function is:

$$\begin{aligned} L(\Theta_t \mid B_t, S_t) = &(1-\alpha)e^{-\varepsilon}\frac{\varepsilon^B}{B!}e^{-\varepsilon}\frac{\varepsilon^S}{S!} \\ &+\alpha\delta e^{-\varepsilon}\frac{\varepsilon^B}{B!}e^{-(\mu+\varepsilon)}\frac{(\mu+\varepsilon)^S}{S!} \qquad (1) \\ &+\alpha(1-\delta)e^{-(\mu+\varepsilon)}\frac{(\mu+\varepsilon)^B}{B!}e^{-\varepsilon}\frac{\varepsilon^S}{S!}, \end{aligned}$$

where B_t and S_t are the total number of buy and sell induced trades per day and $\Theta_t\ (\alpha, \delta, \varepsilon, \mu)$ is the parameter vector per day. This likelihood function represents a mixture of distributions weighted with the probabilities of a "good news day" $\alpha\ (1 - \delta)$, a "bad news day" $\alpha\ \delta$ and a "no event day" $(1 - \alpha)$. As days are assumed to be independent from each other, the likelihood of observing data $M = (B_t, S_t)_{t=1}^{T}$ over T days is the product of the daily likelihoods.

$$L = (M \mid \Theta) = \prod_{t=1}^{T} L(\Theta \mid B_t, S_t) \quad (2)$$

Following Easley, Engle, O'Hara and Wu (2000) the likelihood function can be rearranged for computational efficiency in the following way:

$$\begin{aligned} L(M \mid \Theta) = &\sum_{t=1}^{T}[-2\varepsilon + M\ln x + (B+S)\ln(\mu+\varepsilon)] \\ &+\sum_{t=1}^{T}\ln[\alpha(1-\delta)e^{-\mu}x^{S-M} + \alpha\delta e^{-\mu}x^{B-M} + (1-\alpha)x^{S+B-M}], \end{aligned} \quad (3)$$

where $M = min\ (B, S) + max\ (B, S) / 2$ and $x = \varepsilon / (\mu + \varepsilon)$. The variable x can be interpreted as the ratio of the arrival rates of "wrong trades" to that of "right trades". A "wrong trade" is defined as a buy (sell) in presence of a bad (good) signal and a right trade is vice versa.

The summary proxy for asymmetric information is the probability of informed trading (*PIN*). PIN is the unconditional probability that a randomly selected trade originates from an informed trader and is calculated as follows:

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[14] See Easley, Kiefer and O'Hara (1997a), Easley, Kiefer and O'Hara (1997b), Easley, Kiefer, O'Hara and Paperman (1996) and Easley, Hvidkjaer and O'Hara (2002).

$$PIN = \frac{\alpha\mu}{\alpha\mu + 2\varepsilon} \quad (4)$$

The original model by Easley, Kiefer, O'Hara and Paperman (1996) is applied to daily data. Similar to Barclay and Hendershott (2003) and Goldstein, van Ness and van Ness (2002) we change this model by dividing the day into two periods, namely trading during regular hours (9:00 a.m. – 5:30 p.m.) and trading during evening hours (5:30 p.m. - 8:00 p.m.). Computing the parameters of the vector Θ depends hugely on the starting values for the optimization procedure. For each estimation we use several different starting values, resulting in n different possible results. We choose the vector Θ_n, which fulfills the following restrictions. Firstly, every parameter of the vector Θ_n has to be greater zero. Secondly, α_n and δ_n of Θ_n have to be less than one, as they are interpreted as probabilities. Finally, the maximum likelihood function (3) has to maximum across all n vectors ($max[L(M| \Theta_i)]$ *with* $i=1,2...n$).

6.2. Results

Table V documents the findings for the probability of informed trading at FSE around the change in operating hours at Xetra. We report medians across all securities. Pairwise Mann-Whitney U tests are used to test the null-hypothesis that two samples are drawn from identical populations.

