Essays on Liquidity in Financial Markets

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to my family

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Introduction

The smooth functioning of financial markets hinges on the ability of market places to limit trading frictions. Liquidity, the possibility to trade a certain amount of an asset at a given point in time without a large price impact, measures the degree of frictions. It is a parameter of great importance for market places wanting to attract order flow from investors, possibly to the detriment of competing trading venues. It is relevant for traders since it determines their transaction costs. Besides, investors and firms care about liquidity because of its link to asset pricing. Liquidity in financial markets depends on various factors. Market microstructure research, which analyzes the process and outcomes of exchanging assets under explicit trading rules, has shown that the organization of a financial market has impacts on liquidity and asset prices. Based on this literature, this dissertation provides new empirical evidence on the determinants of liquidity within a given market and on liquidity migration between competing trading platforms.

Financial markets have been broadly classified as either quote driven dealer markets or order driven auction markets. In *quote driven* markets dealers supply liquidity to the market by posting bid and ask prices. At these prices, they are willing to trade a specified number of securities with public market participants. In pure dealer markets, investors cannot trade without a dealer's or market maker's intervention. Quote driven markets include major foreign exchange and bond markets. This dissertation focuses on electronic limit order markets, which are by now the most important market places for stocks and other securities in many countries throughout the world. In these *order driven* auction markets, traders directly interact with each other without the intermediation of dealers. Liquidity is typically supplied endogenously by market participants submitting limit orders to an open limit order book. It is demanded by market orders or marketable limit orders which initiate a trade by hitting the best posted limit order in the book. Investors can sell a security at the bid price established by the best buy order standing in the book and can buy at the best ask price. Order driven auction markets can be organized as call auction markets or continuous auction markets. In *call auctions*, trading only takes place at certain points in time according to specified rules, often at a single market clearing price. In *continuous auction* markets, trading may occur at any time the limit order book is open and orders are standing in the book. Many exchanges start and end the trading day with call auctions while trading in between is organized as continuous auctions. Often, markets have implemented hybrid features. Chapter 1 of this dissertation examines liquidity provision in a hybrid order driven market where designated market makers compete with other designated liquidity providers and the limit order book. It extends and complements empirical evidence by Nimalendran and Petrella (2003), Anand et al. (2005) and Menkveld and Wang (2008) on whether the introduction of hybrid market structures increases liquidity in electronic limit order markets.

While the first chapter investigates determinants of liquidity within a financial market, liquidity is also a main criterion of distinction for securities exchanges trying to generate and attract high trading volumes. Today, situations in which several trading venues compete for order flow in the same instruments are the rule rather than the exception. To improve our understanding of how competition for order flow influences liquidity, Chapters 2 and 3 analyze rival trading platforms. They relate to theoretical work like Hendershott and Mendelson (2000) or Parlour and Seppi (2003), and a large body of empirical work including Lee (1993) or Boehmer and Boehmer (2003). Chapter 2 contains an analysis of the two important market functions - liquidity and price discovery - on two exchanges in the recently created European market for CO2 emission rights. Chapter 3 investigates the market entry of a pan-European equity trading platform competing for liquidity with primary stock exchanges of 14 European countries.

"Liquidity" is a widely used concept in academic research. However, no single accepted definition exists. As a consequence, there are different interpretations and applications of liquidity in distinct areas, ranging from international finance to asset pricing. Clearly, liquidity is a multi-dimensional concept. Above, it was defined as the possibility to trade a certain amount of a given asset at a given point in time without a large price impact. This definition is in line with the notion of, e.g., Black (1971) and Harris (1990) who distinguish four dimensions of liquidity: width, depth, immediacy, and resilience. These dimensions are made applicable for academic research as follows: The first dimension, width, refers to the bid-ask spread for a given number of securities. The bid-ask spread is defined as the difference between the best quoted ask and the best quoted bid price in the market. It can be interpreted as the cost of a round-trip trade (i.e., of an instantaneous buy and sell transaction). The second dimension, depth, is the corresponding volume or number of securities that can be traded at the given ask or bid price. The third dimension, immediacy, refers to the time period needed to accomplish a transaction of a given size at a given cost. The last dimension, resiliency, measures how fast prices revert to prior levels after having changed due to large transactions that were initiated by uninformed traders and that have no impact on the value of the underlying asset. Apparently, these dimensions are interdependent. For instance, bid-ask spreads are typically a function of volume. Both dimensions depend on immediacy as patient traders may be able to obtain better transaction prices or trade a larger amount at given prices compared to impatient traders. Immediacy is only present if a market is resilient. Otherwise, the possibility to trade instantaneously with a low price impact rarely occurs.

While most liquidity dimensions are at least implicitly covered, the main focus of this dissertation is on bid-ask spreads, which is one of the most prominent liquidity measures analyzed in the market microstructure literature. In quote driven markets or hybrid markets with designated market makers, bid and ask prices are set by dealers or market makers. The theoretic literature on bid-ask spreads concentrates on the quote setting behavior of dealers. It can be broadly divided into three branches. The first branch starting with Roll (1984) explains the existence of bid-ask spreads by order handling costs like labor or telecommunication costs, which are incurred by dealers and reflected in quoted prices. A second class dealing with inventory costs (for instance Garman (1976), Stoll (1978) and Ho and Stoll (1981)) models spreads as arising because of risk-averse dealers who have to be compensated for taking the diversifiable risk of bearing unwanted inventory positions. A third class of models on asymmetric information costs has been pioneered by Bagehot (1971). Formal models include Copeland and Galai (1983), Glosten and Milgrom (1985) and Kyle (1985). These models focus on the adverse selection exposure of market makers posting quotes in the presence of informed as well as uninformed traders. It can be shown that even in markets without explicit transaction costs, with perfect competition and risk-neutral dealers, a spread emerges to compensate the market makers for losses to informed traders. O'Hara (1995) provides an excellent overview on the theoretical work. In pure order driven markets, liquidity is supplied endogenously by market participants. Whereas liquidity providers also incur order handling costs and may want to protect themselves against losses from the existence of asymmetric information in the market, inventory costs are less important since traders do not have an obligation to act as market makers and take unwanted inventory positions. Obviously, an understanding of the sources of trading frictions in a market is important in order to reduce them, and therefore several procedures have been suggested to decompose the bid-ask spread into its components. Chapters 1 and 2 of this dissertation use trade indicator models developed for that purpose by Glosten and Harris (1988) and Madhavan et al. (1997). Apart from theoretical literature on the bid-ask spread, there exists a large body of empirical literature on the determinants of the bid-ask spread and on its components. An overview on this related work is provided in the surveys by Biais et al. (2005) or Madhavan (2000).

One assumption underlying this dissertation is the perception that liquidity is beneficial, both for investors and platform providers. While this view has many proponents and is widely accepted in the market microstructure literature, there is also a literature on the “dark” side of liquidity (compare for instance Keynes (1936)). It points to the fact that liquidity may impose costs on markets and, hence, it can be a source of market destabilization.

The present dissertation examines aspects in liquidity provision which have become relevant due to the proliferation of electronic limit order platforms and ongoing changes in market design and political market regulation. In general, the subsequent analysis is positive. It aims at achieving a better understanding of the determinants of liquidity within a given market as well as liquidity migration between competing trading platforms. By shedding light on determinants of market frictions, the results may give guidance for platform providers, political regulators as well as investors choosing their preferred trading venue. Thus, their implications are important beyond the academic world. This applies to the results of Chapter 1 in which evidence is provided that a particular market design can increase liquidity in that market. It also applies to the findings of Chapters 2 and 3 which indicate that regarding competition for order flow, changes in market organization have rather weak effects, if any. Hence, it appears that with respect to attracting investors to differing trading venues, there are limits to what commonly used changes in market design can achieve.

Chapter 1.[1] One important market design issue for electronic limit order markets is

[1]This chapter is based on the working paper “Designated Sponsors and Bid-Ask Spreads on Xetra” (Hengelbrock (2008)).

the question of whether or not to implement hybrid market structures. While it is not clear from theoretic work that a hybrid market outperforms pure order driven systems (compare, e.g., Glosten (1994), Seppi (1997), Parlour and Seppi (2003) and Viswanathan and Wang (2002)), today many markets have implemented hybrid trading structures. Empirical research suggests that for small and illiquid firms, switching from a pure order driven system to a hybrid system in which a designated market maker competes with the public limit order book improves market quality (compare, e.g., Nimalendran and Petrella (2003), Anand et al. (2005) or Menkveld and Wang (2008)). Chapter 1 extends this line of research by investigating the role of *designated sponsors* on the German electronic equity trading platform Xetra. The Xetra market structure is of research interest for two reasons: In contrast to other exchanges, hiring designated sponsors is *mandatory* for most stocks traded in the continuous auction model. While prior research has focused on illiquid stocks, we investigate benefits of a hybrid system for actively traded stocks affected by these rules. Second, unlike other exchanges, Xetra provides the possibility of trading with more than one designated market maker. Listed sample firms actively use this option. We extend previous research by investigating whether the use of multiple market makers instead of one significantly improves firms' liquidity. Furthermore, we assess *through which channels* multiple market makers have an impact on liquidity by linking the number of designated market makers to components of the bid-ask spread, the measure of liquidity which we employ throughout the paper.

Our results from investigating the influence of the number of designated liquidity providers on magnitude and components of the bid-ask spread confirm that, ceteris paribus, quoted and effective bid-ask spreads of firms trading with one or two designated sponsors are lower than those of firms trading without sponsors. In terms of liquidity, further increases in the number of specialists only pay out for the smallest stocks in our sample. Decomposing the bid-ask spread into its components using the method suggested by Glosten and Harris (1988) and alternatively the concept of realized spreads, we show that benefits of hiring multiple market makers in Xetra mainly stem from inter-dealer competition and inventory risk-sharing. A contribution of the chapter related to the methodological approach is the use of panel data analysis. Contrary to the cross-sectional framework typically employed in the literature, the panel setup allows us to cope with the potential endogeneity of the determinants of the bid-ask spread. Overall, Chapter 1 shows that hybrid elements in an order driven market can improve liquidity for large and actively traded stocks. The findings thus support to promote the use of multiple market makers in electronic limit order markets.

Chapter 2.[2] While in Chapter 1, we investigate competition between market makers and the limit order book within an electronic equity exchange, Chapters 2 and 3 address competition between exchanges. The motivation for Chapter 2 stems from the creation of a European market for CO2 emission rights in January 2005. During the first trading period from 2005 to 2007, organized allowance trading has been fragmented across five trading platforms. The aim of this chapter is twofold. Apart from providing an overview of the development of CO2 trading in the first trading period, we compare the two main futures exchanges ECX and Nord Pool along the main market functions liquidity and price discovery (compare Hasbrouck (1995) and O'Hara (2003)). With respect to liquidity, we estimate traded bid-ask spreads following the approach of Madhavan et al. (1997). To analyze price discovery, the incorporation of new information into prices, we employ the VECM framework by Engle and Granger (1987) and use two measures to quantify the markets' relative contributions to the price discovery process. Our analysis is the first microstructure approach to the European CO2 market which is by now the largest carbon market world wide. No prior work has investigated liquidity in this recent market. While a few studies have investigated price discovery between spot and futures markets in the European carbon market using daily data (compare Seifert et al. (2008), Daskalakis et al. (2009) and Milunovich and Joyeux (2007)), we are the first who investigate price discovery on the most liquid futures exchanges and employ intraday data.

We present evidence that trading frictions in form of transaction costs have markedly decreased on both exchanges in the first trading period and were lower on the larger exchange ECX. Trading volume has strongly increased and price discovery takes place across exchanges with ECX being the price leader for most contracts and time periods. Hence, from a trading perspective the market has made a lot of progress since its operational start in January 2005. The finding that the market has achieved some form of "operational efficiency" is of interest for other countries considering the launch of new emissions trading schemes. Our data allow us to assess how competition between the main exchanges developed over time. Interestingly, our results do not indicate that changes in the platforms' trading protocols cause trends or patterns with respect to liquidity and price discovery on ECX and Nord Pool, a finding which is of interest for platform providers.

[2] This chapter draws on joint work with Eva Benz (Benz and Hengelbrock (2008)).

Chapter 3.[3] Next to investigating competition for liquidity within a securities market and between two securities markets, Chapter 3 analyzes competition between several trading venues. Competition between exchanges in Europe has been spurred by recent regulatory changes, in particular the Markets in Financial Instruments Directive (MiFID) of the European Union allowing the inception of new pan-European trading platforms, the *multilateral trading facilities (MTFs)*. Given that not all new platforms survive, this chapter analyzes determinants of success of a new entrant and addresses questions on whether an increased level of competition leads to an increase in market quality and trading volumes in the primary markets. From a theoretical point of view the answers to these questions are not straightforward because of the existence of network externalities creating barriers to entry. Because fragmentation of the order flow may be detrimental to liquidity, increased competition for order flow does not necessarily increase liquidity.

In particular, we analyze the market entry of the pan-European MTF Turquoise on which by October 2008, stocks from 14 European primary markets could be traded. We analyze cross-sectional determinants of Turquoise market shares, considering both firm-specific and market-specific variables. We use a panel approach to examine whether changes in market design by primary exchanges had an impact on market shares. We further test whether the entry of Turquoise has led to an increase in total trading volumes and/or liquidity in the home market. Our main results are that both stock and market characteristics determine Turquoise market shares, the most important variables being measures of liquidity, volatility, firm size and market capitalization of the primary markets. We find ambiguous evidence as to whether overall market quality changed after the entry of Turquoise. Our data furthermore suggest that average best bid-ask spreads on Turquoise exceeded those of the primary markets in the period between November 2008 and January 2009. The research is closely related to other papers analyzing competition for order flow. While different theoretical work like Hendershott and Mendelson (2000), Parlour and Seppi (2003) and Degryse et al. (2009) concludes that the introduction of an additional market has an ambiguous effect on overall welfare, existing empirical evidence yields the conclusion that competition is “good”. Our own results are somewhat weaker, but indicate a slightly positive impact on market quality.

[3] This chapter draws on joint work with Erik Theissen (Hengelbrock and Theissen (2009)).

Chapter 1

Designated Sponsors and Bid-Ask Spreads on Xetra

In order to enhance liquidity, Deutsche Börse AG postulates that most firms listed on the electronic limit order platform Xetra contract services of a designated sponsor. Interestingly, a lot of firms opt for trading with more than one designated liquidity provider. This chapter provides a panel data assessment of the influence of designated sponsors on magnitude and components of the bid-ask spread. We find that while spreads narrow when trading with one or two designated sponsors, further increases in the number of specialists do not necessarily pay out in terms of higher liquidity. Results differ across market segments and sponsor firms. We provide evidence that the effect of designated sponsors on bid-ask spreads is related to inter-dealer competition and risk sharing, but not to a decrease in adverse selection costs.

1.1 Introduction

While organized stock markets have traditionally been classified as either quote driven dealer markets or order driven auction markets, today most exchanges have implemented hybrid market structures. The proliferation of electronic open limit order books and theoretic work like Glosten (1994), Seppi (1997), Parlour and Seppi (2003) and Viswanathan and Wang (2002) has led to the empirical question of whether market quality in order driven systems can be improved by introducing hybrid elements into the market structure. Recent empirical evidence suggests that for small and illiquid firms, switching to a hybrid order driven system in which a designated market maker competes with the public limit order book improves market quality measures (compare e.g. Nimalendran and Petrella (2003), Anand et al. (2005) or Menkveld and Wang (2008)). The present chapter extends this line of research by investigating the role of designated market makers on the electronic platform Xetra. *Designated sponsors* have been introduced at the end of the 1990s as mandatory market makers for stocks with "insufficient" liquidity. By posting binding bid and ask quotes as well as participating in call auctions, the existence of designated sponsors assures that assets can be traded at a "fair" price at any point in time and thus increases incentives for investing in these securities.

Examining the hybrid market structure on Xetra is interesting for two reasons: First, one peculiarity of Xetra is that hiring designated sponsors is *mandatory* for most stocks traded in the continuous auction model. Since the reduction of liquidity risk is expected to be particularly beneficial for rather illiquid stocks with a low market capitalization,[1] this leads to the question of whether the restriction makes sense for rather actively traded stocks. Second, unlike other exchanges, Xetra provides the possibility of (and even used to require) trading with more than one designated market maker. Listed sample firms make active use of this option, trading with up to five designated sponsors. We extend previous research by investigating whether increasing the number of designated market makers beyond one has significant effects on firms' liquidity.[2] Furthermore, we assess *through which channels* multiple market makers have an impact on liquidity by linking the number of designated market makers to single components of the bid-ask spread in line with inventory models like in Biais et al. (2005). We focus our attention on bid-ask spreads as one of the most important measures of trading costs and liquidity in financial markets. Note that while Menkveld and Wang (2008) also analyze a multiple market maker setting, the authors address complementary questions.

Our results from investigating the influence of the number of liquidity providers on magnitude and components of the bid-ask spread confirm that, all else equal, bid-ask spreads of firms trading with (several) designated sponsors are lower compared to those of firms trading without sponsors. Results apply to rather actively traded stocks in the mid cap, technology, and small cap market segments of Xetra during the time period from January 2004 to December 2006. While bid-ask spreads clearly decrease when hiring the first designated sponsor, effects of contracting further sponsors depend on the market segment

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[1] Compare e.g. Pastor and Stambaugh (2003) or Acharya and Pedersen (2005). Compare as well Amihud et al. (2005) for an extensive survey of theoretical and empirical literature on liquidity (risk) and asset pricing.

[2] Due to data restrictions, the present analysis solely focuses on liquidity. It would be interesting to conduct a cost-benefit analysis taking into account that firms often compensate sponsors for their services.

under scrutiny. The existence of a bid-ask spread is typically explained by trading frictions associated with the existence of order handling costs, inventory costs, asymmetric information costs or non-competitive mark-ups. We show that benefits of hiring multiple market makers on Xetra mainly stem from inter-dealer competition and inventory risk-sharing. Apart from contributing to the literature by investigating the case of several designated market makers instead of one and by examining their influence not only the size, but also on the single components of the bid-ask spread, this paper includes a nice methodological feature. We make use of the fact that the number of market makers in our sample varies both in the cross-section and over time and investigate determinants of bid-ask spreads in a panel data set up as opposed to existing cross-sectional work. This approach allows us to mitigate issues related to the endogeneity of variables like trading volume which related work often has to neglect.

In addressing our questions of interest we proceed as follows: After a brief literature review in section 2, section 3 contains the institutional background, introducing the reader to the market structure, the concept of designated sponsoring and the data set. Sections 4 and 5 present the empirical analysis: Section 4 introduces several spread measures and presents a panel data approach to investigate the influence of designated sponsors on bid-ask spreads. Section 5 applies a trade-indicator model to the data and uses obtained results in order to assess which component of the spread is particularly influenced by the market makers. Furthermore, results from a spread decomposition using realized spreads are presented. Section 6 concludes.

1.2 Related Literature

Apart from the vast literature on NYSE specialists, there exist a few studies on a more “European” type of liquidity provider on electronic limit order platforms, enjoying markedly lower privileges compared to the US-American counterpart.[3] All studies analyzing the introduction of designated market markers find an increase in market quality as measured by bid-ask spreads, depth or volatility levels. Often, the announcement of the introduction of liquidity providers is accompanied by positive abnormal stock returns. Specifically, Nimalendran and Petrella (2003) investigate a regulatory change by

[3]With respect to general literature on market microstructure, compare e.g. O’Hara (1995) or the surveys by Madhavan (2000) and Biais et al. (2005). Relating to literature on the NYSE specialist, compare e.g. Venkataraman and Waisburd (2007).

the Italian Stock Exchange (ISE) to improve market quality of thinly traded stocks. In 1997, these stocks were given the option to either trade on a pure order driven market or on a hybrid system with a specialist and a limit order book. Using a matched-sample event study approach, the authors isolate the specialists' effect for 20 stocks choosing the hybrid system.[4] Nimalendran and Petrella differentiate their analysis with respect to stock liquidity and find that "very" illiquid shares (classified by market capitalization) profit more from the adoption of a hybrid system compared to moderately illiquid shares. In a similar study, Anand et al. (2005) examine the 2002 decision by the Stockholm Stock Exchange allowing firms to contract liquidity providers in order to assure quality standards as maximum spread or minimum depth levels. The authors employ an event study framework to investigate changes in market quality for a sample of 50 firms and use cross-sectional regressions to study determinants of liquidity provider compensation and contract terms.[5] Venkataraman and Waisburd (2007) examine the value of designated market makers for non-liquid stocks on the Paris Bourse, also implementing an event study approach. In their sample consisting of 75 firms choosing the market maker approach and 206 firms trading without, the authors find that younger, smaller and less volatile firms are more likely to opt for trading with an *animateur* who will induce more frequent trading as well as lower book imbalances. As a fundamental difference to the other studies, Venkataraman and Waisburd (2007) study stocks that trade in two daily call auctions and not continuously. The authors argue that positive announcement returns from the introduction of designated market makers show that purely endogenous liquidity provision might not be the optimal trading mechanism for smaller stocks. A related study is Menkveld and Wang (2008), investigating designated market making on Euronext in the Netherlands. Contrary to the three studies above, the authors employ a panel data approach comprising 20 months for 74 firms which had contracted at least one DMM (Designated Market Maker) in October 2001. To our knowledge, this paper is the only one next to us examining an electronic limit order market with active use of the possibility to hire *more than one* liquidity provider. The authors address the question of how designated market making creates firm value as measured by abnormal announcement returns and find that value creation is related to changes in both the liquidity level and liquidity risk. We now introduce the reader to the institutional background.

[4] Compare Nimalendran and Petrella (2003), p. 1831.

[5] The authors stress that liquidity providers in their analysis differ in "very fundamental ways" from NYSE specialists. Compare Anand et al. (2005), p. 3.

1.3 Institutional Background and Data

1.3.1 Market structure

Xetra is the fully electronic order-driven trading system of Deutsche Börse AG for cash market trading in equities and other instruments. It was introduced in November 1997. Today, more than 90% of equity trading on German stock exchanges is conducted on Xetra. Equities can be traded in call auctions or continuously. Continuous trading is initiated with an opening auction and ends with a closing auction. It is interrupted by a regular intra-day call auction, volatility interruptions may occur. During the time of a call auction, the order book is partially closed. Continuous trading on Xetra takes place from 9.00 a.m. till 5.30 p.m. The opening auction starts at 8.50 a.m. while the closing auction begins at 5.30 p.m.[6] Buy and sell orders are matched in the order book, orders are executed according to price and time priority. Trading is anonymous for all parties, trades are processed through a central counterparty.[7]

1.3.2 Designated sponsors

Designated sponsors were introduced on Xetra at the end of the 1990s in order to provide liquidity to the market, to smooth prices and to bridge temporary imbalances in order flow. They assure higher liquidity by quoting binding bid and ask prices (subject to maximum spread and minimum depth restrictions), by participating in call auctions, volatility interruptions and by responding to quote requests. Unlike on other electronic limit order platforms, it is mandatory for listed firms with low levels of liquidity to trade with a designated sponsor if they want to use the continuous trading model. Deutsche Börse AG recommends trading with two designated sponsors. The designated sponsor requirements are based on both the daily computed Xetra Liquidity Measure XLM and on turnover. Before April 2003, the mandatory number of designated sponsors was linked to the index segment, being two (one) for stocks in the trading segment NEMAX (SMAX). XLM reflects market impact costs or implicit transaction costs and is computed as the difference between average execution price and quoted midpoint for a round-trip of a given

[6]Note that the daily auction times for stocks listed in the MDAX and SDAX segment compared to DAX or TecDAX stocks slightly differ.

[7]Information is obtained from Deutsche Börse's official website www.deutsche-boerse.com and in particular from the section on the Xetra Market Model.

order volume. Deutsche Börse AG ranks stocks quarterly on the basis of the preceding four months period and publishes the updated liquidity categories. Stocks in category A do not require designated sponsoring services, while stocks in category B do so. Depending on XLM size, minimal quoting criteria and maximum spreads are set.[8] The sponsor's performance is measured and published quarterly.

Sponsors are compensated for their service through several channels: In case of fulfilling their obligations, they benefit from a rebate of exchange fees. Since designated market making is not generally a profit-making activity, especially for volatile stocks, sponsors are often compensated by a fee from the respective company. A recent survey reports an average annual fee of 34,000 Euro.[9] Designated sponsors are mainly financial services providers, brokers or banks. Due to the fact that they continuously watch the market, liquidity suppliers gain expertise. They often use this information to offer additional services to their clients in areas like research, sales or investor relations. Cross-selling aspects may be a dominant motivation to offer market making services. For the covered firm, these services might be attractive in that they provide access to a broader investor base and in that they increase investor awareness, transparency and possibly market valuation. Figure 1 depicts the development of the average number of designated sponsors over time. Interestingly, the behavior differs across market segments.

1.3.3 Data

In order to construct our panel data set and to compute spread measures, we employ time-stamped Xetra data of best bid, best ask and transaction prices from January 2004 to December 2006 which we obtained from Deutsche Börse AG. Our original sample consists of 130 stocks listed in the mid cap, technology and small cap market segments MDAX, TecDAX and SDAX after the index reorganization in April 2003. We exclude penny stocks and stocks with an average price below 2 Euro from the analysis. Doing the same for stocks for which less than 25 months of observations are available due to de-listing,

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[8] Category A contains stocks with an XLM smaller or equal 100 base points for a hypothetical order volume of 25,000 Euro and an average daily turnover of 2.5 million Euro or more. Stocks not complying with both criteria are classified as category B and are divided into several sub-groups. For instance, for stocks with an XLM between 100 and 500 base points, the minimum quoting volume is equal to 20,000 Euro and the maximum spread is set to 4%. For further information, compare the website www.deutsche-boerse.com.

[9] Compare *Going Public*, Volume 10/07, p. 56.

takeovers or the like, our sample for the panel data analysis is further reduced to 110 stocks. Prices determined during intra-day call auctions, opening and closing auctions are omitted as are relative price jumps above 50% compared to the prior price. An indication whether the trade was buyer- or seller-initiated is not included in the data. We therefore use the trade classification algorithm proposed by Lee and Ready (1991).[10] We pool trades which occur within the same centisecond in the same direction to account for volume related effects and calculate volume weighted transaction prices. In a last step, we build monthly averages of computed spread measures. Summary statistics for our sample are presented in Table 1.1. They are disaggregated by trading segments. Other firm data is obtained from Thomson Reuters Datastream.

1.4 Methodology and Results I

1.4.1 Quoted, effective and realized spreads

In this section, we introduce different spread measures following Huang and Stoll (1996) and subsequently employ them as dependent variables in panel data estimations. The *quoted spread* is the difference between the best quoted ask and the best quoted bid price and can be interpreted as the cost of a round-trip trade (i.e. of an instantaneous buy and sell transaction). Since we want to measure the cost per transaction, we employ quoted half spreads. The definition of the (percentage) quoted half spread is given by

$$S/2_t^{quoted} = (a_t - b_t)/2, \qquad S/2_t^{quoted} \text{ in } \% = 100(a_t - b_t)/2M_t,$$

where a_t is the best quoted ask price, b_t is the best quoted bid price and $M_t = \frac{a_t+b_t}{2}$ is the midpoint between the best quotes. The upper panel of Table 1.2 reports average quoted half spreads for our sample disaggregated by market segments. Expectedly, the MDAX segment, which contains the largest stocks, reports the lowest spreads with average percentage half spreads amounting to 0.19%, followed by TecDAX stocks with 0.36% and

[10]The trade classification algorithm by Lee and Ready identifies transactions as purchases and sales by comparing the transaction price to the best quoted bid and ask prices. A transaction is considered as buyer-initiated if it is closer to the ask price of the prevailing quote and vice versa. If the transaction occurs exactly at the midpoint of the quote, a tick test is implemented. In case the last price change prior to the transaction is positive (negative), the transaction is categorized as buyer-/seller-initiated.

Table 1.1: Descriptive statistics I: Firm characteristics

MDAX averages of	Mean	Std.Dev.	Min.	Max
Market cap. in million Euro	2,556.55	3,280.45	92.57	27,118.91
Total assets in million Euro	14,732.13	36,104.59	134.08	228,578.00
Common shares in million	108.00	134.33	7.43	802.13
Market to book value	2.32	1.81	0.24	12.61
Number of DS	1.47	0.95	0.00	5.00
Price	37.93	37.03	3.04	316.80
Trading volume in shares	657.91	436.25	103.75	3,016.37
Trading volume in Euro	16,273.12	7,028.99	3,120.04	63,957.06
Monthly turnover in million Euro	121.82	150.34	1.07	1130.45
TecDAX averages of	Mean	Std.Dev.	Min.	Max
Market cap. in million Euro	1,061.62	2,105.193	34.28637	13,368.98
Total assets in million Euro	817.09	1,178.84	38.37	6,308.60
Common shares in million	93.31	225.24	5.68	1,223.89
Number of DS	1.97	1.04	0.00	6.00
Market to book value	2.33	1.70	0.52	12.51
Price	17.62	13.73	2.24	63.32
Trading volume in shares	828.92	571.45	162.13	7,800.51
Trading volume in Euro	9,810.37	4,949.18	1,025.00	69,307.39
Monthly turnover in million Euro	50.37	79.89	0.00	940.70
SDAX averages of	Mean	Std.Dev.	Min.	Max
Market cap. in million Euro	409.37	398.46	15.59	2,862.94
Total assets in million Euro	2,288.15	14,223.24	101.05	117,859.10
Common shares in million	34.41	32.10	3.78	165.91
Market to book value	2.26	2.03	0.17	16.92
Number of DS	1.45	0.68	0.00	4.00
Price	20.66	19.81	1.35	157.42
Trading volume in shares	705.95	501.88	69.69	4,189.80
Trading volume in Euro	9,323.04	5,532.27	1,350.84	69,382.88
Monthly turnover in million Euro	7.54	10.57	0.04	102.85

This table contains summary statistics for the 110 sample stocks disaggregated by the trading segment. Key financial figures are obtained from Thomson Reuters Datastream.

Table 1.2: Descriptive statistics II: Average half spreads

Index	Quoted Half Spread	Std.Dev.	Min.	Max.	Half Spread in %	Std.Dev.
MDAX	0.0604	0.0502	0.0080	0.3193	0.1890	0.1165
TecDAX	0.0490	0.0573	0.0054	0.9295	0.3550	0.9268
SDAX	0.1108	0.1242	0.0104	1.9260	0.5965	0.3127
Index	Effective Half Spread	Std.Dev.	Min.	Max.	Half Spread in %	Std.Dev.
MDAX	0.0375	0.0305	0.0068	0.2666	0.1221	0.0805
TecDAX	0.0361	0.0601	0.0053	1.0200	0.2973	1.1287
SDAX	0.0807	0.0857	0.0084	0.7304	0.4418	0.2383
Index	Realized Half Spread	Std.Dev.	Min.	Max.	Half Spread in %	Std.Dev.
MDAX	0.0096	0.0150	-0.0545	0.1614	0.0395	0.0503
TecDAX	0.0161	0.0472	-0.0145	0.9252	0.1602	0.9308
SDAX	0.0418	0.1279	-0.5434	4.1043	0.2317	0.3368

This table contains summary statistics for different bid-ask spread measures that were computed for the 110 sample firms and aggregated to monthly averages.

SDAX stocks with 0.60%.[11]

The *effective half spread* measures the difference between the trade price and the time-of-trade quote midpoint. It is also called the liquidity premium and is defined as follows:

$$S/2_t^{effective} = |P_t - M_t|; \qquad S/2_t^{effective} \text{ in } \% = 100|(P_t - M_t)|/M_t.$$

P_t is the transaction price at time t and M_t is defined as above. The effective half spread is only measured during transactions, in contrast to the quoted spread. It is then equal to the quoted spread since transactions only take place at the bid or ask price. However, due to the fact that trades rather occur when spreads are relatively tight, the average effective spread is smaller than the average quoted spread for all index segments (compare the middle panel of Table 1.2).

The *realized spread* is the gross revenue of the liquidity provider and equals the differ-

[11]Comparing spread magnitudes to those of other papers presented in section 1.2, we find that our sample stocks are markedly more liquid, which is partly due to the different time horizon and firm size chosen.

ence between the initial trade price and a subsequent trade price when the position is liquidated. As is common in the literature, we compare transaction prices to the quoted midpoint in place five minutes after the trade.[12] Then, conditional on a trade at the ask or bid price, the realized (percentage) half spread can be computed as:

$$S/2_t^{realized|a_t} = [P_t - M_{t+\tau}|P_t = a_t], \quad S/2_t^{realized|a_t} \text{in } \% = 100[P_t - M_{t+\tau}|P_t = a_t]/M_t;$$
$$S/2_t^{realized|b_t} = [M_{t+\tau} - P_t|P_t = b_t], \quad S/2_t^{realized|b_t} \text{in } \% = 100[M_{t+\tau} - P_t|P_t = b_t]/M_t.$$

Because of potential information possessed by some traders, prices tend to move against the market maker after a trade, meaning that they rise (fall) after a market maker's sale (purchase). In this case, the gross revenue of the dealer will be smaller than the effective spread. Asymmetric information costs of a trade can then be computed by subtracting realized from effective spreads. Sample averages for realized half spreads are depicted in the lower panel of Table 1.2, they are markedly smaller than effective spreads.[13]

1.4.2 Panel data estimation

To exploit the fact that we have variation in the number of market makers not only in the cross-section but also the time series dimension, we use a panel data framework to examine the influence of designated sponsors on the bid-ask spread. A general panel data model takes the following form:

$$y_{it} = x_{it}'\alpha + w_{it}'\beta + v_i + u_{it}, \quad i = 1, ..., N; \quad t = 1, ..., T. \tag{1.1}$$

x_{it} is a vector of strictly exogenous covariates, possibly including time constants. w_{it} is a vector of potentially endogenous covariates, all of which might be correlated with v_i, the unobserved individual heterogeneity. w_{it} might include lagged values of the dependent variable y_{it}. u_{it} is the i.i.d. error term. When estimating model (1.1), one mainly faces two problems. The first one is how to cope with the unobserved individual heterogeneity v_i, the second one is how to account for possible endogeneity of regressors. With respect

[12] Ideally, the realized spread is calculated by comparing the transaction price to the next differently signed transaction price after time τ has passed. τ is to be set long enough such that information related to the trade has been impounded into prices, but short enough such that prices do not change due to other incoming information. Compare the discussion in Huang and Stoll (1996), pp. 326.

[13] Disaggregated by index segments, equality of quoted and effective, quoted and realized as well as realized and effective half spreads can be rejected at a 1% significance level.

to the first problem, standard procedures like first differencing or the fixed effects (within) transformation can be used. If we are willing to assume that all regressors are strictly exogenous in a statistical sense,[14] a natural estimation approach is fixed effects (within) estimation, delivered by averaging model (3.4) over time and then subtracting averages from the original equation in order to remove v_i. We can then estimate the following equation by OLS:

$$y_{it} - \overline{y}_i = (x_{it} - \overline{x}_i)'\alpha + (w_{it} - \overline{w}_i)'\beta + u_{it} - \overline{u}_i, \quad i = 1, ..., N, \quad t = 1, ..., T, \qquad (1.2)$$

where $\overline{a}_i = 1/T \sum_{t=1}^{T} a_{it}$. Unfortunately, this approach is inconsistent if an explanatory variable in some period is correlated with the error term. In our application, besides our main variables of interest, we include control variables like average market capitalization, average trading volume in shares, standard deviation of returns and average stock price as regressors.[15] Regarding the literature, a contemporaneous relation between the average trade size and average bid-ask spreads has been stated. It is not clear whether this relation persists on a monthly basis, but it may be wise to introduce another approach besides fixed effects estimation.

With respect to control variables, we believe that for the time horizon of our estimations, it is reasonable to regard firm size, stock price and volatility as exogenous. For the most important regressor, the number of designated sponsors, the question to ask is whether firms base their decision to alter their sponsor structure on (current) trading conditions.[16] It appears reasonable that it typically takes at least a month to establish a contact to a sponsor and to set up a contract. Since contracts are typically specified for at least a year, firms cannot dismiss their sponsor quickly, reducing a contemporaneous relation between the number of sponsors and u_{it}. Most important, all firms and sponsors we talked to confirmed that they regard the choice of a sponsor as a long-term decision. They do not seem to react to a temporary change in market conditions.[17] This implies that if past market conditions influence the number of designated sponsors, it is reasonable to

[14]Compare e.g. Wooldridge (2002), pp. 252.

[15]For empirical cross-sectional evidence on determinants of the bid-ask spread, cf. related literature of e.g. Stoll (2000), Corwin (1999), Cao et al. (1997) or Madhavan (2000).

[16]From section 1.3.2, we know that the requirement to hire the first sponsor is a function of lagged bid-ask spreads and trading volumes. However, firms tend to have more sponsors than they need and we hardly observe reactions to changes in liquidity classes.

[17]In fact, it seems that in most cases firms decide whether or not to alter the number of sponsors towards the end of the contract period which typically does not coincide with the calender year.

assume a delay of several months. This facilitates the econometric analysis if, as a second approach, we remove individual heterogeneity by first differencing to obtain:

$$\Delta y_{it} = \Delta x'_{it}\alpha + \Delta w'_{it}\beta + \Delta u_{it}, \quad i = 1, ..., N, \quad t = 1, ..., T, \tag{1.3}$$

where $\Delta a_{it} = (a_{it} - a_{it-1})$. This approach has the advantage that lags of endogenous variables from time $t-2$ to the beginning of the estimation period are uncorrelated with the error term Δu_{it}.[18] Our discussions imply that only average trade size has to be instrumented with its lags. Out of efficiency considerations, we opt for a GMM procedure that instruments the differenced variables which are not strictly exogenous with available lags in levels.[19] Since the Arellano-Bond (1991) estimator has been designed for dynamic models, we will later on confirm that results are robust to dynamic specifications including y_{it-1} as a pre-determined variable. Applied to our model setting, the specification becomes:

$$\begin{aligned} \Delta S/2_{it} &= \alpha_1 \Delta DS_{it} + \alpha_2 \Delta LnMarketcap_{it} + \alpha_3 \Delta SD_{it} \\ &\quad + \alpha_4 \Delta Price_{it} + \beta_1 \Delta Volume_{it} + \Delta u_{it}, \quad i = 1, ..., N, \quad t = 1, ..., T. \end{aligned} \tag{1.4}$$

The dependent variable S is either the quoted or effective half spread, denoted in percentage terms. DS stands for the influence of designated sponsors which we will test in several specifications. $LnMarketcap$ is the log market capitalization, $Volume$ denotes the average trading volume in shares. SD stands for the standard deviation of daily returns computed on a monthly basis, $Price$ for the average trading price.[20] All averages are monthly. For all estimations, we employ the robust Huber/White sandwich estimator of the variance-covariance matrix.

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[18]Consider e.g. the simple case with $\Delta y_{it} = \alpha_1 \Delta x1_{it} + \beta_1 \Delta w1_{it} + \Delta u1_{it}$ and $\Delta w1_{it} = \gamma_1 \Delta y_{it} + \delta_1 \Delta w1_{it-1} + \Delta e_{it} = \gamma_1 \Delta(\alpha_1 \Delta x1_{it} + \beta_1 \Delta w1_{it} + \Delta u1_{it}) + \delta_1 \Delta w1_{it-1} + \Delta e_{it}$. Apparently, $\Delta w1_{it}$ is correlated with $\Delta u1_{it}$ as is $\Delta w1_{it-1}$, but there is no more correlation from $t-2$ onwards.