< insert Table V about here >

Estimated parameters for stocks with low trading volume during evening hours are stable across time. This is remarkable, considering a strong and statistically significant increase of (un)informed trading during regular hours. Thus, we have to conclude that despite an ongoing unobserved trend during regular business hours, trading during evening hours does not change significantly for stocks with low trading volume. Stocks with high trading volume behave differently. The arrival rates of informed and uninformed traders show significant growth over time. The probability of informed trading is the highest for trading during evening hours before Nov. 3rd, 2003 compared to all other sub-samples. For all samples the probability is approximately 0.21 but during evening hours it rises up to 0.27. The probability of informed trading during evening hours approached to the overall average, since Xetra is closing earlier. This observation is mainly driven by a relatively small arrival rate of uninformed traders at the beginning and a corresponding strong increase afterwards.

The probability that an information event takes place decreased in all sub-samples from before Nov. 3rd, 2003 to after Oct. 31st, 2003. This decrease is quite large, thus drives the probability of informed trading significantly. This change might be due to an underlying, unobserved trend. There is no indication that this trend is related to the early closing of Xetra.

A ratio (ε / μ) is reported in Table V, presenting the fraction of arrival rate of uninformed traders over arrival rate of informed traders. We see that ε / μ behaves differently for highly and less liquid stocks. On the one hand, stocks with low trading volume only change statistically significant during regular operating hours. The ratio ε / μ decreases, meaning that the arrival rate of informed traders increases stronger than the arrival rate of uninformed traders. On the other hand, stocks with high trading volume change statistically significant during evening hours and the measure ε / μ increases, meaning that the arrival rate of uninformed traders increases stronger than the arrival rate of informed traders. The results are in line with previously obtained findings in Section 5 and support Hypothesis 2 and 4b. The results differ hugely between highly liquid and less liquid stocks. Securities with low trading volume during evening hours appear to be stable across time, despite an unobserved trend during operating hours. Securities with high trading volume receive more uninformed traders compared to informed traders.

7. Informational Efficiency of Prices

7.1. Methodology

Boehmer, Kelley and Pirinsky (2005) differentiate between three different approaches measuring the informational efficiency of prices. First approach is the analysis of long-term and short-term return variances, as done by Barnea (1974) or Hasbrouck and Schwartz (1988). Even though this measure is simply to compute, it is sensitive to the horizons chosen for comparison. Second approach estimates prices changes associated with new information using liquidity ratios that relate volume to returns (Schreiber and Schwartz (1986)). But this approach does not differentiate between permanent and temporary price changes. The third approach is suggested by Hasbrouck (1993) and is applied in this study. Hasbrouck (1993) resolves a non-stationary time series of returns into a random-walk component and a residual stationary component. He assumes that the random-walk component represents the efficient price driven by information-based permanent changes and that the residual stationary component represents temporary price changes, which should quickly reverse. Thus, the observed log transaction prices (p_t) can be decomposed into an efficient price (m_t) and a pricing error (s_t).

$$p_t = m_t + s_t \quad (5)$$

$$r_t = \ln(p_t / p_t - 1) \quad (6)$$

Here t is assumed to index stock transactions. It is assumed that the pricing error follows a zero-mean covariance-stationary process. Therefore, the standard error of the pricing error (σ_s) can be interpreted as a measure of its magnitude. Given the zero-mean, the standard error describes how closely the observed transaction prices follow the efficient prices over time.

Hasbrouck (1993) derives σ_s from the vector autoregressive (VAR) model:

$$\begin{aligned} r_t &= a_1 r_{t-1} + a_2 r_{t-2} + \cdots + b_1 x_{t-1} + b_2 x_{t-2} + \cdots + v_{1,t} \\ x_t &= c_1 r_{t-1} + c_2 r_{t-2} + \cdots + d_1 x_{t-1} + d_2 x_{t-2} + \cdots + v_{2,t} \end{aligned} \quad (7)$$

where x_t represents the signed trade volume, positive if the agent initiated the buy and negative if the agent initiated the sell. The variables $v_{1,t}$ and $v_{2,t}$ are the trade innovations which are zero-mean, serially uncorrelated disturbances. For further calculations Hasbrouck (1993) transforms the VAR model in a vector moving average (VMA) model, expressing the exogenous variables in terms of current and lagged disturbances.

$$\begin{aligned} r_t &= a_0^* v_{1,t} + a_1^* v_{1,t-1} + a_2^* v_{1,t-2} + \cdots + b_0^* v_{2,t} + b_1^* v_{2,t-1} + b_2^* v_{2,t-2} \\ x_t &= c_0^* v_{1,t} + c_1^* v_{1,t-1} + c_2^* v_{1,t-2} + \cdots + d_0^* v_{2,t} + d_1^* v_{2,t-1} + d_2^* v_{2,t-2} \end{aligned} \quad (8)$$

Hasbrouck (1993) shows that based on the pricing process (5), the vector autoregressive model (7) and the restriction suggested by Beveridge and Nelson (1981) the pricing error may be expressed as:

$$s_t = \alpha_0 v_{r,t} + \alpha_1 v_{r,t-1} + \cdots + \beta_{10} v_{x,t} + \beta_{11} v_{x,t-1} \quad (9)$$

while α and β are computed as follows:

$$\alpha_j = -\sum_{k=j+1}^{\infty} a_k^* \qquad \beta_j = -\sum_{k=j+1}^{\infty} b_k^* \quad (10)$$

Finally, we obtain the standard deviation of the pricing error σ_s as:

$$\sigma_s = \sum_{j=0}^{\infty} \left[\alpha_j \beta_j\right] \mathrm{cov}(v) \begin{bmatrix} \alpha_j \\ \beta_j \end{bmatrix} \quad (11)$$

To control for cross-section differences in return variance, we divide σ_s (11) by the standard deviation of r_t (6) and refer to it as *VR(s/p)*. For estimating the returns: we exclude all transactions where the previous price differs by more than 30 percent. Additionally, we exclude in our sample of the VAR-model all overnight returns.

Before estimating the pricing error the number of lags for the VAR model has to be defined. In previous rresearch the numbers of lags vary to a large degree, because it is not possible to derive the number of lags theoretically. Thus, we apply the likelihood ratio as suggested by Sims (1980) to estimate the appropriate number of lags. In general, VAR model may differ in length of their lags. A longer lag model is viewed as unrestricted model, while a model with shorter lags is called restricted. Sims (1980) computes a likelihood ratio statistics to test for the significance of imposing the restrictions by deleting an additional lag from the model. If the restriction leads to a statistical significant degradation of the model, we conclude that the longer model is more appropriate. We compute the likelihood ratio across all securities and conclude that three lags are the most appropriate. We require a minimum of seventy observations for estimating meaningful pricing errors. Unfortunately, most securities are not able to fulfill those requirements for trading during after-hours. Thus, we do not compute the pricing error for the sample of less liquid stocks and the sample of stocks with high trading volume is reduced to 27 securities.

Additionally, we calculate a second more simple measure for the informational efficiency of prices, because of the restriction of *VR(s/p)*. The second measure is the absolute transaction-price-return first-order autocorrelation and demands less data restrictions, but has a theoretical shortcoming. Nevertheless, it provides further robustness of the results in combination with *VR(s/p)*. We compute this measure as follows: All transaction price information observed during a period of fifteen minutes are aggregated to one price information using the last price fixing (close) of this period. Using this price series, we compute returns and estimate absolute correlation coefficients, while ignoring overnight-returns. We refer to this measure as |*Corr15*|. It is assumed that efficient prices follow a random walk. The more a price series resembles a random walk, the less autocorrelation should be. We report the absolute autocorrelation, because we are interested in the deviation of the price series from the random walk but not in the direction.

While Hasbrouck (1993) distinguishes between information related and unrelated price changes, |*Corr15*| does not. Applying an autocorrelation based measure ignores that autocorrelation is not necessarily induced by inefficient pricing but might be also caused by efficient price discovery. As for example an informed trader chooses to split his orders over time, prices gradually incorporate information and cause a positive autocorrelation, even though all publicly available information are efficiently processed. Hence, this "efficient" autocorrelation leads to an overstating of |*Corr15*|. One feature of this study mitigates our concerns. We do not use |*Corr15*| in an absolute sense. Our analysis focuses on the change of |*Corr15*| around the change of opening times of Xetra. If the effect of "efficient" autocorrelation is constant over time then our results are unbiased.