[19]Compare e.g. Holtz-Eakin et al. (1988) and Arellano and Bond (1991). In our application, we reduce the number of instruments stepwise to keep them not too large compared to the number of groups. Presented results include lags 2 to 5. Correlations between differenced volume and its lags are significant at a level of 1%, the Hansen/Sargan statistic assures that instruments are not correlated with the error term.

[20]Employing lagged values of the standard deviation does not change results.

Results

Our Xetra sample includes data on 110 stocks selected as indicated in section 1.3.3 for the 36 months period from January 2004 to December 2006. For estimations using stocks from all market segments, we exclude firm months in which less than 100 trades were observed. Hence, we focus on more active shares that trade on average at least four to five times a day in the continuous trading model.[21] As a consequence, we dispose of a maximum of 3,603 observations for our estimations. We estimate all specifications including the variables introduced above, year dummies and index dummies. Stata results for quoted and effective half spreads are reported in Tables 1.3 to 1.8.[22]

In order to assess whether firms with designated sponsors have lower spreads compared to firms trading without sponsors, we start by estimating model (1.4) including the indicator variables $DS1$, $DS2$ and $DS345$ that are equal to one if the firm has hired one (two, three to five) designated sponsors and zero otherwise.[23] The index (a) in specifications denotes OLS fixed effects estimation while (b) to (e) stand for GMM estimation. Our focus is on GMM estimations since they control for potential endogeneity of trading volume. Results for quoted and effective spreads are presented in Tables 1.3 and 1.4. The coefficients of $DS1$, $DS2$ and $DS345$ are negative in all specifications. While $DS2$ and $DS345$ are statistically significant at a level of at least 5% in all models, $DS1$ is statistically different from zero at a level of 10% in all quoted spread estimations, but only in two of five effective spread estimations. For all GMM specifications, test of equality fail to reject the null hypothesis that the value of $DS2$ is equal to the value of $DS345$. Note that the magnitude of estimates is in general lower for effective spreads in line with the fact that effective spreads are lower than quoted spreads.

To obtain an idea of the economic significance of estimates, imagine two otherwise identical firms from the sample population with a monthly trading turnover of 10 million Euro. One firm is trading with one designated sponsor as required, the other firm has contracted two sponsors. Specification (2b) predicts that monthly transaction costs measured by effective spreads for the first firm are 2,200 Euro above the costs of the second firm per month or

[21]This filter is mainly implemented with respect to subsequent realized spread estimations. Results from including “inactive firm months are similar. For comparability, we depict some estimation results in Tables 1.3 to 1.8.

[22]For more details on the xtabond2 estimation procedure in Stata, compare Roodman (2006).

[23]Since only about 11% of firms trade with more than two sponsors, we collapse these observations into one indicator $DS345$ instead of creating more indicators.

26,400 Euro per year. Note, however, that due to the indirect nature of our investigation, we are rather cautious about a quantitative interpretation of results.

With respect to control variables, we detect a significantly negative impact of log market capitalization and trading volume. The coefficient of SD is positive and significant at a level of 1% in all cases, in line with the theory that compensation for risk-averse liquidity providers increases in security risk. The average price level of stocks does not systematically influence bid-ask spreads. Signs for time and index dummies (not depicted) meet our expectations. Overall, results for the control variables are in line with former literature which is reassuring with respect to model specification.[24]

The static GMM estimations (1b) and (2b) serve as baseline specifications. As we stated before, we include dynamic versions of our different specifications as a robustness check. Results are similar and presented as specifications (c). Another issue relates to *commonality in liquidity*, the finding that one firm's bid-ask spreads are often influenced by bid-ask spreads of other firms in the market or industry (compare e.g. Chordia et al. (2000)). To control for commonality in liquidity, we repeat the same exercise but additionally include a variable measuring the average spread of all firms j in the sample except for firm i. The variable $S/2_{-i}$ is highly significant at a level of 1% and positive in all specifications (d) while other results remain stable.[25]

In order to model the fact that effects of designated market making are not linear, we estimate analog specifications in which we include the number of designated sponsors NO_DS and its square NO_DS2 as regressors instead of indicator variables for designated sponsorship. Results are depicted in Tables 1.5 and 1.6 and confirm the picture from the first estimations: Firms trading with designated sponsors have c.p. lower spreads compared to firms trading without as can be inferred from the negative sign of the NO_DS coefficient. The effect of adding sponsors is not linear which is indicated by a positive sign of NO_DS2. Note, however, that the square of the number of sponsors is not always significant. Hence, it appears that the more flexible approach using indicator variables better fits our data structure.

Overall, controlling for all variables known to influence monthly bid-ask spreads on equity

[24] For the GMM estimations, these and all further specifications pass the Hansen test of over-identifying restrictions. However, with reasonable lags included as instruments, the number of instruments remains above the number of observations, significantly weakening the results of the Hansen test.

[25] Note that estimation results for static specifications are similar.

Table 1.3: Results with $DS1$, $DS2$ and $DS345$ for quoted half spreads in %

	$S^{Quoted}/2$ in %					
	OLS	GMM	GMM	GMM	GMM	GMM
	(1a)	(1b)	(1c)	(1d)	(1e)	(1e')
	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.
Variable	$(\lvert t-stat\rvert)$	$(\lvert z-stat\rvert)$	$(\lvert z-stat\rvert)$	$(\lvert z-stat\rvert)$	$(\lvert z-stat\rvert)$	$(\lvert z-stat\rvert)$
$DS1$	-0.067***	-0.056**	-0.042*	-0.056**	-0.056**	-0.333**
	(4.43)	(2.01)	(1.88)	(2.02)	(2.01)	(2.20)
$DS2$	-0.113***	-0.091***	-0.084***	-0.111***	-0.109***	-0.371**
	(6.51)	(2.76)	(2.82)	(3.22)	(3.11)	(2.26)
$DS345$	-0.117***	-0.081**	-0.099***	-0.131***	-0.128***	-0.386**
	(6.13)	(2.34)	(3.03)	(3.34)	(2.98)	(2.36)
$LnMCap$	-0.217***	-0.189***	-0.173***	-0.144***	-0.144***	-0.206***
	(13.53)	(5.04)	(5.15)	(4.10)	(4.10)	(4.53)
$Volume$	-8e-05***	-9e-05***	-1e-04**	-8e-05**	-8e-05**	-1e-04**
	(5.59)	(2.01)	(2.10)	(2.10)	(2.10)	(2.24)
SD	3.097***	2.271***	2.428***	2.043***	2.043***	2.374***
	(8.24)	(5.46)	(5.48)	(4.58)	(4.58)	(5.37)
$Price$	0.001***	2e-04	1e-04	0.001	0.001	0.004**
	(4.66)	(0.25)	(0.17)	(1.20)	(1.20)	(2.09)
$S^{Quot.}/2_{t-1}$			0.172**	0.151*	0.150*	0.148**
			(2.46)	(1.90)	(1.90)	(2.18)
$S^{Quot.}/2_{-i}$				0.366***	0.366***	0.496***
				(6.32)	(6.28)	(5.71)
$\mathbf{1}_{Broker}$					-0.008	-0.147***
					(0.23)	(2.73)
$Const.$	4.967***					
	(15.05)					
$Obs.$	3,603	3,498	3,497	3,497	3,497	3,809
R^2 within	0.34					

Remark: ***, ** and * denote significance at the 1%, 5%, and 10% level, respectively. z- and t-statistics are based on robust standard errors. Model (1a) is estimated by OLS fixed effects estimation (FE, within estimator), the other models by GMM. The instruments are lagged levels from $t-2$ to $t-5$ of average trading volume in shares and, additionally, the average spread of sample firms excluding firm i in specifications (1d) and (1e). DSx and $DSxyz$ are indicator variables equal to one if the average number of designated sponsors for the current month equals x, y or z and zero otherwise. Model (1e') corresponds to model (1e) including inactive firm months with less than 100 trades. For the definition of the other variables and more details, compare section 1.4.2. Time and index dummies are not depicted.

Table 1.4: Results with $DS1$, $DS2$ and $DS345$ for effective half spreads in %

	$S^{Effective}/2$ in %					
	OLS (2a)	GMM (2b)	GMM (2c)	GMM (2d)	GMM (2e)	GMM (2e')
Variable	Coef. ($\|t-stat\|$)	Coef. ($\|z-stat\|$)	Coef. ($\|z-stat\|$)	Coef. ($\|z-stat\|$)	Coef. ($\|z-stat\|$)	Coef. ($\|z-stat\|$)
$DS1$	-0.036***	-0.020	-0.027*	-0.029	-0.028	-0.244***
	(3.25)	(1.49)	(1.69)	(1.37)	(1.35)	(3.28)
$DS2$	-0.080***	-0.042**	-0.060***	-0.067***	-0.064***	-0.241***
	(6.30)	(2.15)	(2.80)	(2.59)	(2.51)	(2.87)
$DS345$	-0.092***	-0.038**	-0.071***	-0.080***	-0.076***	-0.254***
	(6.25)	(2.01)	(3.04)	(2.90)	(2.60)	(2.91)
$LnMCap$	-0.165***	-0.123***	-0.141***	-0.133***	-0.134***	-0.141***
	(12.97)	(3.65)	(4.26)	(3.90)	(3.91)	(3.27)
$Volume$	5e-05***	-6e-04**	-8e-05**	-7e-05**	-7e-05**	-1e-04**
	(5.36)	(2.08)	(2.13)	(2.16)	(2.16)	(2.23)
SD	3.246***	1.489***	1.587***	1.473***	1.470***	1.757***
	(7.83)	(4.61)	(4.85)	(4.40)	(4.39)	(4.78)
$Price$	9e-04***	4e-05	2e-05	6e-04	6e-04	0.003*
	(4.69)	(0.07)	(0.03)	(0.85)	(0.84)	(1.87)
$S^{Eff.}/2_{t-1}$			-0.005**	-0.005**	-0.005**	0.010
			(2.35)	(2.37)	(2.08)	(0.60)
$S^{Eff.}/2_{-i}$				0.198***	0.198***	0.372***
				(4.49)	(4.47)	(5.07)
$\mathbf{1}_{Broker}$					-0.011	-0.136***
					(0.34)	(3.61)
$Const.$	3.716***					
	(14.32)					
Obs.	3,603	3,498	3,498	3,498	3,498	3,810
R^2 within	0.34					

Remark: ***, ** and * denote significance at the 1%, 5%, and 10% level, respectively. z- and t-statistics are based on robust standard errors. Model (2a) is estimated by OLS fixed effects estimation (FE, within estimator), the other specifications by GMM. The instruments are lagged levels from $t-2$ to $t-5$ of average trading volume in shares and, additionally, the average spread of sample firms excluding firm i in models (2d) and (2e). DSx and $DSxyz$ are indicator variables equal to one if the average number of designated sponsors for the current month equals x, y and z and zero otherwise. Model (2e') corresponds to model (2e) including inactive firm months with less than 100 trades. For the definition of the other variables and more details, compare section 1.4.2. Time and index dummies are not depicted.

Table 1.5: Results with NO_DS and NO_DS2 for quoted half spreads in %

	$S^{Quoted}/2$ in %					
	OLS (3a)	GMM (3b)	GMM (3c)	GMM (3d)	GMM (3e)	GMM (3e')
Variable	Coef. ($\|t-stat\|$)	Coef. ($\|z-stat\|$)	Coef. ($\|z-stat\|$)	Coef. ($\|z-stat\|$)	Coef. ($\|z-stat\|$)	Coef. ($\|z-stat\|$)
NO_DS	-0.072***	-0.056***	-0.054***	-0.056**	-0.055**	-0.192*
	(5.67)	(2.75)	(2.82)	(2.45)	(2.45)	(1.83)
NO_DS2	0.010***	0.009**	0.006	0.003	0.003	0.029
	(4.42)	(2.00)	(1.40)	(0.57)	(0.55)	(1.38)
$LnMCap$	-0.217***	-0.189***	-0.173***	-0.143***	-0.143***	-0.202***
	(13.45)	(5.07)	(5.17)	(4.06)	(4.06)	(4.34)
$Volume$	-8e-05***	-9e-05**	-1e-04**	-8e-05**	-8e-05**	-1e-04**
	(5.58)	(2.01)	(2.10)	(2.11)	(2.12)	(2.18)
SD	3.098***	2.270***	2.430***	2.046***	2.046***	2.393***
	(8.25)	(5.45)	(5.49)	(4.60)	(4.61)	(5.37)
$Price$	0.001***	2e-04	1e-04	0.001	0.001	0.003*
	(4.57)	(0.20)	(0.18)	(1.17)	(1.17)	(1.94)
$S^{Quot.}/2_{t-1}$			0.172**	0.149*	0.148*	0.166***
			(2.46)	(1.87)	(1.88)	(2.57)
$S^{Quot.}/2_{-i}$				0.371***	0.371***	0.480***
				(6.40)	(6.34)	(5.39)
$\mathbf{1}_{Broker}$					-0.004	-0.135**
					(0.11)	(2.15)
$Const.$	4.929***					
	(14.91)					
Obs.	3,603	3,498	3,497	3,497	3,497	3,809
R^2 within	0.34					

Remark: ***, ** and * denote significance at the 1%, 5%, and 10% level, respectively. z- and t-statistics are based on robust standard errors. Model (3a) is estimated by OLS fixed effects estimation (FE, within estimator), the other models by GMM. The instruments are lagged levels from $t-2$ to $t-5$ of average trading volume in shares and, additionally, the average spread of sample firms excluding firm i in specifications (3d) and (3e). No_DS denotes the average number of hired designated sponsors in the current month, $(No\_DS)^2$ denotes its square. Model (3e') corresponds to model (3e) including inactive firm months with less than 100 trades. For the definition of the other variables and more details, compare section 1.4.2. Time and index dummies are not depicted.

Table 1.6: Results with NO_DS and NO_DS2 for effective half spreads in %

	$S^{Effective}/2$ in %					
	OLS	GMM	GMM	GMM	GMM	GMM
	(4a)	(4b)	(4c)	(4d)	(4e)	(4e')
	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.
Variable	$(\|t-stat\|)$	$(\|z-stat\|)$	$(\|z-stat\|)$	$(\|z-stat\|)$	$(\|z-stat\|)$	
NO_DS	-0.057***	-0.024**	-0.035**	-0.031*	-0.030*	-0.115**
	(6.15)	(2.07)	(2.37)	(1.68)	(1.71)	(2.02)
NO_DS2	0.007***	0.003	0.003	-4e-05	-4e-05	0.017
	(4.33)	(0.97)	(0.77)	(0.01)	(0.01)	(1.48)
$LnMCap$	-0.165***	-0.123***	-0.141***	-0.133***	-0.133***	-0.141***
	(12.94)	(3.67)	(4.28)	(3.89)	(3.90)	(3.18)
$Volume$	-5e-05***	-6e-05**	-8e-05**	-7e-05**	-7e-05*	-1e-04**
	(5.38)	(2.09)	(2.13)	(2.17)	(2.17)	(2.16)
SD	2.246***	1.490***	1.590***	1.478***	1.475***	1.772***
	(7.83)	(4.62)	(4.89)	(4.43)	(4.43)	(4.88)
$Price$	9e-04***	5e-05	4e-05	6e-04	6e-04	0.003*
	(4.80)	(0.07)	(0.06)	(0.84)	(0.83)	(1.72)
$S^{Eff.}/2_{t-1}$			-0.004**	-0.005**	-0.005**	0.008
			(2.37)	(2.43)	(2.02)	(0.68)
$S^{Eff.}/2_{-i}$				0.201***	0.201***	0.368***
				(4.61)	(4.59)	(5.11)
$\mathbf{1}_{Broker}$					-0.008	-0.130***
					(0.23)	(2.99)
$Const.$	3.734***					
	(14.27)					
Obs.	3,603	3,498	3,498	3,498	3,498	3,810
R^2 within	0.34					

Remark: ***, ** and * denote significance at the 1%, 5%, and 10% level, respectively. z- and t-statistics are based on robust standard errors. Model (4a) is estimated by OLS fixed effects estimation (FE, within estimator), the other models by GMM. The instruments are lagged levels from $t-2$ to $t-5$ of average trading volume in shares and, additionally, the average spread of sample firms excluding firm i in specifications (4d) and (4e). No_DS denotes the average number of hired designated sponsors in the current month, $(No\_DS)^2$ denotes its square. Model (4e') corresponds to model (4e) including inactive firm months with less than 100 trades. For the definition of the other variables and more details, compare section 1.4.2. Time and index dummies are not depicted.

markets, bid-ask spreads on Xetra are found to decrease in a non-linear way in the number of designated sponsors. For our sample composed of active MDAX, TecDAX and SDAX firms, hiring one or two sponsors is effective, but it is not clear that it pays out to hire more than two sponsors. Re-estimating specifications and including firm months in which less than 100 transactions took place, the magnitude of coefficients is markedly higher while qualitative results remain unchanged. Exemplary results are presented in the last columns of Tables 1.3 to 1.6 as specifications (e').

Results disaggregated by index segments

Since we have chosen a broad sample of rather large (MDAX), rather small (SDAX) and rather innovative and risky firms (TecDAX), we cannot resist to test whether liquidity effects differ across market segments (which differ by market capitalization, turnover or industries) and divide our sample into three sub-samples. If we recall that any market participant can serve as a liquidity provider by posting limit orders, one would imagine that effects of price competition are higher for firms for which it is not attractive to post limit orders like, e.g., volatile technology shares small cap stocks with high idiosyncratic risk. GMM estimation results for quoted and effective spreads are presented in Tables 1.7 and 1.8. The first specification for each index segment is static, the second one is dynamic. Since especially the number of groups for TecDAX stocks is very small, results are only indicative.[26]

The estimates clearly suggest that benefits of designated sponsoring vary across market segments. For the most liquid mid cap stocks, having one or two sponsors is broadly related with the same benefits in terms of spread reduction, while it does not seem favorable to hire more than two sponsors, compare models (5a) to (5b) and (6a) to (6b). For stocks in the volatile technology segment TecDAX, the magnitude of the influence of sponsors is pronouncedly higher for both spread measures as can be seen in models (5c), (5d), (6c) and (6d). In terms of liquidity, it seems optimal to trade with two designated sponsors since firms trading with more than two sponsors do not show significantly lower spreads. For the least liquid SDAX segment, results are depicted in columns (5e), (5f),

[26]Since the number of groups is markedly reduced to 45 groups for MDAX, 40 groups for SDAX and 25 groups for TecDAX stocks, the problem of a high number of instruments relative to groups may be severe. We again reduce the number of lags used as instruments to alleviate this problem. Note that in this section we include inactive stock months with less than 100 transactions.

(6e) and (6f). Since none of these stocks trades without a sponsor, $DS2$ and $DS345$ are to be interpreted relative to the case of trading with one designated sponsor instead of trading with zero sponsors as before such that coefficients are not directly comparable. It can be observed that effects for trading with more than two sponsors are higher compared to trading with one or two sponsors, however, the difference is not always statistically significant. Interestingly, security risk as measured by the standard deviation of returns is most important for the least liquid stocks. Results confirm the expectation that effects of designated sponsoring are highest for small and volatile stocks and less important for larger stocks. The recommendation of Deutsche Börse to trade with two sponsors seems overall reasonable.