7.2. Results

Table VI presents evidence on the informational efficiency at FSE around the change in operating hours at Xetra. The efficiency measures *VR(s/p)* and |*Corr15*| for stocks with low trading volume are not coherent across the sub-samples. While *VR(s/p)* suggests a strong quality increase during regular operating hours, |*Corr15*| shows no changes. This result is consistent to the results for less liquid stocks in Section 6. For highly liquid stocks our results are much more coherent. On the one hand, the pricing error and the first-order autocorrelation show that the market efficiency during regular business hours increased. This is in line with our expectations, as we showed in Section 5 that liquidity increased statistically significant. On the other hand, *VR(s/p)* and |*Corr15*| decreases during evening hours. Even though the p-values are rather weak (0.1003 and 0.1989), they show tendencies.

< insert Table VI about here >

Similar with the results in Section 6 we do not find any evidence that the event did have an effect on stocks with low trading volume. Furthermore, there is at least weak indication that the market quality decreased. In general these results are in line with our expectations. As the decrease of market quality for highly liquid stocks during evening hours is comparably small, FSE is able to provide own contribution to price discovery nearly as efficient as done by Xetra during the evening hours. These observations are in line with Hypothesis 3 and 4c.

8. Conclusion

We examine for the German stock market the effects of the reduction of the daily business hours of a screen based main trading system while a parallel floor based trading system keeps on operating. While prior research on parallel trading focuses on changes due to a growing number of trading venues, we present first evidence on market effects when the main trading platform reduces trading hours. Herewith, our study contributes to the growing literature on parallel markets. While most studies focus on an increasing number of trading venues, we show what happens if potential trading channels decreases.

We study a unique event as a natural experiment, when the main trading platform Xetra reduces its operating hours. We provide evidence that the FSE is able to increase its liquidity on a stand alone basis. Furthermore, we observe that the probability of informed trading decreases during evening hours. This is due to a stronger increase of arrival rates of uninformed traders compared to informed traders. These observations only hold true for highly liquid stocks. Finally, we see that the informational efficiencies of transaction prices decrease weakly.

The results are important for a couple of reasons. The documented evidence illustrates the impact of the changes of liquidity, informed trading and market efficiency when the main market stops to operate and smaller trading systems are no longer able to profit from price discovery provided by the main stock exchange anymore. Obviously do liquidity externalities not have such a major impact that the overall performance of FSE declines. This implies that evening hour trading yields added value, despite less favorable market conditions.

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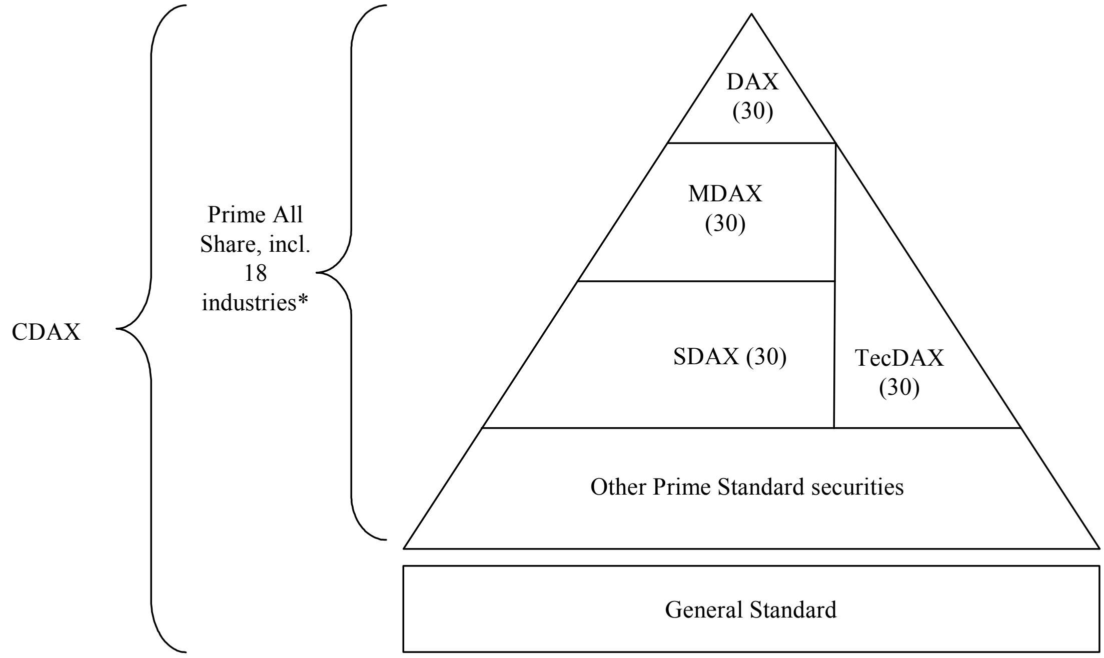
Figure I: Equity Indices in Germany