The choice of the designated sponsor firm

Finally, we perform an exercise related to the fact that firms are free to choose their preferred designated sponsors. The 130 firms of our original sample trade with 35 different designated sponsors, leading to the question whether, all else equal, the magnitude of spreads differs across sponsor firms.[27] Since we know the identities of sponsor firms in a given month for each of the sample firms, we can test whether c.p. identity or characteristics of a sponsor firm exert an influence on the bid-ask spread. All sponsors we contacted agreed on the fact that there is a high degree of competition in the market. Furthermore, sponsors believe that there are qualitative differences in market making and other services which can be quite pronounced.[28] This is particularly interesting given that all sponsor firms in our sample obtain the highest rating of Deusche Börse AG.[29] When we perform the same estimations as before but additionally include the identities of designated sponsors as dummy variables, we can reject the null hypothesis of no differences in spreads across sponsor firms at the 1% level. Trying to relate these differences to a proxy for "expertise" of the sponsor firm (defined e.g. as the size of a sponsor firm in terms of its mandates or the growth of mandates over the estimation period), we do not find evidence that our proxies influence bid-ask spreads on a monthly level.

[27] Compare also the work of Cao et al. (1997) on NYSE specialist firms.

[28] Apparently, it is rarely the case that firms set up contracts specifying lower spreads or higher quantities than officially demanded. Hence, differences across firms are in general not due to the fact that firms simply pay more to obtain lower spreads.

[29] Some designated sponsors might choose to only fulfil minimum AA requirements and exit the market in "difficult" times if their time bonus allows them to.

Table 1.7: Results with $DS1$, $DS2$ and $DS345$ for quoted half spreads in % by index segment

	$S^{Quoted}/2$ in %		$S^{Quoted}/2$ in %		$S^{Quoted}/2$ in %	
	GMM (5a)	GMM (5b)	GMM (5c)	GMM (5d)	GMM (5e)	GMM (5f)
Index	MDAX		TecDAX		SDAX	
Variable	Coef. ($\|z-stat\|$)	Coef. ($\|z-stat\|$)	Coef. ($\|z-stat\|$)	Coef. ($\|z-stat\|$)	Coef. ($\|z-stat\|$)	Coef. ($\|z-stat\|$)
$DS1$	-0.206*	-0.221	-1.702***	-1.441***		
	(1.92)	(1.48)	(73.73)	(3.19)		
$DS2$	-0.217**	-0.222	-1.793***	-1.556***	-0.137**	-0.140**
	(2.02)	(1.46)	(69.06)	(3.58)	(2.45)	(1.88)
$DS345$	-0.175*	-0.132	-1.765***	-1.556***	-0.175**	-0.155*
	(1.77)	(1.10)	(51.01)	(3.56)	(2.45)	(1.88)
$LnMCap$	-0.142**	-0.113***	-0.223***	-0.284***	-0.140**	-0.165***
	(2.48)	(2.56)	(2.86)	(4.33)	(2.10)	(2.98)
$Volume$	-5e-05	-9e-05**	-1e-05	-5e-05	-2e-04**	-1e-04***
	(1.38)	(2.00)	(0.65)	(1.20)	(2.34)	(2.67)
SD	1.203***	1.387***	1.214	0.775	5.929***	6.160***
	(3.59)	(3.16)	(1.23)	(1.42)	(9.28)	(7.80)
$Price$	8e-04	7e-05	-6e-04	-7e-04	1e-04	0.001
	(0.83)	(0.01)	(0.26)	(0.23)	(0.09)	(0.80)
$S^{Quoted}/2_{t-1}$		0.401***		0.014		0.348***
		(4.84)		(0.21)		(5.41)
$Obs.$	1,559	1,556	865	863	1,390	1,390

Remark: ***, ** and * denote significance at the 1%, 5%, and 10% level, respectively. z-statistics are based on robust standard errors. Time and index dummies are not depicted. Specifications are estimated by GMM using instrumental variables as described in section 1.4.2. $DSxyz$ are indicator variables equal to one if the average number of designated sponsors for the current month equals x, y or z and zero otherwise. For the definition of the other variables and the econometric specifications, compare section 1.4.2.

Table 1.8: Results with $DS1$, $DS2$ and $DS345$ for effective half spreads in % by index segment

	$S^{Eff.}/2$ in %		$S^{Eff.}/2$ in %		$S^{Eff.}/2$ in %	
	GMM (6a)	GMM (6b)	GMM (6c)	GMM (6d)	GMM (6e)	GMM (6f)
Index	MDAX		TecDAX		SDAX	
Variable	Coef. ($\|z - stat\|$)	Coef. ($\|z - stat\|$)	Coef. ($\|z - stat\|$)	Coef. ($\|z - stat\|$)	Coef. ($\|z - stat\|$)	Coef. ($\|z - stat\|$)
$DS1$	-0.151*	-0.180	-0.564***	-0.511***		
	(1.73)	(1.44)	(32.43)	(13.06)		
$DS2$	-0146*	-0.172	-0.634***	-0.597***	-0.067	-0.086**
	(1.82)	(1.45)	(37.77)	(13.47)	(1.59)	(2.46)
$DS345$	-0.123	-0.137	-0.612***	-0.587***	-0.093**	-0.090
	(1.63)	(1.18)	(25.68)	(12.14)	(1.98)	(1.55)
$LnMCap$	-0.101**	-0.093*	-0.181**	-0.251***	-0.002	-0.027
	(2.14)	(1.80)	(2.30)	(3.99)	(0.02)	(0.32)
$Volume$	-2e-05	4e-05	-2e-05	-4e-05	-1e-04**	-9e-05***
	(0.27)	(0.51)	(1.20)	(1.14)	(2.47)	(2.59)
SD	0.812***	0.653*	1.249	0.466	4.076***	4.514***
	(3.52)	(1.89)	(0.96)	(1.01)	(10.18)	(9.26)
$Price$	6e-04	0.001	-5e-04	8e-04	-0.001	2e-04
	(0.51)	(0.92)	(0.19)	(0.36)	(0.48)	(0.14)
$S^{Eff.}/2_{t-1}$		0.130		-0.007*		0.416***
		(1.17)		(1.83)		(5.81)
$Obs.$	1,559	1,556	865	864	1,390	1,390

Remark: ***, ** and * denote significance at the 1%, 5%, and 10% level, respectively. z-statistics are based on robust standard errors. Specifications are estimated by GMM using lagged regressors as instruments as described in section 1.4.2. $DSxyz$ are indicator variables equal to one if the average number of designated sponsors in the current month equals x, y or z and zero otherwise. For the definition of the other variables and the econometric specifications, compare section 1.4.2. Time and index dummies are not depicted.

Since the designated sponsoring industry consists of both banks and brokers (or banks having their origin in the brokerage business), we investigate possible differences across institutional groups. On the one hand, one might expect that bid-ask spreads quoted by brokerage firms are smaller since market making is one of their core businesses. On the other hand, at least the banks with many mandates may have a similar expertise. Since they tend to have a higher interest in cross-selling activities, they will do their best not to dissatisfy customers. While costs appear to be more or less homogenous among institutional groups, sponsor firms that have their origins in the brokerage business may charge lower fees compared to banks, both with respect to market making and to additional services.[30] We test this issue by repeating the above estimations and including the indicator variable *Broker* which is equal to one if the firm has hired at least one sponsor with origins in the brokerage business and zero otherwise.[31] Results are depicted in the last two columns from the right of Tables 1.3 to 1.6 as specifications (e) and (e'). The coefficient of *Broker* always bears a negative sign. While it is statistically different from zero at a level of at least 5% in all estimations (e') including inactive trading months, we do not observe significant coefficients in the specifications (e). This indicates that potential advantages of contracting brokers mainly exist for inactively traded stocks.

Summing up, we find robust evidence that trading with designated sponsors increases liquidity on Xetra by decreasing quoted and effective bid-ask spreads. Effects are not linear and vary across trading segments. Spreads of firms contracting brokers are significantly lower compared to those of firms only contracting banks if we regard the whole data set, but not if we exclude firm months of low trading frequency. We remind the reader that our analysis only focuses on bid-ask spreads and does not consider other costs and benefits of designated sponsorship.

1.5 Methodology and Results II

We now proceed to analyze which particular component of the bid-ask spread the designated sponsors influence. As was stated before, the different components relate to

[30] Typically, however, the range of additional services provided by brokers is limited compared to banks, the same is true for the access to potential investor groups.

[31] Note that there is no significant dispersion across stock characteristics and market segments with respect to institutional types of sponsors contracted. This mitigates concerns that results are driven by the fact that e.g. brokers may only cover stocks for which effects of sponsorship are highest.

theoretic literature on determinants of the bid-ask spread. Literature from Roll (1984) onwards has shown that the existence of order handling costs such as labor or telecommunication costs induces a bid-ask bounce. For literature on the inventory spread component, compare e.g. Garman (1976), Stoll (1978) or Ho and Stoll (1981). For models on the adverse selection spread component, compare e.g. Bagehot (1971), Copeland and Galai (1983) or Glosten and Milgrom (1985). Finally, if market makers possess some market power, the existence of a bid-ask spread may relate to the degree of non-competitiveness in the market.

Why would we expect that designated sponsors exert an influence on the transitory non-information spread component, i.e. on (transitory) inventory costs, order handling costs or costs related to non-competitive pricing? Standard inventory models like Ho and Stoll (1981) argue that risk averse market makers have to be compensated for bearing the risk of building up inventory positions in order to accommodate public order flow. Typically, this cost increases in security risk, in risk aversion of the liquidity providers and in trade size. An increase in the number of market makers c.p. reduces the exposure risk each liquidity supplier has to bear, hence inventory risk sharing implies lower spreads.[32] Note that in our setup, inventory costs are limited by the fact that designated sponsors can choose to quote no more than the required minimum amount or even to stay out of the market for a limited time period. As an intuition why pure order handling costs may decrease in the number of designated sponsors, one could imagine that an increase in the overall number of market makers on the exchange leads to an increase in the average number of contracted firms per sponsor, implying reductions in average costs per firm. If we assume that an increase in the number of designated sponsors changes trading volumes transacted by the market maker, this factor might additionally influence costs. Finally, if market makers possess market power which they translate into bid-ask spreads, price competition should clearly decrease this component unless there is tacit collusion. Predictions are quite clear cut and we formulate the following hypothesis:

"The transitory spread component decreases in the number of designated sponsors."

With respect to the asymmetric information component, the spread balances losses to informed traders with profits from uninformed traders, ensuring that market makers do not lose money on average. There are several possibilities how this component might be affected by an increase in the number of market makers: If market makers reduce opaque-

[32] Compare also Biais et al. (2005), p. 221.

ness of the covered firm, this might reduce the relative information advantage of informed traders (e.g. in form of the private signal received or the signal-to-noise-ratio), reducing adverse selection costs. Conversely, since informed traders are more likely to track the stock and trade when mid-quotes are far from efficient prices, a more efficient price from increasing the number of market makers should reduce informed trades. However, a decrease in the private signal received by an informed agent could potentially increase the quantity transacted if a reduced price impact outweighs effects from a decreased marginal valuation by the informed trader reducing demanded volume. If the information structure of the market does not change after the introduction of designated sponsors but the quantity supplied at a given price increases, the informed trader might decide to transact more compared to the situation before, rendering the problem more severe for the market. Since it is a priori not evident which effect prevails we test the following hypothesis:

"The adverse selection spread component is not influenced by the number of designated sponsors."

1.5.1 Trade indicator model

We test our hypotheses by means of two different approaches. We start with a trade indicator model, employing binary variables of the trade direction in order to model short-run price dynamics. In this class of models as proposed by e.g. Glosten and Harris (1988), Huang and Stoll (1997) and Madhavan et al. (1997), one assumes that information about the stock is contained in signed order flow. Like Cao et al. (1997) or Theissen and Grammig (2005), we opt for the Glosten-Harris approach which enables us to incorporate trade size as an explanatory variable. Alternatively and as a robustness check, we use the empirical concept of realized spreads. Since we expect inventory costs to be relatively small, we do not opt for a three-way procedure explicitly singling it out, but rather use an approach focusing on the adverse selection component. Compare also e.g. Cao et al. (1997), referring to empirical evidence with respect to the relative size of the inventory cost component.

In particular, let Q_t be a trade indicator variable where $Q_t = 1$ if the transaction at time t is buyer-initiated and $Q_t = -1$ if it is seller-initiated. Furthermore, let μ_t stand for the post-trade expectation of the "true" value of the stock conditional on public information and on the information revealed by the trade initiation variable. The innovation in beliefs between $t-1$ and t due to dissemination of public information is denoted by ϵ_t.

We assume that μ_t evolves according to

$$\mu_t = \mu_{t-1} + Z_t Q_t + \epsilon_t, \tag{1.5}$$

where Z_t is the adverse selection component of the spread and measures the sensitivity of the post-trade expected value to the information revealed by the trade direction.[33] Furthermore, we assume that the price generating process is determined from the unobserved process above by adjusting for the costs C_t of providing liquidity services (i.e. order handling costs, baseline inventory costs or mark-ups from non-competitive pricing):

$$P_t = \mu_t + C_t Q_t + e_t = \mu_{t-1} + Z_t Q_t + C_t Q_t + \epsilon_t + e_t. \tag{1.6}$$

The sum of the asymmetric information and the transitory component is the half spread. e_t is white noise and captures possible rounding errors. First-differencing equation (1.6), the price change is given by:

$$\begin{aligned} \Delta P_t &= \Delta\mu_t + C_t Q_t - C_{t-1}Q_{t-1} + e_t - e_{t-1}, \\ &= Z_t Q_t + C_t Q_t - C_{t-1}Q_{t-1} + \nu_t, \\ \text{where}\ \ \nu_t &= \epsilon_t + e_t - e_{t-1}. \end{aligned} \tag{1.7}$$

1.5.2 Application of Glosten-Harris model

When estimating model (1.7) from the data, we have reasons to believe that the spread is not constant, but may depend on trade size. Hence, we include trading volume as an explanatory variable and postulate a linear relation of $Volume_t$ and both the adverse selection component and the transitory component:[34]

$$Z_t = z_0 + z_1 \cdot Volume_t, \quad C_t = c_0 + c_1 \cdot Volume_t.$$

Inserting these specifications into model (1.7), we obtain:

[33] We subsequently employ the terms adverse selection component, asymmetric information component and permanent component interchangeably.

[34] One might as well employ the logarithm or the square root of trading volume being equally ad hoc as a linear specification.

$$\begin{aligned}\Delta P_t &= (z_0 + z_1 \cdot Volume_t)Q_t + (c_0 + c_1 \cdot Volume_t)Q_t - (c_0 + c_1 \cdot Volume_{t-1})Q_{t-1} + \nu_t, \\ &= c_0 \Delta Q_t + c_1 \Delta(Q_t Volume_t) + z_0 Q_t + z_1 Q_t Volume_t + \nu_t, \qquad (1.8) \\ &\text{where } \; \Delta X_t = X_t - X_{t-1}.\end{aligned}$$

When applying model (1.8) to the data, we expect a positive sign for c_0 since some of the transitory costs can be assumed to arise independently of trade size. If we allow for the existence of economies of scale, transaction costs will decrease in volume, rendering c_1 negative. With respect to the adverse selection component we expect related costs to increase in trade size, implying a positive z_1. Finally, the constant z_0 should be positive since otherwise the possibility of adverse-selection benefits arises for small trade sizes.
We employ Newey-West HAC standard errors to account for the fact that the error-term ν_t is serially correlated by construction.[35] As was stated, we apply the Lee and Ready (1991) algorithm in order to infer the trade direction. Analog to before, we estimate the model on a monthly basis. For the vast majority of stocks, coefficients show the expected signs and are statistically significant. Like Glosten and Harris (1988), Cao et al. (1997) and Theissen and Grammig (2005), we find that the transitory component of the spread is markedly larger than the permanent component. If evaluated at average trading volume, we find that the estimated spread $\hat{c}_0 + \hat{c}_1 \cdot \overline{Volume} + \hat{z}_0 + \hat{z}_1 \cdot \overline{Volume}$ underestimates the percentage effective half spread as computed from the data by about one fourth. However, the correlation between both measures lies at 96%. Subsequent results rely on the assumption that the decomposition does not systematically bias the relative magnitude of spread components.

1.5.3 Decomposition of the influence of designated sponsors

We employ the obtained estimates in order to assess whether designated sponsors are found to influence the transitory, the adverse selection, or both components of the bid-ask spread. The empirical strategy is analog to the panel estimations from the first part, the dependent variables being replaced by the estimated spread components. As in the first part, we report results for all 110 firms. Restricting the sample to firms for which an average of at least 150 observations in the Glosten-Harris model is available does not

[35] Alternatively estimating the model by GMM leaves results virtually unchanged.

change any conclusions, nor does the choice of a static instead of a dynamic specification. Results are depicted in Table 1.9.

Regarding model (7a), the transitory spread equation for the Glosten-Harris decomposition, the indicator variables $DS2$ and $DS345$ are negative and statistically significant. The same yields for the variable NO_DS from an alternative specification the results of which are presented in excerpts in the lower panel of the table. Average trading volume and firm size are negatively related to the transitory spread component. The standard deviation of returns is not significant which indicates that competition among liquidity providers may be more important compared to inventory risk sharing. With respect to specification (7b) for the adverse selection component we find that as expected, adverse selection costs are lower for larger and less volatile firms. Regarding the impact of designated sponsors, only $DS345$ is significant at a level of 10%, NO_DS and NO_DS2 are insignificant such that our null hypothesis of no influence of designated sponsors is not rejected.

Finally, we conduct the same analysis using the concept of realized spreads introduced in section 1.4. Recall that the realized spread equals the market maker's gross revenue. We use the realized half spread as the non-information related transitory spread component and the difference between effective and realized half spread as the adverse selection component. The latter is equal to $S/2^{Adv.|a_t} = M_{t+\tau} - M_t$ for trades at the ask and to $S/2^{Adv.|b_t} = M_t - M_{t+\tau}$ for trades at the bid. Results are depicted as specifications (8a) and (8b). While significance levels and magnitudes differ from those of the Glosten-Harris decomposition, results weakly indicate an effect of sponsors on the non-information spread component as the variables $DS2$ and NO_DS are weakly statistically significant. As can be seen in equation (8b), no effect of designated sponsoring on the adverse selection component measure can be identified. We believe that the overall poorer fit in specifications (8a) and (8b) relates to the loss of information from pooling positive and negative realized spreads on a monthly level. If we re-estimate the model excluding firms with $S_{it}^{realized} > S_{it}^{effective}$ or $S_{it}^{realized} < -S_{it}^{effective}$, significance levels increase and results more closely match those of specifications (7a) and (7b).