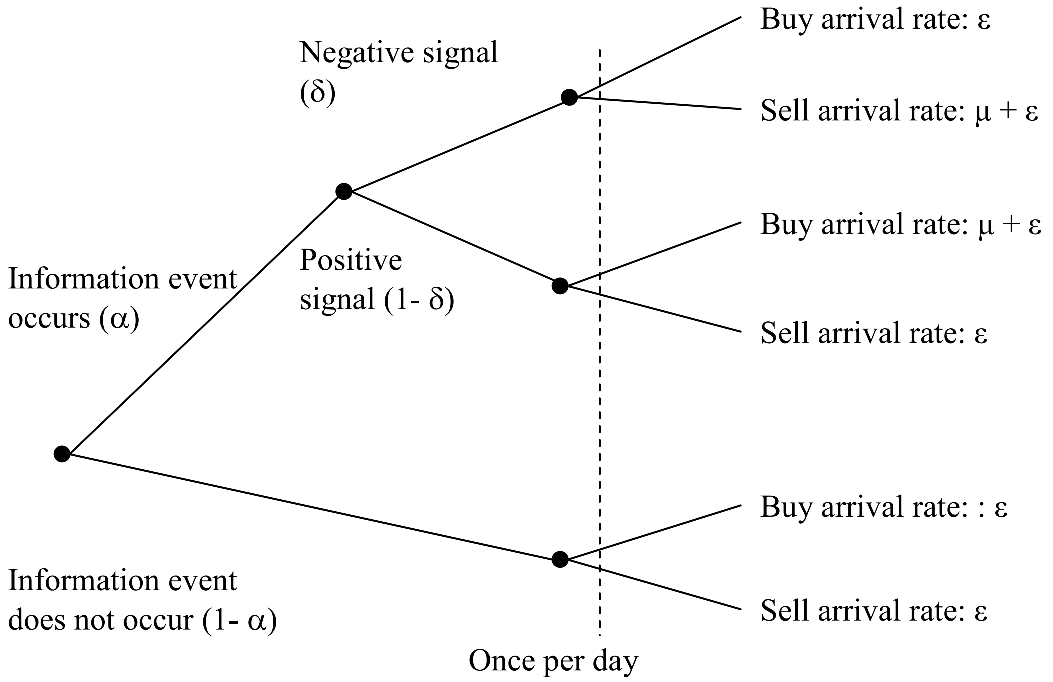


* Automobile, Banks, Basic Resources, Chemicals, Construction, Consumer, Financial Services, Food & Beverages, Industrial, Insurance, Media, Pharma & Healthcare, Retail, Software, Technology, Telecommunication, Transport & Logistics, Utilities.

Source: Theissen (2003a).

Figure II: Tree diagram of the trading process

This figure presents the tree diagram of the trading process. The parameter μ (ε) is the arrival rate of (un)informed traders, α is the probability of an information event and δ is the probability that the information event is negative. Nodes to the left of the dotted line occur only once a day.



Source: Easley, Kiefer, O'Hara and Paperman (1996).

Table I: Index Capitalization

This table presents the index capitalization (in Mio. Euro) for DAX, MDAX, SDAX, TecDAX and domestic equities for the year 2003.