Overall, the spread decomposition both by means of the Glosten-Harris model and the concept of realized spreads shows that designated sponsors decrease the transitory spread component but have no impact on the adverse selection component, hence our hypotheses are not rejected. We conclude that the influence of designated sponsors on bid-ask spreads

Table 1.9: Results for spread decompositions

	Glosten-Harris in %		Realized Spreads in %	
	$\hat{S}^{Trans.}/P$	$\hat{S}^{Adv.}/P$	$S^{Real.}in\%$	$S^{Adv.}in\%$
	GMM	GMM	GMM	GMM
	(7a)	(7b)	(8a)	(8b)
	Coef.	Coef.	Coef.	Coef.
Variable	$(\|z-stat\|)$	$(\|z-stat\|)$	$(\|z-stat\|)$	$(\|z-stat\|)$
$\hat{S}^{Trans.}/P_{-1}$	-0.053			
	(0.48)			
$\hat{S}^{Adv.}/P_{-1}$		0.176**		
		(2.20)		
$S^{Real.}in\%_{-1}$			-0.003	
			(0.97)	
$S^{Adv.}in\%_{-1}$				-0.003
				(0.85)
$DS1$	-0.016	-0.011	-0.040	0.018
	(1.37)	(1.15)	(1.53)	(0.78)
$DS2$	-0.036**	-0.014	-0.79*	0.025
	(2.43)	(1.35	(1.73)	(0.57)
$DS345$	-0.041**	-0.021*	-0.094	0.036
	(2.44)	(1.68)	(1.53)	(0.66)
$LnMCap$	-0.055***	-0.051***	-0.076**	-0.041
	(2.57)	(3.30)	(2.25)	(1.26)
$Volume$	-5e-05**	-4e-05**	5e-05	-9e-05
	(1.99)	(2.12)	(0.70)	(1.25)
SD	-0.046	1.284***	-1.909***	3.276***
	(0.18)	(6.45)	(2.86)	(5.47)
$Price$	5e-06	4e-05	0.001	-6e-04
	(0.01)	(0.13)	(0.92)	(0.62)
Obs.	3,476	3,476	3,496	3,496
Excerpt of results using NO_DS and NO_DS2				
NO_DS	-0.025**	-0.004	-0.046**	0.007
	(2.51)	(0.54)	(1.97)	(0.30)
NO_DS2	0.003	-4e-04	0.004	6e-04
	(1.36)	(0.24)	(1.15)	(0.19)

Remark: ***, ** and * denote significance at the 1%, 5%, and 10% level, respectively. GMM estimation and control variables are as before. The dependent variables $\hat{S}^{Trans.}/P$ and $\hat{S}^{Adv.}/P$ in models (7a) and (7b) stand for the estimated transitory resp. adverse selection component of the Glosten-Harris model, evaluated at the average trading volume. $S^{Real.}in\%$ and $S^{Adv.}in\%$ in models (8a) and (8b) stand for the percentage realized half spread and the difference between effective and realized half spreads in percent. At the bottom of the table, excerpts of specifications using the number of designated sponsors of each firm and its square are presented. Time and index dummies are not depicted.

on Xetra mainly stems from competition and risk-sharing among multiple market makers.

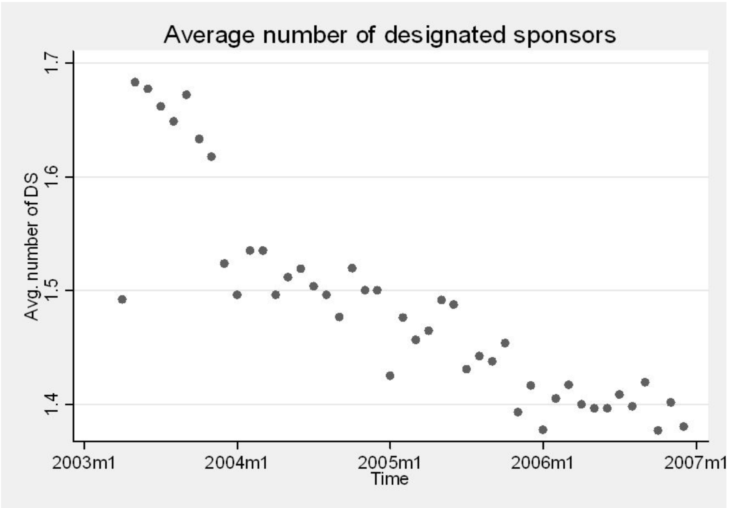
1.6 Conclusion

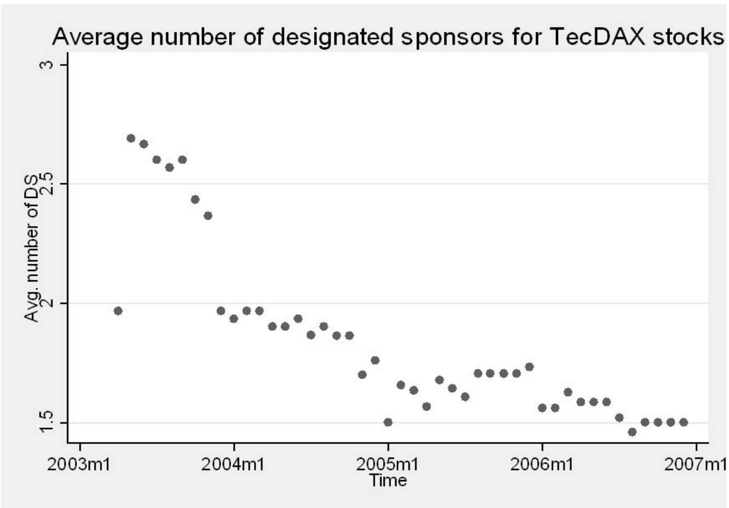
In this chapter, we empirically tested whether designated sponsors have an influence on magnitude and components of bid-ask spreads on the electronic limit order platform Xetra. We first presented an instrumental variables GMM framework and analyzed impacts of designated sponsoring on average monthly quoted and effective half spreads for a sample of 110 stocks and separately for index segments. In a next step, we decomposed the bid-ask spread into its single components using the trade indicator model developed by Glosten and Harris (1988) and alternatively the concept of realized spreads. Estimates were then used to assess the impact of multiple liquidity providers on spread components. In summary, designated sponsors were found to be liquidity enhancing for a broad sample of German stocks. This implies that the current Xetra regulation which postulates trading with designated sponsors also for rather actively traded stocks is reasonable. In terms of liquidity, it pays out for all sample firms to invest in one or two designated sponsors. Depending on firm characteristics, hiring additional sponsors may be useful, which is especially the case for the smallest stocks in the sample from the SDAX segment. We provide (weak) evidence that also the choice of a sponsor firm can be a factor deserving attention for firms wanting to improve their liquidity. For inactively traded stocks, it appears good to contract at least one brokerage house next to or alternatively to trading with a market maker from a bank. However, banks typically provide a more extensive range of services than brokerage houses, making a mixture between institutional forms appear to be a good choice. Decomposing the spread into its components, we find evidence that realized spreads earned by designated sponsors as well as the transitory spread component decrease in the number of designated sponsors, hence increased competition and risk-sharing increase liquidity. We find, however, no evidence of an influence on the adverse selection component of the bid-ask spread.

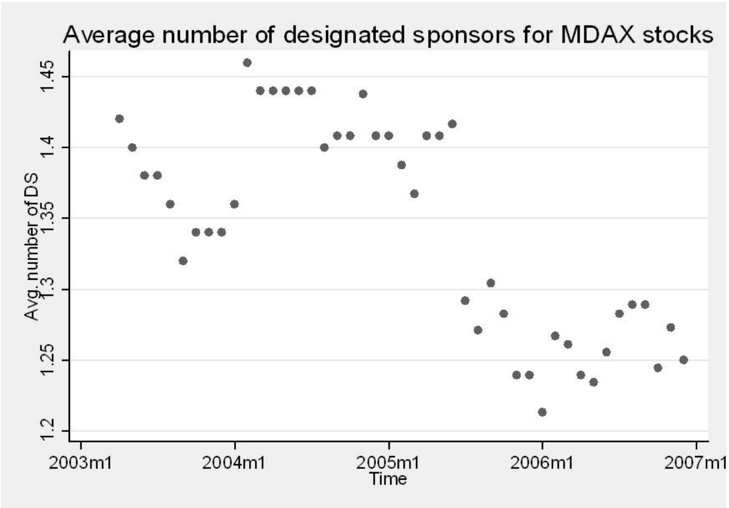
We believe that our findings are of interest for other limit order platforms which may want to consider the introduction of market makers also for more actively traded stocks or offer listed firms the option of increasing the number of designated liquidity providers beyond one. Mainly two issues are of interest for further research: First, it would be interesting to investigate cross-sectional determinants of the chosen number of designated sponsors and its variation over time. Second, especially in current market conditions, it would be very interesting to conduct a similar analysis disposing of information on actual market maker trading and quoting behavior. After all, the designated sponsor requirements are mainly binding at times when the market is not willing to provide liquidity endogenously. As a consequence, firms may want to choose the number of sponsors depending on how liquidity providers actually behave in adverse market conditions.

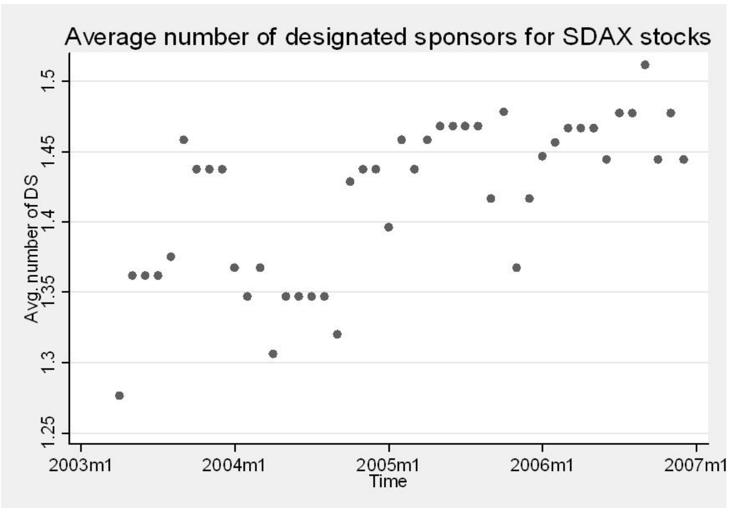
1.7 Figures

Figure 1.1: Plots of the average number of designated sponsors per stock over time






Average number of designated sponsors for MDAX stocks
Avg. number of DS
1.2
1.25
1.3
1.35
1.4
1.45
2003m1
2004m1
2005m1
2006m1
2007m1
Time


Average number of designated sponsors for SDAX stocks
Avg. number of DS
1.25
1.3
1.35
1.4
1.45
1.5
2003m1
2004m1
2005m1
2006m1
2007m1
Time

Chapter 2

Liquidity and Price Discovery in the European CO2 Futures Market: An Intraday Analysis

European Union CO_2 Allowances (EUAs) are traded on several markets with increasing intensity. This chapter provides an intraday data analysis of the EUA futures market for the complete first trading period 2005-2007. To investigate the trading process in this young market, we compare the two main trading platforms ECX and Nord Pool with respect to liquidity and price discovery. We analyze liquidity by estimating traded bid-ask spreads following the approach of Madhavan et al. (1997) and study price discovery using the VECM framework of Engle and Granger (1987). We find that estimated transaction costs are always lower on the larger exchange ECX. While price discovery mostly takes place on ECX, our results indicate that the less liquid platform Nord Pool also contributes to price discovery, especially during the first months of trading.

2.1 Introduction

With the official start of the European Union Greenhouse Gas Emission Trading Scheme (EU ETS) in January 2005, a new European commodity market has been created. In the market for European Union Allowances (EUAs), purchasing one EUA entitles the holder to emit one ton of CO_2 equivalent greenhouse gases. With an increasing range of new instruments (e.g. spot, forwards, futures and options) the carbon market has steadily gained complexity. Currently, the EU ETS is the largest CO_2 trading scheme world wide. While prices from the OTC market have served as reference prices at the beginning of the EU ETS, their importance has declined with the development of standardized carbon products on distinct trading platforms. During the first trading period (Phase 1), which lasted from 2005 to 2007, organized allowance trading has been fragmented across five trading platforms: European Climate Exchange (ECX), Nord Pool, Powernext, European Energy Exchange (EEX) and Energy Exchange Austria (EXAA). Since the underlying asset is equal on all exchanges, questions with respect to liquidity migration and price discovery across trading platforms are important factors to investigate.

The end of the first trading period of the EU ETS in December 2007 provides an excellent opportunity to address these questions and to give a comprehensive overview of the European carbon market development. Being the first to have access to intraday transactions data, we are able to complement the existing literature by investigating this very recent market from a microstructure angle. Since almost all trading takes place in the futures markets, we focus on futures price data supplied by ECX and Nord Pool, the two most liquid European trading exchanges for futures EUAs. The aim of this chapter is twofold. Apart from providing an overview of the development of trading on both exchanges, we compare two market functions that are of high relevance to potential traders: liquidity and price discovery. With respect to liquidity, we start by comparing overall trading volumes as well as the development of trading frequencies across exchanges. We then estimate traded bid-ask spreads following the approach of Madhavan et al. (1997) that allows the estimation of spreads when no quote data but only transaction data and a trade indicator variable are available. Applying this procedure has the advantage that it enables us to infer main causes of trading frictions and, hence, transaction costs. To analyze relative price discovery on both exchanges we use the VECM framework by Engle and Granger (1987) building on the cointegration relationship between transaction price series. To quantify the two markets' relative contributions to the price discovery process we apply two different measures: common factor weights proposed by Gonzalo and Granger (1995) and information shares as introduced by Hasbrouck (1995).

Our analysis is part of a growing field of research on the European carbon market including Mansanet-Bataller et al. (2007), Alberola et al. (2008), Benz and Trück (2009), Seifert et al. (2008), Borak et al. (2006) or Daskalakis et al. (2009). It is furthermore related to a vast body of market microstructure literature that investigates liquidity and price discovery on financial markets. Regarding the European carbon market, there is no literature analyzing bid-ask spreads. A few studies have addressed the question of price discovery between spot and futures markets (compare Seifert et al. (2008), Daskalakis et al. (2009), and Milunovich and Joyeux (2007)), but no work has investigated price discovery between futures prices on distinct exchanges. Since almost all trading volume takes place in futures markets, we believe our study to be of high relevance. Furthermore, the mentioned studies only use daily data, possibly blurring results of price leadership if price discovery takes place at finer trading intervals.

We believe that our results are of interest for regulatory authorities that are in charge of the design of the upcoming commitment periods, for operators of exchange platforms, for researchers interested in the application of microstructure tools to new markets and, equally important, for agents who trade actively in the market like market makers, brokers or arbitrageurs. We do not find evidence that changes in the platforms' trading protocols cause trends or patterns with respect to liquidity and price discovery on ECX and Nord Pool. This may be of interest for both platform operators and researchers investigating reasons behind liquidity migration between exchanges. It is possible to use our results in order to evaluate the relative development of the market. From the public, a lot of criticism has been raised about the European carbon market in Phase 1 mainly due to the significant over-allocation of EUAs. Academic work like Daskalakis and Markellos (2008) and Milunovich and Joyeux (2007), using data until the end of 2006, conclude that weak form informational efficiency in the European CO_2 market is violated. However, Uhrig-Homburg and Wagner (2007) finds evidence in favor of a cost-of-carry pricing mechanism for futures expiring within Phase 1 of the market. Our evidence shows that trading frictions in forms of transaction costs have decreased over the first trading phase, trading volume has increased and price discovery takes place across exchanges. Hence, it appears that from a trading perspective, the market has made a lot of progress since its operational start in January 2005.

The remainder of this chapter is organized as follows. Section 2.2 introduces the reader briefly to the organization of the European carbon market and to the institutional details that are relevant for the data collection procedure. Section 2.3 describes the methodology of the bid-ask spread analysis and its econometric application. The price discovery process using an error correction model is explained in section 2.4. Estimation results for both types of analysis are displayed subsequent to the description of the methodology. Section

2.5 contains the conclusion and an outlook on the future of carbon trading in Europe.

2.2 Market Structure and Data

2.2.1 Institutional background

The EU ETS started in January 2005 as a central instrument for member states of the European Union to achieve the emission reduction targets of the Kyoto Protocol in a cost-effective way.[1] It covers over 10,000 installations in the energy and industrial sectors that are collectively responsible for about 50% of European CO_2 emissions. Trading is organized in several stages. The first trading period served as a pilot phase and covers the years 2005-2007 while the second trading period from 2008-2012 constitutes the Kyoto commitment period (Phase 2). Plans for the post Kyoto trading period 2013-2020 (Phase 3) became more concrete after the United Nations summit in Bali in December 2007. Besides, in January 2008 the European Commission has agreed on a "Climate and Energy Package", which makes first regulatory suggestions and improvements for the continuation of action against climate change in the EU.

The EU ETS is organized as a cap-and-trade scheme where participating firms have to reduce the amount of emitted CO_2 and annually demonstrate that their level of EUAs corresponds to their actual emissions. Every year, at the end of February, a certain amount of EUAs is allocated to the compliant firms for the current trading year according to National Allocation Plans (NAPs). On April 30 of the following year, firms have to deliver the required EUAs to the national surveillance authorities according to their actual emissions volume. Not handing in the required amount of emissions is fined with an extra fee of Euro 40 (Euro 100) per missing EUA in the pilot period (Phase 2) additional to delivering the missing amount of EUAs. Companies being able to keep emissions below their allocation level are free to sell excess allowances in the market. Firms which need additional allowances to comply with their output levels have the choice to either invest in emissions-reducing technologies, to switch to less emissions-intensive production technologies or, if marginal abatement costs are higher than the market price of EUAs, to buy EUAs on the European CO_2 market. Within Phase 1 and Phase 2 surplus allowances

[1] On an EU-wide level, emissions have to be reduced by 8% in the first Kyoto commitment period 2008-2012 relative to the output level of 1990.

can be transferred for use during the following year (banking). Banking between Phase 1 and Phase 2 was forbidden by most of the countries. Only France and Poland allowed for restricted banking. As allocation always takes place in February, borrowing of EUAs from the following year is indirectly possible as the compliance date for the preceding year is April 30. However, it was not possible to borrow EUAs between 2007 and 2008.[2] Trading is organized as bilateral, over-the-counter (OTC) and organized exchange trading. It takes the form of agency or proprietary trading and may be for compliance, speculative or arbitrage purposes.

To obtain an overview of how many allowances have been exchanged by market participants, Table 2.1 displays the total trading volumes split into futures and spot activities since the EU ETS has been operating and includes both OTC and exchange trading. It can be seen that overall trading volume markedly increased from 121 Million tons of CO_2 in 2005 to 1,123 Million tons of CO_2 in 2007. The share of spot relative to overall trading volume declined from 8.5% to 5.4%.

Table 2.1: Overall trading volumes of the EUA spot and futures market in Phase 1 (2005-2007) in Million tons of CO_2

Year	Spot [Mio t of CO_2]	Futures [Mio t of CO_2]
2005	10.25	110.82
2006	49.53	508.29
2007	60.26	1,062.42

Source: Own calculations. Mio t denotes million tons.

2.2.2 Market structure of carbon exchanges

In Phase 1, organized EUA trading took place on five exchange platforms. ECX only offers futures, Powernext and EXAA only offer spot trading whereas on EEX and Nord Pool both instrument types can be traded. In the following analysis we focus on the two main trading venues ECX and Nord Pool which comprise by far the largest exchange traded futures volume: In 2006, ECX being a member of the Climate Exchange Plc group

[2]Note that consequently there exist essentially two spot markets, one for Phase 1 and one for Phase 2, compare Seifert et al. (2008).

possessed a market share of 86.5%. The Norwegian platform Nord Pool had a share of 12.5%, see also Daskalakis et al. (2009). In terms of overall market share, in early 2007 ECX accounted for 56% of EUA trading volume, being followed by OTC trading volume with 42%.

The traded futures instruments on both platforms are standardized contracts giving the holder the right and the obligation to buy or sell a certain amount of EUAs at a certain date in the future at a pre-determined price. On both exchanges, one futures contract ('lot') corresponds to 1,000 EUAs and hence delivers the right to emit 1,000 tons of CO_2 equivalent. The contracts allow to lock in prices for delivery of EUAs at given dates in the future with delivery guaranteed by the respective clearing house. Counterparty risk is mitigated by specific margin requirements. The contracts are supposed to facilitate trading, risk management, hedging and physical delivery of EUAs. While contracts with monthly expiry and annual contracts with expiry in March exist, we focus on the by far most liquid annual contracts with expiry in December. These contracts expire on the first business day of December on Nord Pool and on the last Monday of December on ECX.[3] Settlement is three days after the last trading day.

The following information in this section refers to the first trading period: On both exchanges, trading is organized as continuous trading and takes place anonymously on electronic platforms. Exchange hours are from 08:00 to 18:00 CET on ECX and from 08:00 to 15:30 CET on Nord Pool.[4] On ECX the trading period is preceded by a pre-opening session from 07:45 to 07:59 CET. No actual trading takes place during this period, traders can only input orders that they wish to execute once trading begins at 08:00 CET. The daily closing period lasts from 17:00 to 17:15 CET. On Nord Pool, daily closing prices are determined between 15:20 and 15:30 CET at a randomly selected point in time. No exchange has implemented intraday call auctions. As of July 2008, ECX had 92 and Nord Pool had 97 members engaging in EUA trading.

With respect to order processing, both exchanges do not show markable differences. Incoming orders are binding until the end of the trading day if they have not been executed,

[3] If there is a public holiday in the respective trading week, the prior Monday is taken. The procedure continues until there is no public holiday in the trading week.

[4] On Nord Pool, trading hours were extended in June 2005 from 09:00 (10:00) to 15:30 CET (Central European Time) in March (February) 2005.

changed or canceled. Order types include order book (limit) orders, market orders and stop orders. Matching occurs according to price and time priority. Initially, the minimum tick size for ECX futures was Euro 0.05 per CO_2 emission allowances. On March 27, 2007 it was reduced to Euro 0.01. On Nord Pool the minimum tick size has always been fixed at Euro 0.01 per CO_2 emission allowance. Trading and clearing fees per contract amount to Euro 3.50 on ECX and to Euro 3.00 on Nord Pool for members.[5] The annual fee for full members is Euro 2,500 on ECX and Euro 3,000 on Nord Pool.

Both exchanges have introduced market makers to boost liquidity. Until June 18, 2006, EdF Trading Limited was active as a market maker for the EUA market on Nord Pool. On January 9, 2007, the new market maker Alfa Kraft AB started to operate. As a minimum requirement, market makers have to quote prices from 08:30 to 10:00 CET and from 13:00 to 15:30 CET. Before 2007, the minimum quoting periods were from 10:30 to 12:00 and from 14:00 to 15:30. Restrictions with respect to maximum spreads and minimum volumes apply. While the minimum offered volume is 5,000 tons, maximum spreads are Euro 0.50 for the nearest December contract and Euro 0.75 for the following December contract. As another method to enhance liquidity and to promote electronic trading, Nord Pool has launched a so-called initiator/aggressor fee model in January 2006. Electronically incoming quotes from “initiators” can be executed free of trading charges such that only clearing fees remain. “Aggressors” (price takers) have to pay the ordinary trading fees. ECX launched a market maker program in July 2007. Currently, Fortis Bank Global Clearing and Jane Street Global Trading are active as market makers. Requirements are stricter compared to Nord Pool in that both bid and ask prices must be quoted for at least 85% of the trading time between 09:00 to 18:00 CET. Spreads may not exceed Euro 0.15 for the December 2008 contract and Euro 0.25 for the other Phase 2 contracts. The minimum quoting volume corresponds to 10,000 tons. Market makers have to respond to quote requests within five minutes.[6]

Overall, we believe that differences in the market organization of both markets do not

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[5]On ECX, trading and clearing fees for order routing customers and client business amount to Euro 4.00 per contract. Note that fees have decreased over time. For instance on Nord Pool trading and clearing fees amounted to Euro 70.00 per contract at the launch of EUA trading before gradually declining to Euro 3.00 in December 2006.

[6]Information was obtained from the official websites www.europeanclimateexchange.com and www.nordpool.no in July 2008.

allow us to predict a clear pattern for differences in bid-ask spreads and price discovery across exchanges. The main features of the trading process are similar on both markets. Regarding differences, traders on Nord Pool have to pay lower transaction costs compared to ECX which may however be offset by a higher annual fee. Furthermore, while we could not obtain historical fee data for ECX, we know that trading costs on Nord Pool were markedly higher in the beginning. Hence, it may be the case that trading fees on ECX were lower compared to Nord Pool before the end of 2006. While market makers have been introduced earlier on Nord Pool than on ECX, maximum applicable spreads are markedly tighter on ECX. In the initiator/aggressor model trading costs are waived for the initial price quoters. This may attract additional liquidity suppliers on Nord Pool whose competition might narrow spreads on this platform. Finally, the possibility to trade longer on ECX may be one reason to favor trading on ECX over trading on Nord Pool. The data reveal that 20% of daily ECX trades occur within the last 2.5 trading hours (from 15:30 to 18:00 CET), i.e. after trading on Nord Pool has stopped.

2.2.3 Data set and summary statistics

In the following analysis we use intraday transaction data for annual standardized EUA futures and forward contracts being traded from April 22, 2005 to December 28, 2007 on ECX and from February 11, 2005 to December 28, 2007 on Nord Pool. After providing summary statistics to obtain an idea about the development of trading on both platforms, we briefly address some data collection issues that result from investigating data from two distinct markets. Table 2.2 depicts trading volumes (without OTC) of EUA futures with expiry in December for both platforms disaggregated by years and contracts. It can be seen that trading volumes have markedly increased both over years and over contracts, but to a higher extent on ECX compared to Nord Pool. Highest trading activity takes place in the nearby futures contract. The development of the Dec07 contract in 2007 is an exception and is due to the publication of the large EUA over-allocation in April 2006, which led to a marked price decline (compare also Figure 2.1 showing the development of futures prices on ECX for Phase 1). Due to lack of liquidity, for the rest of the paper we only consider the Dec05 to Dec08 contracts and disregard those with later expiry, i.e. the Dec09 to Dec12 contracts.

Table 2.2: Trading volumes of EUA futures with expiry in December on ECX and Nord Pool by contract and year

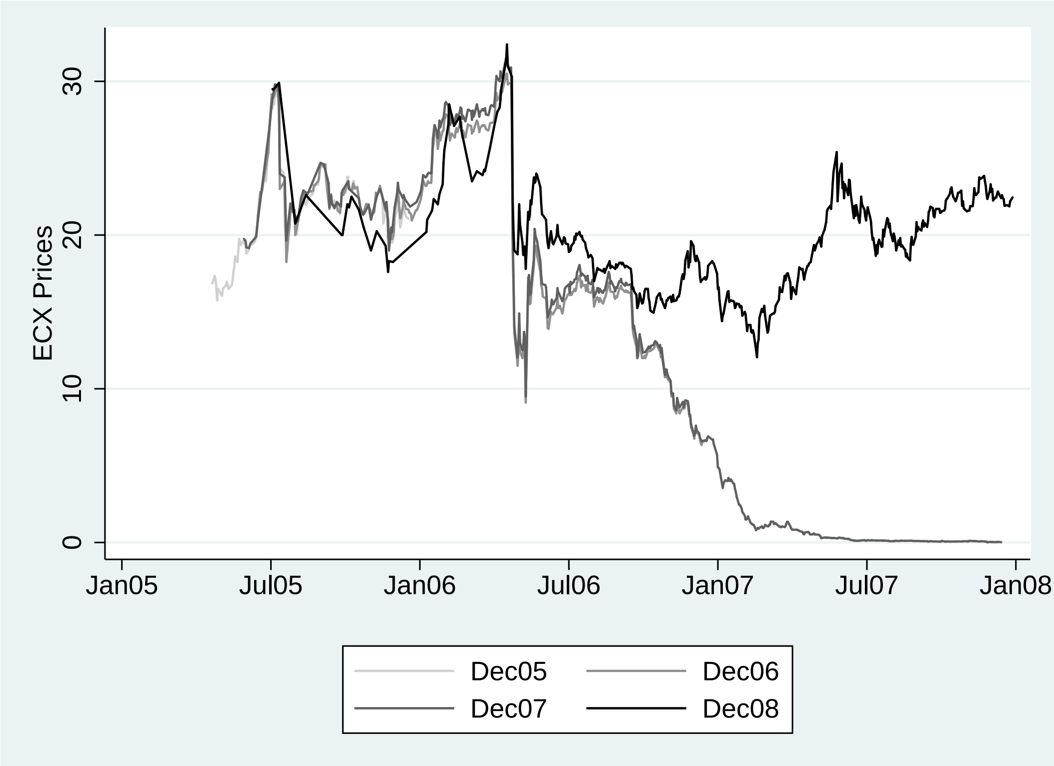
		ECX		Nord Pool	
Year	Contract	Mio t of CO_2	Mio Euro	Mio t of CO_2	Mio Euro
2005	Dec05	22.96	522.79	6.76	139.89
	Dec06	6.78	151.88	1.91	41.86
	Dec07	1.93	43.91	1.05	23.39
	Dec08	0.49	10.46	0	0
	Dec09-Dec12	0.02	0.43	0	0
	Sum	32.18	729.47	9.72	205.14
2006	Dec06	93.77	1,763.93	9.92	182.47
	Dec07	35.25	520.51	1.25	19.66
	Dec08	29.56	540.10	0.37	6.87
	Dec09-Dec12	0.46	9.16	0	0
	Sum	159.04	2,833.7	11.54	209
2007	Dec07	50.24	65.22	3.10	4.03
	Dec08	258.96	5,237.18	18.38	380.78
	Dec09-Dec12	29.44	652.86	0.25	5.41
	Sum	338.64	5,955.26	21.73	390.22

Source: ECX, Nord Pool.

Note that trading volumes exclude OTC trading.

Figures 2.2 and 2.3 depict the daily transaction frequencies and the average monthly standard deviation of daily returns for each platform and contract. Again, it can be inferred that transaction frequencies are highest for the nearby contract and hence markedly increase in December of the year prior to expiry. If we compare volatility across contracts and exchanges we observe high volatility in the market where the respective contract is launched first. For the Dec05 and Dec06 contracts there are two peaks that disturb the relatively smooth volatility pattern; one in July 2005 for the Dec05 contract and one in April/May 2006 for Dec06 contract. The first one probably relates to large price fluctuations as a consequence of unexpected selling in the market by some Eastern European

Figure 2.1: EUA futures prices for the Dec05 to Dec08 contracts on ECX in Phase 1



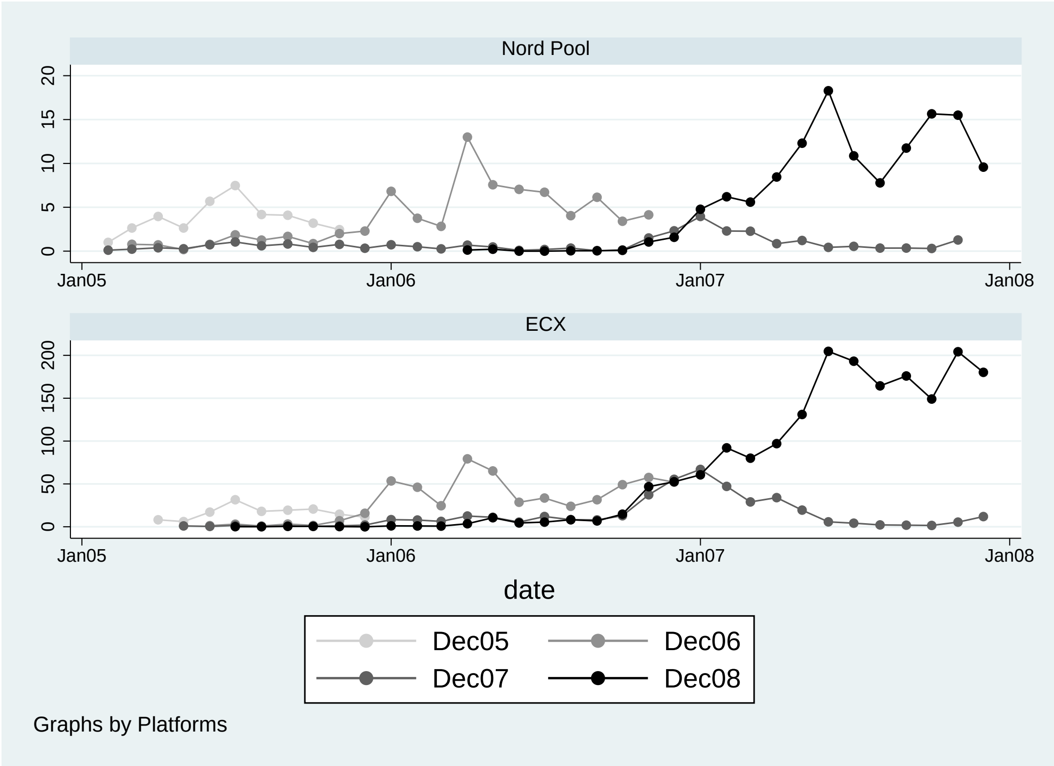
countries that succeeded to obtain access to the carbon market earlier than anticipated. The second peak can be clearly linked to the market breakdown when the significant over-allocation of EUAs became public at the end of April 2006.[7] Consequently, the Dec07 contract became worthless to the firms as they were not allowed to transfer excess EUAs from 2007 into 2008. This price decline translates into high return volatility in the year 2007, especially in the last months of trading when price variations of Euro 0.01 were very high compared to a price level of about Euro 0.03. Finally, for the Dec08 contract, except for the high volatility at the launch of the contract on both platforms, the volatility pattern is smooth. Comparing the two figures, it can be observed that often trading intensity and market volatility move in the same direction.

Data collection

When investigating the development of bid-ask spreads and price discovery on both exchanges, we have to address some issues related to the differences in trading protocols

[7] Compare the weekly newsletter at www.climatecorp.com.

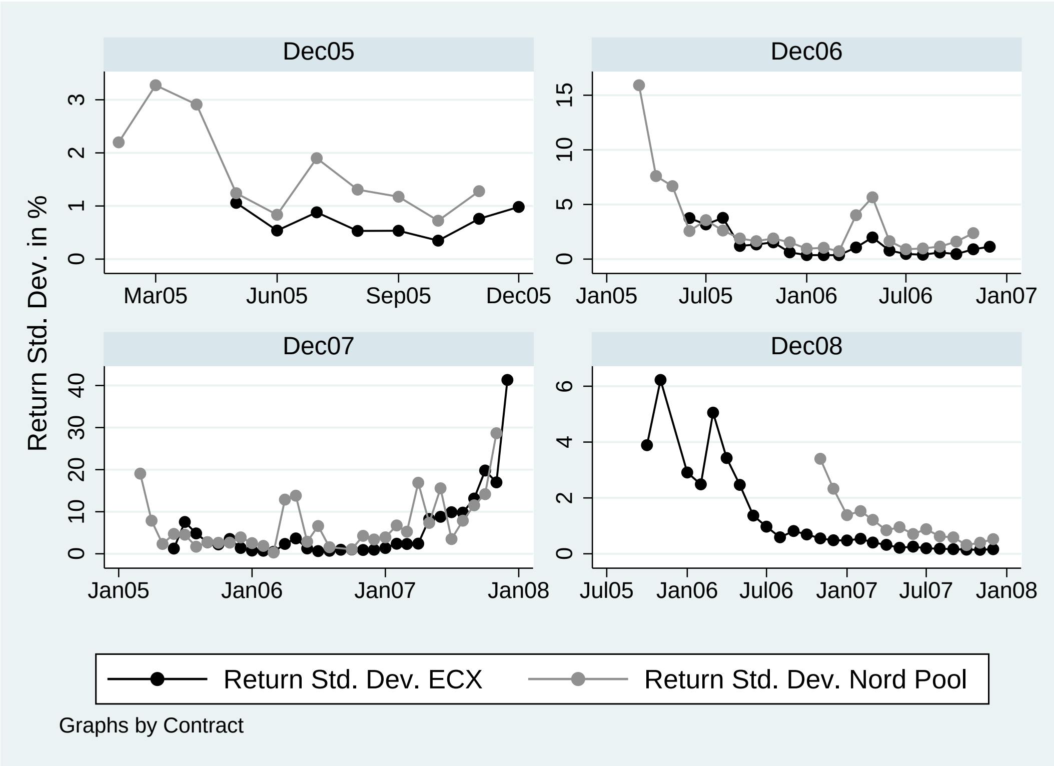
Figure 2.2: Daily transaction frequencies for the Dec05 to Dec08 contracts on ECX and Nord Pool in Phase 1



and contract specifications as well as some standard high frequency issues. To start with, for both types of analysis we omit overnight returns that could induce heteroskedasticity into our data set. Then, for comparing bid-ask spreads across exchanges over the whole trading period of contracts, we omit non-overlapping trading intervals and focus only on periods when the respective contract was traded on both exchanges. We furthermore aggregate all trades within the same second that have the same trade indicator to account for price effects of orders walking up or down the book. Finally, we only include data from continuous trading periods into our analysis and hence exclude pre-opening and post-closing prices.

Regarding the price discovery analysis, some further re-organization of the data set is necessary prior to estimation. First, in order to synchronize trading hours we delete ECX trades that occur after 15:30. Thus, throughout the paper we only use data from 08:00 until 15:30 CET. Second, in our price discovery analysis we postulate a one-to-one relationship between the prices of futures contracts traded on different markets. However,

Figure 2.3: Monthly average return standard deviation for the Dec05 to Dec08 contracts on Nord Pool and ECX in Phase 1



that relationship does not exactly hold due to differing expiration dates on both exchanges. Hence, we discount all contracts to their present value on the respective trading using linear interpolation if the interest rate for a given time span is not available.[8] The third and probably most important aspect that has to be considered is the question of price synchronization. Transactions do not occur at regular intervals, nor do transactions on the two competing trading platforms take place simultaneously. Explicitly, our data include much more transaction prices for ECX than for Nord Pool. Thus several futures prices have to be eliminated from the series. To synchronize the two price series we form three different data sets of matched trade pairs. First, beginning at the start of each trading day, for every transaction price on Nord Pool we identify the most recent transaction price on ECX. These pairs are saved and generate the price series for our model (NP-Match). This method favors Nord Pool, the less liquid exchange. Estimation results that

[8]Interest rate data is obtained from Datastream. For very short discounting horizons, we use EONIA interest rates, for horizons up to a year we use Euribor interest rates, and for horizons of more than one year we employ European monthly corporate interest swap rates.

systematically use "stale" prices of ECX are likely to underestimate the role of ECX and are hence a very conservative measure for price leadership of ECX. It is easy to inquire the robustness of these findings by applying an analogous synchronization procedure favoring ECX (ECX-Match). A third possibility not clearly favoring one exchange over the other has been suggested by Harris et al. (1995).[9] The authors synchronize the data as follows. Beginning at the start of each trading day, as soon as a trade has taken place on both exchanges the trade which has occurred latest in time is matched with the most recent trade on the other exchange. This pair is saved and a new matched trade pair is formed in the same manner for the whole data sample (Harris-Match).[10] Obviously, for the Harris-Match the frequency of the data is determined by the market with the fewest trades, which is in our analysis Nord Pool. Since we expect price discovery to take place at the larger and more liquid trading platform ECX, we opt for choosing the NP-Match disfavoring ECX as a benchmark and refer to other matching algorithms as a robustness check.

2.3 Spread Analysis

In this section, we investigate the development of transaction costs on both exchanges for Phase 1. We measure transaction costs by estimating bid-ask spreads, which are defined as the difference between the best quoted ask and the best quoted bid price in the market. This measure can be interpreted as the costs of trading a round-trip (i.e. costs paid by a liquidity demander to a liquidity supplier for an instantaneous buy and sell transaction). The existence of a bid-ask spread and hence of trading frictions is typically explained with the existence of order handling costs, inventory costs or asymmetric information costs. Order handling costs include costs like telecommunications costs or exchange fees that have to be paid by the liquidity provider. Inventory costs arise for risk-averse liquidity suppliers who bear the risk of having to build up unwanted inventory positions to accommodate public order flow. Asymmetric information costs arise if traders with private

[9] Another possibility of synchronization is the use of equidistant time intervals. This procedure consists of matching the last observed prices at the end of pre-specified time intervals (e.g. 5 minutes, 30 minutes) in each market. If no price updating has taken place within one time interval, the most recent price in the respective market is used for the matching. In our analysis we do not consider this matching approach as the probability that the most recent price comes from the more liquid market ECX is high. Consequently, ECX would be favored compared to Nord Pool as a relatively new ECX trade would be probably matched with an older Nord Pool price.