Month	DAX	MDAX	SDAX	TecDAX	Domestic Equities*
Jan	279,856	27,466			631,496
Feb	259,408	26,349			607,327
Mar	247,099	26,278	3,676	5,493	575,707
Apr	299,923	30,489	4,227	6,491	673,740
May	304,067	32,249	4,413	6,729	676,511
Jun	330,741	32,547	4,366	7,038	714,158
Jul	358,190	35,358	4,763	7,636	754,930
Aug	357,853	37,396	4,902	8,675	764,702
Sep	341,914	33,948	4,983	9,188	723,655
Oct	383,825	37,377	5,220	10,664	816,577
Nov	393,269	37,400	5,395	10,546	831,557
Dec	422,288	40,132	5,688	11,058	855,452

* Market capitalization figures are not freefloat-based.

Source: Deutsche Börse (2003).

Table II: Market Shares of German Stock Exchanges

This table presents the total amount (in Mio. Euro) and the market shares of orderbook turnover of Xetra, FSE and all other exchanges cumulated in Germany for the indices DAX, MDAX, TecDAX and SDAX for the year 2003.

	Xetra	FSE	Other exchanges	Total
DAX	716,096	16,564	6,436	739,096
	(96.89%)	(2.24%)	(0.87%)	(100.00%)
MDAX	31,712	2,866	627	35,205
	(90.08%)	(8.14%)	(1.78%)	(100.00%)
SDAX	1,700	792	152	2,644
	(64.30%)	(29.95%)	(5.75%)	(100.00%)
TecDAX	10,448	1,607	359	12,414
	(84.16%)	(12.95%)	(2.89%)	(100.00%)

Source: Deutsche Börse (2003).

Table III: Descriptive Statistics

This table shows the descriptive statistics of the data and the securities included in the sample. Stocks are sorted according their Euro trading volume into two groups. All figures (except for number of securities) are equal-weighted means for the securities included in the group. Market value and free float are calculated for the October 1st, 2003. We report medians across securities. Pair-wise Mann-Whitney U tests are used to test the null-hypothesis that two samples are drawn from identical populations. Characteristics from the less liquid stock sample that differ from corresponding characteristics at the sample with highly liquid stocks at a 0.01; 0.05 or 0.1 level are denoted with a ***; **; *, respectively.

	Low trading volume	High trading volume	p-Value
Number of securities	39	40	
Number of transactions per security	2,554	12,089	0.0000
Market value per security in Mio. Euro	1,133	7,492	0.0000
Free float per security in percent	55.00%	75.00%	0.1153

Table IV: Trading Activities at the Frankfurt Stock Exchange (FSE)

This table shows an analysis of the liquidity at the FSE around the change in operating hours at Xetra. The sample is divided into "Before Nov. 3rd, 2003" / "After Oct. 31st, 2003", trading between during regular hours (9:00 a.m. - 5:30 p.m.) / during evening hours (5:30 p.m. - 8:00 p.m.) and high / low trading volume. The following variables are reported: trade size in Euro (*TS*), trade duration (*TD*) and turnover duration (*TOD*). We report medians across all trading sessions. Pair-wise Mann-Whitney U tests are used to test the null-hypothesis that two samples are drawn from identical populations. Values after Oct. 31st, 2003 that differ from corresponding value before Nov. 3rd, 2003 at a 0.01; 0.05 or 0.1 level are denoted with a ***; **; *, respectively.

		Before Nov. 3rd, 2003	After Oct. 31st, 2003		p-Value
Low Trading Volume					
Trading period: 9:00 a.m. - 5:30 p.m.	*TS*	6,454	6,419		0.6325
	TD	00:15:59	00:11:13	***	0.0000
	TOD	00:07:38	00:05:50	***	0.0015
Trading period: 5:30 p.m. - 8:00 p.m.	*TS*	5,892	5,258		0.6841
	TD	00:40:56	00:25:40	***	0.0000
	TOD	00:17:05	00:12:22	***	0.0050
High Trading Volume					
Trading period: 9:00 a.m. - 5:30 p.m.	*TS*	7,882	8,061		0.7052
	TD	00:02:21	00:01:47	***	0.0001
	TOD	00:00:54	00:00:34	***	0.0000
Trading period: 5:30 p.m. - 8:00 p.m.	*TS*	6,965	12,261	***	0.0000
	TD	00:07:49	00:04:24	***	0.0000
	TOD	00:02:55	00:01:01	***	0.0000

Table V: Probability of information based trading at Frankfurt Stock Exchange (FSE)