[10] Compare Harris et al. (1995), pp. 566. This matching procedure is referred to as "REPLACE ALL".

information are active in the market and trade on their information. In order to balance losses to informed traders, liquidity providers may charge a spread.[11]

As examples for the latter in the carbon market, one can think of firms' private decisions that concern e.g. the start-up, closure or expansion of new and old installations as well as private news about market entrants. Furthermore, market participants might have different incentives and possibilities to acquire information about e.g. market developments (current and future market scarcity, abatement costs and potential of other firms) and about regulatory issues (National Allocation Plans for upcoming trading phases, development of CER market or the incorporation of other trading schemes into the EU ETS).[12] It is reasonable to assume that big companies, which are more affected by the EU ETS, have better sources of information or higher incentives to invest in information than smaller firms. The resulting asymmetric information and the related uncertainty influence market scarcity and thus the market price for EUAs or project based EUAs (CERs).

Since we do not have access to best ask and bid quotes, bid-ask spreads cannot be calculated immediately from the data. Fortunately however, the market microstructure literature has proposed a variety of procedures to estimate the spread and its components. Given that our data set identifies transactions as either buyer-initiated or seller-initiated, we can use a so called trade indicator model to estimate and compare traded spreads on ECX and Nord Pool.

2.3.1 Methodology

Trade indicator models assume that information about the underlying asset is contained in the order flow. They use this variable in form of a binary trade initiation indicator to model short-run dynamics of quotes and transaction prices and to estimate traded spreads. Trade indicator models have been proposed by e.g. Glosten and Harris (1988), Huang and Stoll (1997) and Madhavan et al. (1997). Since we observe a significant degree of autocorrelation in our trade initiation variable, we opt for the GMM-approach suggested by Madhavan et al. (1997) that does not restrict autocorrelation in the order flow to be zero. One potential drawback of this approach is the assumption of a constant trade

[11] Compare also the surveys by Madhavan (2000) and Biais et al. (2005).

[12] Additional to EUAs, a market for Certified Emissions Reductions (CERs) - assets, which arise from energy-reducing projects in developing countries - has been created.

size. Since median trade size is equal across exchanges, we believe that the model can be applied to our setup.[13]

Let P_t denote the transaction price of our underlying futures contract at time t, x_t is a trade indicator variable with $x_t = 1$ if the transaction at time t is buyer-initiated and $x_t = -1$ if it is seller-initiated.[14] We assume that purchases and sales are (unconditionally) equally likely, so that $E[x_t]$=0 and Var$[x_t]$=1. We further assume that beliefs about the asset value might change due to new public information announcements that are not associated with the trading process and due to the order flow that provides a noisy signal about the future value of the underlying asset. The innovation in beliefs between $t-1$ and t from dissemination of public information is denoted by η_t which is an i.i.d. random variable with mean zero and variance σ_η^2. Buy (sell) orders are considered as a noisy signal about an upward (downward) revision in beliefs given that there are some traders with private information in the market. We assume that the revision in beliefs (or price impact) $\theta \geq 0$ is positively correlated with the innovation in order flow $x_t - E[x_t|x_{t-1}]$, such that the change in beliefs due to order flow is $\theta(x_t - E[x_t|x_{t-1}])$. Finally, let μ_t stand for the post-trade expectation of the "true" value of the stock conditional on public information and on the information revealed by the trade initiation variable. μ_t evolves according to

$$\mu_t = \mu_{t-1} + \theta(x_t - E[x_t|x_{t-1}]) + \eta_t. \tag{2.1}$$

We assume that the price generating process P_t is determined from the unobserved process (2.1) by adjusting for the costs of providing liquidity services ϕ_t (order handling costs, baseline inventory costs or mark-ups from non-competitive pricing). ϕ captures the non-permanent (transitory) effect of order flow on prices. Quotes are ex-post rational and are conditional on the trade initiation variable being a buy or a sell order, such that a bid-ask spread emerges ($P_t^a = [P_t|x_t = 1] > P_t^b = [P_t|x_t = -1]$):

$$P_t = \mu_t + \phi x_t + \xi_t = \mu_{t-1} + \theta(x_t - E[x_t|x_{t-1}]) + \phi x_t + \eta_t + \xi_t, \tag{2.2}$$

with ξ_t being an i.i.d. random variable with mean zero. To estimate Equation (2.2), we need to make assumptions about the dynamic behavior of the order flow. We assume a

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[13] If, as a robustness check, we drop the assumption of a constant trade size and incorporate trading volume into the model similar to Glosten and Harris (1988), results are very similar.

[14] Compare Madhavan et al. (1997), pp. 1039.

general Markov process for the trade indicator variable where $\gamma = Pr[x_t = x_{t-1}|x_{t-1}]$ denotes the probability that a trade at the ask (bid) follows a trade at the ask (bid). Positive serial correlation in the order flow arises for a variety of reasons such as the breaking up of orders or price continuity rules, leading to $\gamma > 0.5$. Let ρ denote first order autocorrelation of the stationary trade indicator variable x_t, i.e. $\rho = E[x_t x_{t-1}]/Var[x_t]$. It is straightforward to show that $\rho = 2\gamma - 1$ such that autocorrelation in the order flow is an increasing function of the probability of a continuation. In order to estimate Equation (2.2), we need to compute $E[x_t|x_{t-1}]$, i.e. the conditional expectation of the trade initiation variable given public information. It can be easily seen that $E[x_t|x_{t-1}] = \rho x_{t-1}$.[15] Now we only have to substitute out the unobservable belief μ_{t-1} of Equation (2.2) to obtain an equation which we can estimate. We can do so by noting that $\mu_{t-1} = P_{t-1} - \phi x_{t-1} - \xi_{t-1}$ and obtain

$$P_t - P_{t-1} = (\phi + \theta)x_t - (\phi + \rho\theta)x_{t-1} + e_t, \tag{2.3}$$

where $e_t = \eta_t + \xi_t - \xi_{t-1}$. In the absence of asymmetric information and transaction costs, the price follows a random walk process. In the presence of frictions, movements in the price P_t reflect order flow and noise induced by price discreteness as well as public information news. From Equation (2.3), we see that the implied bid-ask spread at time t is equal to $P_t^a - P_t^b = 2(\phi + \theta)$.[16]

2.3.2 Estimation approach

Analog to Madhavan et al. (1997), we estimate Equation (2.3) by GMM as an elegant way to account for autocorrelation of the error term and for possible conditional heteroskedasticity. We estimate the model using standard orthogonality conditions and make use of the definition of the autocorrelation parameter $\rho = E[x_t x_{t-1}]/Var[x_t]$ as an additional constraint to separately identify our two parameters of interest θ (asymmetric information component) and ϕ (transitory spread component).[17]

[15] Since $E[x_t|x_{t-1} = 1] = Pr[x_t = 1|x_{t_1} = 1] - Pr[x_t = -1|x_{t_1} = 1] = \gamma - (1 - \gamma) = \rho$ and analogously $E[x_t|x_{t-1} = -1] = -\rho$.

[16] $P_t^a - P_t^b = (\phi + \theta) \cdot 1 - (\phi + \theta) \cdot (-1) = 2(\phi + \theta)$.

[17] Note that the GMM estimation parameters are identical with OLS parameters.

Table 2.3: Estimated half spreads for the four contracts on ECX and Nord Pool

	ECX			Nord Pool			
Contract	$\hat{s}/2$	Adj. R^2	Obs.	$\hat{s}/2$	Adj. R^2	Obs.	t-stat.
Dec05	0.062	0.21	2,256	0.075	0.18	501	-0.98
Dec06	0.053	0.17	8,011	0.088	0.09	1,266	-3.06***
Dec07	0.032	0.06	5,197	0.049	0.12	296	-1.79*
Dec08	0.028	0.17	23,482	0.058	0.25	2,248	-9.38***

The table depicts estimated half spreads $\hat{s}/2 = \hat{\phi} + \hat{\theta}$ in Euro and percent for ECX and Nord Pool obtained by GMM estimation of model (2.3) under the given moment conditions. Estimation periods for the Dec05, Dec06, Dec07, Dec08 contracts are 05/01/2005-12/01/2005, 07/01/2005-12/01/2006, 06/01/2005-12/03/2007 and 05/01/2006-12/28/2007, respectively.

2.3.3 Estimation results

This section contains the results of GMM estimations of model (2.3) for the different contracts traded on ECX and Nord Pool. In order to obtain comparable results for the complete trading periods, we estimate the model using observations starting from the calender month in which we have observations for both exchanges until the last common trading day of the contracts. As stated before, we also exclude overnight returns.[18] We furthermore only report results for estimations with at least 100 observations. To get a first intuition on liquidity in both exchanges at the contract level, Table 2.3 provides an overview of estimated half spreads in Euro ($\hat{s}/2 = \hat{\phi} + \hat{\theta}$) for each instrument estimated over the whole common sample period.

It can be seen that for each contract estimated half spreads on ECX are significantly lower than on Nord Pool except for the Dec05 contract.[19] As 2005 was the initial trading

[18] The exclusion of overnight returns drastically reduces the number of observations especially for the least liquid Dec07 contract on Nord Pool. Results from including overnight returns are similar.

[19] As estimates are based on non synchronized data, i.e. on different trading frequencies, it is not possible to directly compare spread magnitudes in a statistical sense. In order to be able to make a statement, we conduct a t-test of equality of estimated half spreads across exchanges. For the t-test, we assume independent samples with a different sample size and variance. The t-statistic is computed as

$$t = \frac{\hat{s}/2^{ECX} - \hat{s}/2^{NordPool}}{\sqrt{\hat{\sigma}^2_{ECX} + \hat{\sigma}^2_{NordPool}}},$$

where $\hat{\sigma}^2$ is the variance of the estimated half spread for the respective market. ***,**, and * denote statistical rejection at the 1%, 5%, and 10% levels, respectively.

year for both trading platforms, the finding of no significant differences in the first traded contract, Dec05, is not unexpected. The subsequent gradual decrease in spread magnitude on ECX is consistent with a maturing and expanding market. Interestingly, the pattern is slightly different on Nord Pool. While for the Dec05 contract spreads are of similar magnitudes, the relative distance increases over Phase 1. Additionally, absolute estimated half spreads do not monotonically decrease over the differing contracts. Since it seems plausible to detect more frequent price updating on the exchange with lower bid-ask spreads, we expect ECX to be the leader with respect to price discovery, the second part of this chapter. However, if differences in bid-ask spreads stem from the presence of a higher probability of informed trading on Nord Pool relative to ECX, results might be the other way around.[20]

To improve our understanding about how liquidity, measured by traded bid-ask spreads, has developed over time we subdivide the estimation periods into finer time intervals. Table 2.4 shows the development of estimated half spreads in Euro and percent for the most liquid trading year and its calendar quarters. In case that there are less than 100 observations, the preceding month is included into the analysis as indicated at the bottom of the table. If there are still not enough observations, no estimation results are reported.

At the very beginning of trading (Q2 and Q3 of 2005), the relative difference of spreads for the Dec05 contract on Nord Pool and ECX is small. In the fourth quarter (Q4) of 2005 spreads start to differ significantly. Estimated transaction costs on ECX are lower than on Nord Pool, except for the Dec07 contract, the least liquid futures contract. It can be observed that spreads vary over time on both exchanges. The decreasing trend in absolute terms for all contracts is only broken twice. A temporary increase in the third quarter of 2005 might be linked to the surge in oil and gas prices related to damages caused by the hurricanes Katrina and Rita in September 2005 and it may be related to the volatility increase in the market in July 2005. The increase in the second quarter (Q2) 2006, the quarter with the highest absolute and percentage spreads for all contracts traded at that time, can be clearly linked to the market breakdown when the significant over-allocation of EUAs became public at the end of April 2006.[21] Percentage half spreads

[20] Compare also Hasbrouck (1995), p. 1184.

[21] Quarterly results for ECX for the Dec07 and Dec08 contract are available from the authors upon request.

Table 2.4: Estimated half spreads for the four contracts on ECX and Nord Pool by the most liquid year and by its calendar quarters

Contract		ECX				Nord Pool				
		$\hat{s}/2$	in %	Adj. R^2	Obs.	$\hat{s}/2$	in %	Adj. R^2	Obs.	t-stat.
Dec05	2005	0.0624	0.27	0.21	2,256	0.0750	0.33	0.18	501	-0.98
	Q2	0.0614	0.31	0.29	445	0.0594	0.31	0.20	206	0.17
	Q3	0.0769	0.34	0.24	1,240	0.0933	0.40	0.18	270	-0.76
	Q4	0.0418	0.19	0.14	1,093	0.0657	0.29	0.24	156	-1.99**
Dec06	2006	0.0512	0.31	0.18	7,832	0.0890	0.54	0.08	1,140	-3.21***
	Q1	0.0448	0.17	0.24	2,032	0.0810	0.30	0.28	223	-3.34***
	Q2	0.0797	0.50	0.20	2,625	0.1252	0.79	0.07	503	-1.74*
	Q3	0.0362	0.22	0.25	1,493	0.0587	0.36	0.25	286	-3.20***
	Q4	0.0303	0.32	0.14	1,682	0.0347	0.32	0.16	128	-0.52
Dec07	2007	0.0178	1.42	0.21	2,412	0.0246	2.05	0.10	184	-1.06
	Q1	0.0213	1.02	0.23	1,636	0.0322	1.34	0.12	122	-1.30
	Q2	0.0118	2.19	0.22	572					
	Q3	0.0059	4.53	0.18	154					
Dec08	2007	0.0266	0.13	0.26	21,292	0.0563	0.26	0.25	216	-9.67***
	Q1	0.0404	0.27	0.30	3,333	0.0775	0.50	0.31	263	-4.05***
	Q2	0.0321	0.15	0.27	4,944	0.0696	0.31	0.28	722	-6.09***
	Q3	0.0216	0.11	0.27	7,303	0.0608	0.30	0.28	507	-6.86***
	Q4	0.0205	0.09	0.27	5,712	0.0315	0.14	0.20	724	-4.27***

The table depicts estimated half spreads $\hat{s}/2 = \hat{\phi} + \hat{\theta}$ in Euro and percent for ECX and Nord Pool obtained by GMM estimation of model (2.3) under the given moment conditions. Percentage spreads are obtained by dividing the estimated half spread by the median price level of the estimation period. Estimation periods are as indicated with e.g. Q3 2006 denoting July to September 2006. For Nord Pool and ECX, the last estimations for the Dec05 contract are from September to December of the respective year. For ECX, estimates for the third quarter 2007 (Q3 2007) are from June to September 2007. Results with less than 100 observations are not depicted.

that are reported in columns 4 and 8 of Table 2.4 generally move in line with absolute spread magnitudes. Only for the Dec07 contract percentage spreads are increasing while absolute spreads decrease since the market price fell to almost zero. Note that due to the minimum tick size of Euro 0.05 on ECX until the end of March 2007, spreads estimated for ECX during this time period should be at least Euro 0.05. Our estimates capture this institutional characteristic since, except for the first Quarter (Q1) in 2007, estimated half spreads are greater than Euro 0.025.

As our model allows us to decompose the estimated spreads into an asymmetric information (θ_t) and a transitory component (ϕ_t), Table 2.5 provides results for the decomposition of the estimated spreads that are displayed in Table 2.4. We observe that for both exchanges the asymmetric information component $\hat{\theta}$ is significantly positive and constitutes by far the larger share of the traded spread. For all contracts there is a (local) peak in the permanent share in the second quarter of 2006, at the time of highest volatility in the market. Note that the transitory component $\hat{\phi}$ is very small and sometimes even negative, especially for the Nord Pool contracts. Often it is not significantly different from zero.[22] One possibility to circumvent the negative sign of $\hat{\phi}$ is to set ρ and hence $E[x_t|x_{t-1}]$ equal to zero and thus ignore autocorrelation as other trade indicator models do (see e.g. Glosten and Harris (1988)). Thereby, the magnitude of estimated half spreads does not change and we observe positive transitory components that are in most of the cases significant. However, the permanent component still accounts for the much larger share of the estimated half spread. Thus, both approaches yield qualitatively similar results such that the assumption about the conditional expectation does not alter our conclusions.

Overall, it appears that bid-ask spreads charged by liquidity providers in the European CO_2 market are mainly charged as a protection against losses to informed traders (see e.g. Bagehot (1971) or Glosten and Milgrom (1985)) and only to a marginal extent as a compensation for order handling or inventory costs. Given the extensive amount of uncertainty in the market about the development of price drivers as energy and fuel prices or about regulatory issues concerning future National Allocation Plans and the use of project based EUAs (CERs) as well as private news on the installation level, this result is not surprising.

As a last exercise, we assess the intraday pattern of estimated bid-ask spreads. Figure 2.4 plots intraday half spreads for both platforms again estimated over the full common sample period against trading hours. The intervals of the day that we use for estimations are from 08:00 to 09:59, from 10:00 to 11:59, from 12:00 to 13:59, and from 14:00 to 15:29 for ECX and Nord Pool. Since trading on ECX takes place until 18:00 CET, for ECX the last intraday estimates are from 15:30 to 18:00.[23] If the market processes information

[22] Note that estimating the model by OLS and accounting for serial correlation by the use of Newey-West standard errors, significance levels slightly increase.

[23] Note that results are not affected by the choice of time intervals.