This table shows an analysis of the probability of informed trading at the FSE around the change in operating hours at Xetra. The sample is divided into "Before Nov. 3rd, 2003" / "After Oct. 31st, 2003", trading between during regular hours (9:00 a.m. - 5:30 p.m.) / during evening hours (5:30 p.m. - 8:00 p.m.) and high / low trading volume. The parameter μ (ε) is the arrival rate of (un)informed traders, α is the probability of an information event and δ is the probability that the information event is negative. The parameter *PIN* measures the probability of information based trading. We report medians across all securities. Pair-wise Mann-Whitney U tests are used to test the null-hypothesis that two samples are drawn from identical populations. Values after Oct. 31st, 2003 that differ from corresponding value before Nov. 3rd, 2003 at a 0.01; 0.05 or 0.1 level are denoted with a ***; **; *, respectively.

		Before Nov. 3rd, 2003	After Oct. 31st, 2003		p-Value
Low Trading Volume					
Trading day between 9a.m.-5:30p.m.	α	0.342	0.327		0.5841
	δ	0.546	0.646		0.1270
	ε	10.815	16.184	***	0.0004
	μ	12.311	21.456	***	0.0013
	PIN	0.187	0.180		0.9846
	ε / μ #	0.879	0.754		
Trading day between 5:30p.m.-8:00p.m.	α	0.200	0.183		0.2738
	δ	0.365	0.415		0.6815
	ε	0.863	1.068		0.1891
	μ	2.175	2.432		0.4601
	PIN	0.271	0.210		0.2738
	ε / μ #	0.397	0.439		
High Trading Volume					
Trading day between 9a.m.-5:30p.m.	α	0.376	0.325		0.4563
	δ	0.631	0.660		0.4352
	ε	51.792	84.145		0.1525
	μ	112.211	137.227		0.1302
	PIN	0.207	0.201		0.9906
	ε / μ #	0.462	0.613		
Trading day between 5:30p.m.-8:00p.m.	α	0.289	0.248		0.1328
	δ	0.574	0.364	**	0.0333
	ε	4.089	7.891	***	0.0061
	μ	12.496	20.880	*	0.0510
	PIN	0.271	0.201	***	0.0003
	ε / μ #	0.327	0.378		

This parameter is estimated based on the reported ε–and μ-values. Thus no additional pair-wise Mann-Whitney U test is applied.

Table VI: Informational Efficiency at the Frankfurt Stock Exchange (FSE)

This table shows an analysis of the informational efficiency at the FSE around the change in operating hours at Xetra. The sample is divided into "Before Nov. 3rd, 2003" / "After Oct. 31st, 2003", trading between during regular hours (9:00 a.m. - 5:30 p.m.) / during evening hours (5:30 p.m. - 8:00 p.m.) and high / low trading volume. We use a variable constructed from the variance decomposition procedure in Hasbrouck (1993), referred to as *VR(s/p)*. Furthermore, we compute first-order autocorrelations of quote-midpoint returns of equally spaced 15-minutes-intervals, referred to as |*Corr15*|. We report medians across all securities. Pairwise Mann-Whitney U tests are used to test the null-hypothesis that two samples are drawn from identical populations. Values after Oct. 31st, 2003 that differ from corresponding value before Nov. 3rd, 2003 at a 0.01; 0.05 or 0.1 level are denoted with a ***; **; *, respectively.

Measure could not be calculated due to insufficient amount of data.

		Before Nov. 3rd, 2003	After Oct. 31st, 2003		p-Value
Low Trading Volume					
Trading day between 9a.m.-5:30p.m.	*VR(s/p)*	0.411	0.284	***	0.0000
	|*Corr15*|	0.033	0.042		0.8494
Trading day between 5:30p.m.-8:00p.m.	*VR(s/p)*	- / - #	- / - #		
	|*Corr15*|	0.035	0.050		0.8105
High Trading Volume					
Trading day between 9a.m.-5:30p.m.	*VR(s/p)*	0.321	0.260	***	0.0001
	|*Corr15*|	0.106	0.086	*	0.0727
Trading day between 5:30p.m.-8:00p.m.	*VR(s/p)*	0.352	0.433		0.1003
	|*Corr15*|	0.086	0.123		0.1989