Table 2.5: Estimated transitory component $\hat{\phi}$ and permanent component $\hat{\theta}$ for the Dec05 to Dec08 contracts on ECX and Nord Pool for the most liquid year

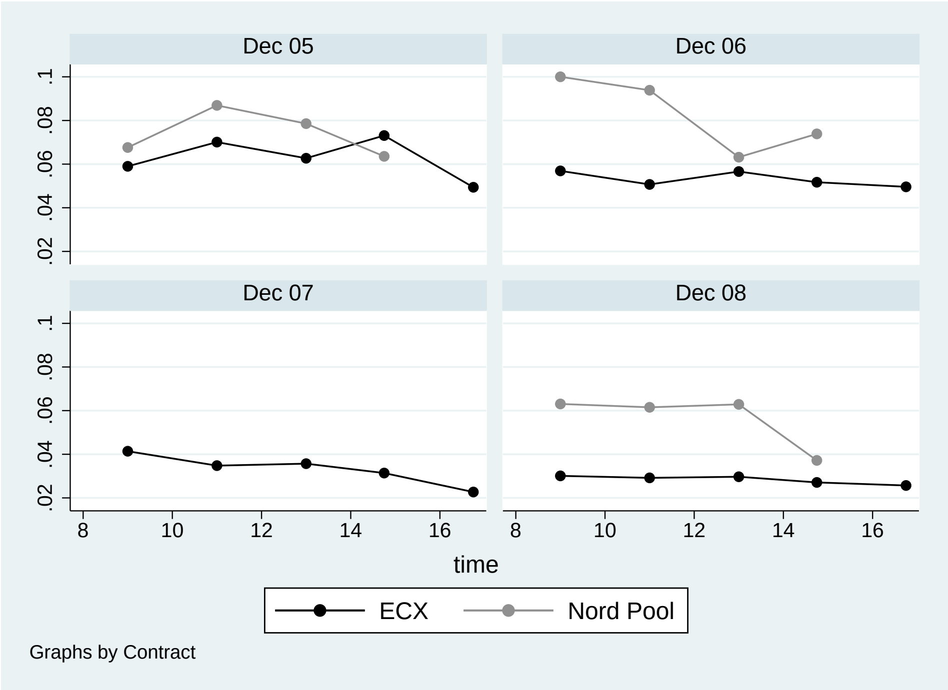
Contract		ECX				Nord Pool			
		$\hat{\phi}$	t-stat.	$\hat{\theta}$	t-stat.	$\hat{\phi}$	t-stat.	$\hat{\theta}$	t-stat.
Dec05	2005	-0.0024	-0.60	0.0648***	13.95	-0.0110	-1.10	0.0860***	7.36
	Q2	-0.0153**	-2.14	0.0767***	9.08	-0.0113	-1.01	0.0708***	5.59
	Q3	-0.0010	-0.17	0.0780***	11.23	-0.0104	-0.68	0.1037***	5.78
	Q4	-0.0005	-0.11	0.0423***	8.97	-0.0078	-0.72	0.0735***	5.17
Dec06	2006	0.0016	0.94	0.0496***	20.20	-0.0008	-0.07	0.0898***	7.89
	Q1	0.0036	1.62	0.0412***	15.75	-0.0135	-1.32	0.0945***	7.19
	Q2	-0.0037	-0.78	0.0834***	13.23	0.0095	0.35	0.1157***	4.79
	Q3	0.0019	0.93	0.0342***	13.61	0.0103	1.60	0.0484***	5.20
	Q4	0.0059***	2.92	0.0243***	9.14	-0.0213**	-2.22	0.0560***	4.35
Dec07	2007	0.0018*	1.80	0.0159***	13.02	0.0015	0.20	0.0231***	3.63
	Q1	0.0004	0.28	0.0210***	12.96	-0.0010	-0.10	0.0332***	3.83
	Q2	0.0043***	3.03	0.0075***	5.59				
	Q3	0.0031**	2.53	0.0028***	2.75				
Dec08	2007	0.0025***	5.85	0.0241***	46.30	-0.0064**	-2.20	0.0628***	17.04
	Q1	0.0054***	3.76	0.0350***	21.62	-0.0075	-0.77	0.0851***	7.87
	Q2	0.0009	0.82	0.0312***	25.39	-0.0123**	-2.16	0.0819***	11.28
	Q3	0.0027***	4.76	0.0188***	28.36	0.0052	0.87	0.0556***	7.61
	Q4	0.0020***	3.51	0.0186***	28.36	-0.0091**	-2.39	0.0407***	10.28

The table depicts estimated half spread components $\hat{\phi}$ and $\hat{\theta}$ in Euro for ECX and Nord Pool obtained by GMM estimation of equation (2.3) under the given moment conditions. Estimation periods are as indicated with e.g. Q3 2006 denoting July to September 2006. For Nord Pool and ECX, the last estimations for the Dec05 contract are from September to December of the respective year. For ECX, estimates for the third quarter 2007 (Q3 2007) are from June to September 2007. Results with less than 100 observations are not depicted. ***,**, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

or resolves uncertainty during the trading day, we would expect to see spreads decline in the course of trading as observed in other markets.[24] Investigating the patterns in Figure 2.4, we observe that half spreads for the first two trading hours are always higher than for the last trading interval at the respective exchange. Considering e.g. the Dec06 contract, on average, the trading day on ECX (Nord Pool) starts with an estimated half spread of Euro 0.06 (Euro 0.10) and closes with a half spread of Euro 0.05 (Euro 0.07).

[24]See e.g. Madhavan et al. (1997) and the discussion in Biais et al. (2005)

Figure 2.4: Intraday pattern of estimated half spreads on ECX and Nord Pool on the contract level



Regarding the share of the permanent spread component relative to the total spread, we find on ECX that except for the Dec07 contract, asymmetric information costs charged by liquidity providers decline over the course of the trading day.[25] For Nord Pool, however, no clear-cut picture emerges.

If the market development continues and overall uncertainty decreases in the future, we expect bid-ask spreads to decrease over the next trading phase 2008-2012 to levels close to Euro 0.01. Overall, the development of transaction costs speaks in favor of a maturing market, in which traded volumes and trading intensity increase over time while transaction costs fall. Continuing from low spread levels at the end of 2007, the EU ETS seems to be on a good way with respect to the functioning of organized EUA trading.

2.4 Price Discovery

In this section we examine on which exchanges price discovery, the processing of information into prices, takes place. Note that the econometric model that we are going to

[25]Results are available from the authors upon request.

apply in this section is not related to the bid-ask spread analysis from the last section. However, the previous results may give some intuition for the expected outcomes with respect to price discovery.

Following common practice in the literature on financial and commodity markets, we approach the question of price discovery by specifying a vector error correction model (VECM). We proceed by describing the econometric methodology before applying it to the EUA futures market making use of high frequency data. As detailed above, observing lower transaction costs and higher trading volumes on the platform ECX, our prior is to expect a leading role for ECX. Correspondingly, before specifying an ECM, we use a conservative matching method that disfavors ECX, which we earlier referred to as NP-Match, in order to be sure that results are not driven by the use of newer ECX prices compared to Nord Pool.

Generally, the use of high frequency data is only more appropriate compared to daily data if events in the market under examination are also of high frequency. To obtain an intuition on whether this is the case, we compute the fraction of zero returns from one matched transaction in one market to the next one. For the matching approach favoring Nord Pool (NP-match), the fraction of zero returns for Nord Pool ranges from 0.19 to 0.34 for the different contracts. For ECX values are higher and range from 0.38 to 0.45. Compared to more mature markets, these figures are rather high. However, apparently there is more information in intraday data compared to daily data such that there is reason to use data of highest frequency.[26]

2.4.1 Methodology

Cointegration and error correction

Generally, price discovery is the process by which markets attempt to find (discover) equilibrium prices by incorporating new information.[27] In case that an identical asset is traded at the same time in several markets, due to no-arbitrage arguments there should

[26]Considering e.g. our third matching approach as suggested by Harris et al. (1995), figures are lower and range from 0.15 to 0.29 for Nord Pool and from 0.10 to 0.18 for ECX. These magnitudes can also be found on more mature financial markets.

[27]It has been argued that the process of price discovery in security markets is one of the most important products of a security market (cf. Hasbrouck (1995), p. 1175). Compare also O'Hara (2003).

be no significant price differences across the markets. Formally, this means that there is an equilibrium price of the asset, which is common to all markets, and the sources of its price variation are attributed to different markets. While market efficiency implies that new information is impounded instantaneously into prices, markets process and interpret news at different rates (e.g. due to institutional factors such as transaction costs) and thus disequilibria occur, especially in an immature market like the EU ETS.

Explicitly, in our case of two markets this means that the two prices may be driven in a fundamental sense by one market, which is the price leader whereas the other market acts as a price taker. The price leader thus incorporates news faster into prices than the other market. Hence, returns on this market should lead the returns on the other market.

To investigate price leadership in the EUA futures market, we apply two relative measures of price discovery which both use the VECM as their basis. Hence, our approach builds on the work of Engle and Granger (1987) who show that a VECM framework is appropriate for cointegrated time series.[28] The idea behind cointegration is that while two (or more) time series are non-stationary I(1) processes, they do not drift too far away from each other, such that their difference is stationary. In that case, a proportion of the deviation from the equilibrium path in one period is corrected in the next period – the error correction (EC) mechanism.[29] Thus formally, returns should be represented by a VECM of the form

$$\Delta p_t = \xi + \sum_{k=1}^{K} \Gamma_k \Delta p_{t-k} + \alpha \beta' p_{t-1} + \epsilon_t \qquad (2.4)$$

where $p_t = (p_t^{ECX}, p_t^{NP})$ are the log futures prices on ECX and Nord Pool, ξ and α are (2×1) vectors of parameters, Γ_k are (2×2) matrices of parameters, and K is the lag-length, which will be determined by the Schwarz criterion. ϵ_t is a (2×1) error vector with mean zero and variance-covariance matrix Ω, Δ is the difference operator (e.g. $\Delta p_t = p_t - p_{t-1}$) and β is the (2×1) cointegrating vector, which is in our case equal to (1 -1)'.[30] In this

[28]This approach is equivalent to estimating a VAR model of log returns on both exchanges augmented by an error correction (EC) term including the difference between lagged prices on both exchanges.

[29]The relationship between error correction models and cointegration was first pointed out by Granger (1981). A theorem showing that cointegrated series can be represented by an error correction model was originally stated and proved by Granger (1983).

[30]We did not explicitly estimate but rather pre-specified the cointegration vector since the long-run equilibrium is given by $p_t^{ECX} - p_t^{NP} = 0$, see e.g. Theissen (2002). This relation holds in our application since we are using discounted price series.

model the current returns are then explained by (i) the past returns on both markets (short-run dynamics induced by market imperfections), and (ii) the deviation from the no-arbitrage equilibrium (long-run dynamics between the price series), i.e. $p_t^{ECX} - p_t^{NP}$.[31] Consequently, the cointegrating vector defines the long-run equilibrium, while the EC dynamics characterize the price discovery process. Note that the coefficient vector of the EC term $\delta = (\delta^{ECX}\ \delta^{NP})$ is (by construction) orthogonal to the EC coefficient vector α. This coefficient vector is needed to compute the following two common factor measures for price discovery.

Common factor measures

One measure dates back to work by Gonzalo and Granger (1995) and Schwarz and Szakmary (1994) and only regards the EC process, i.e. only δ is relevant. The other measure has been suggested by Hasbrouck (1995) and additionally takes into account the variance of the innovations to the common factors of the price series.[32]

Common factor weights (CFW)

Schwarz and Szakmary (1994) argue that the coefficients δ^{ECX} and δ^{NP} in the VECM in model (2.4) represent the permanent effect that a shock to one of the variables has on the system. Therefore they propose to use the relative magnitude of these coefficients to assess the contributions of the two markets to price discovery.[33] Specifically, they propose the measure

$$CFW^{ECX} = \frac{\delta^{NP}}{\delta^{NP} - \delta^{ECX}}; \quad CFW^{NP} = \frac{-\delta^{ECX}}{\delta^{NP} - \delta^{ECX}}. \tag{2.5}$$

A high magnitude of δ_i (i = ECX, NP) in the respective market corresponds to slow information dissemination. Apart from describing adjustment dynamics, the coefficients measure the speed of assimilation to discrepancies between the markets. Thus, the common factor weights quantify the share of total reaction being attributable to one market.

[31] Compare also Baillie et al. (2002), p. 311.

[32] For a comparison of both measures, see the discussions by De Jong (2002) and Baillie et al. (2002).

[33] A formal justification can be derived from the work of Gonzalo and Granger (1995).

Information shares (IS)

The information share approach of Hasbrouck (1995) relates the contribution of an individual market's innovation to the total innovation of the common efficient price instead of only focusing on coefficients of the deviation term. To derive the IS formula, Hasbrouck transforms model (2.4) into a vector moving average (VMA) process

$$\Delta p_t = \Psi(L)e_t. \tag{2.6}$$

Its integrated form can be written as

$$p_t = p_0 + \Psi(1)\sum_{s=1}^{t} e_s + \Psi^*(L)e_t, \tag{2.7}$$

where p_0 is a vector of constant initial values, $\Psi(L)$ and $\Psi^*(L)$ are matrix polynomials in the lag operator, L, and the (2×2) matrix $\Psi(1)$ is the sum of the moving average coefficients. It is called the impact matrix as $\Psi(1)e_s$ (for $s = 1, ..., t$) measures the long-run impact of an innovation on each of the prices. Due to the pre-specified cointegration vector β=(1 -1)', the long-run impact is the same for both prices. This translates into an impact matrix whose rows are identical. With $\psi = (\psi_1\ \psi_2)$ being the common (1×2) row vector of $\Psi(1)$, equation (2.7) becomes

$$p_t = p_0 + \iota(\psi\sum_{s=1}^{t} e_s) + \Psi^*(L)e_t, \tag{2.8}$$

where ι=(1 1)' is a column vector of ones. While $\Psi^*(L)e_t$ simply denotes the transitory portion of the price change, Hasbrouck defines the first part of equation (2.8) – the random-walk component – as the common factor component or the common efficient price in the two markets.[34] The common factor innovations (increments) ψe_t (for $s = 1, ..., t$) are the components of the price change that are permanently impounded into the price and that are presumably due to new information. We are interested in this part when analyzing the process of price discovery.

We observe that the innovations' covariance matrix Ω is not diagonal as price innovations are correlated across the two markets. To investigate the proportion of the total variance

[34] His specification is closely related to the common trend representation of prices from different markets in Stock and Watson (1988).

in the common efficient price that is attributable to innovations in one of the two markets (hence, its information share), the variance of the common factor innovations $\text{Var}(\psi e_t) = \psi\Omega\psi'$ has to be decomposed. The Cholesky factorization of $\Omega = MM'$ can be applied to minimize contemporaneous correlation, where M is a lower triangular (2×2) matrix.[35] The information share for market j is given as follows:

$$IS_j = \frac{([\psi M]_j)^2}{\psi\Omega\psi'}. \tag{2.9}$$

There are many different factorizations of Ω. Due to the nature of the Cholesky decomposition, the lower triangular factorization maximizes the information share of the first market and consequently minimizes the share of the second market. Thus, by permuting ψ and Ω, upper and lower bounds for each market's information share are obtained. Following the literature, we use the mean of the upper and the lower bound as a unique measure of a market's information share. As formally justified by e.g. Martens (1998) and Theissen (2002), the common row vector ψ is directly related to the coefficient vector of the EC term δ, i.e. $\frac{\psi_1}{\psi_2} = \frac{\delta_1}{\delta_2}$. Using equation (2.9) and by noting that $IS_{ECX} + IS_{NP} = 1$, the IS can be rewritten as

$$IS_1 = \frac{(\delta_1 m_{11} + \delta_2 m_{21})^2}{(\delta_1 m_{11} + \delta_2 m_{21})^2 + (\delta_2 m_{22}^2)} \tag{2.10}$$

$$IS_2 = \frac{(\delta_2 m_{22})^2}{(\delta_1 m_{11} + \delta_2 m_{21})^2 + (\delta_2 m_{22}^2)}. \tag{2.11}$$

Both equations show that the IS only depend on the vector α (or its orthogonal vector δ) and Ω.[36] They also show that the factorization imposes a greater IS on the price of the first market (unless $m_{21} = 0$, i.e. no correlation between market innovations exists).

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[35] Hasbrouck (1995) states that most of the contemporaneous correlation comes from time aggregation as in practice, market prices usually change sequentially. As one way to minimize the correlation, he suggests to shorten the interval of observation and to synchronize the data. However, as this will only lessen but not eliminate the contemporaneous correlation, he additionally proposes the triangularization of the covariance matrix.

[36] Note that we use a different matrix indexing than Baillie et al. (2002). With m_{21} we denote the entry of the second line in the first column of the matrix M.

2.4.2 Estimation results

After applying stationarity and cointegration tests to our price series, in this section, we present results of the price discovery analysis. Note that we conducted the same exercise for each data synchronization scheme. As the NP-Match is of highest interest for our analysis, we explicitly report its estimation results and only verbally describe deviations from the other two matches.

Stationarity and cointegration tests

Proper interpretation of cointegration models requires that all futures price series contain a single unit root implying non-stationarity. To test for stationarity we apply the well-known Augmented Dickey-Fuller (ADF) unit root test as well as the Kwiatkowski, Phillips, Schmidt, and Shin (KPSS) stationarity test.[37] For both tests the truncation parameter to select the autocorrelation lag length is chosen according to the Schwarz information criterion. Table 2.6 presents the results of the unit root tests for the whole sample period for the NP-Match (April 2005 to December 2007).[38] For the Dec05 and Dec08 contract we do not explicitly consider a trend in the unit root test as a visual inspection of the data fails to provide an indication of a trend (see e.g. Uhrig-Homburg and Wagner (2007)).

With respect to the log price series, ADF tests reject the null hypothesis of a unit root only for the Dec08 contract on both exchanges. The KPSS tests reject the assumption of stationarity for all contracts except for Dec06. We conclude that the evidence is in favor of non-stationarity as indicated by the mostly insignificant ADF and significant KPSS tests, respectively. For the first-differenced series 15 out of 16 tests indicate stationarity. Note that applying the unit root tests to the ECX-Match yields the same picture as for the NP-Match. For the Harris-Match, the tests clearly indicate non-stationarity of the log prices and of stationarity for the first differences. Testing for cointegration, we use the likelihood ratio test procedure proposed by Johansen (1988, 1991). The results indicate that the time series from Nord Pool and ECX are cointegrated.

[37] While the null hypothesis of the ADF test is the existence of a unit root, the KPSS test assumes a stationary time series. Compare Dickey and Fuller (1979) and Kwiatkowski et al. (1992).

[38] Note that futures trading on Nord Pool started in February 2005, ECX trading was launched in April 2005.

Table 2.6: Stationarity tests for the four log price series on ECX and Nord Pool

	level		first difference	
ECX	ADF	KPSS	ADF	KPSS
log(Dec05)	-2.058	0.632**	-25.371***	0.365*
log(Dec06)	-2.444	0.269	-35.306***	0.068
log(Dec07)	-1.624	0.318*	-22.028***	0.076
log(Dec08)	-3.340***	3.67***	-66.800***	0.224

	level		first difference	
Nord Pool	ADF	KPSS	ADF	KPSS
log(Dec05)	-2.013	0.648**	-25.403***	0.299
log(Dec06)	-2.567	0.269	-36.878***	0.068
log(Dec07)	-1.613	0.339*	-21.718***	0.068
log(Dec08)	-3.536***	3.690***	-69.522***	0.225

The table presents the test statistics from Augmented Dickey Fuller (ADF) tests and Kwiatkowski-Phillips-Schmidt-Shin tests (KPSS) applied to both price levels and the first differences of the time series.*,**, and *** stand for rejection at the 10, 5, and 1 per cent levels.

Error correction model

We apply the VECM derived above to the synchronized high frequency EUA futures log price series. The VECM in equation (2.4) can be written as

$$\Delta p_t^{ECX} = \xi^{ECX} + \sum_{k=1}^{K} \gamma_{11,k} \Delta p_{t-k}^{ECX} + \sum_{k=1}^{K} \gamma_{12,k} \Delta p_{t-k}^{NP} + \delta^{ECX}(p_{t-1}^{ECX} - p_{t-1}^{NP}) + \epsilon_t^{ECX} \tag{2.12}$$

$$\Delta p_t^{NP} = \xi^{NP} + \sum_{k}^{K} \gamma_{21,k} \Delta p_{t-k}^{ECX} + \sum_{k}^{K} \gamma_{22,k} \Delta p_{t-k}^{NP} + \delta^{NP}(p_{t-1}^{ECX} - p_{t-1}^{NP}) + \epsilon_t^{NP}.$$

The coefficients δ^{ECX} and δ^{NP} determine the speed of adjustment of the respective price towards the long-run equilibrium levels, which is assured by the no-arbitrage argument. If ECX incorporates information faster, we expect δ^{ECX} to be insignificant, while δ^{NP} should be significant and bear a positive sign.

Table 2.7 presents estimated common factor measures of the VECM estimation of the NP-

Table 2.7: Estimation results of the error correction model for the Dec05 to Dec08 contracts on ECX and Nord Pool in Phase 1

	EC		CFW		IS for ECX		
Contract	δ^{ECX}	δ^{NP}	ECX	NP	Mean	Range	Obs.
Dec05	++	++	0.593	0.407	0.546	0.790	615
Dec06	+	++	0.811	0.189	0.623	0.725	1433
Dec07		++	0.830	0.170	0.714	0.513	413
Dec08		++	0.847	0.153	0.644	0.693	2402

The table presents the CFWs for both markets and for all contracts together with the information shares for ECX. We report the mean of the upper and lower bound and the corresponding range (difference between upper and lower bound). A '++' or '+' indicates that the coefficients of the error correction vector ($\hat{\delta}^{ECX}\hat{\delta}^{NP}$) are significantly different from 0 at the 5% or 10% level, respectively. For the Dec08 contract, we only use transaction prices from the year 2007.

Match for all four futures contracts and covers the common sample period.[39] To conserve space, we do not display the coefficients of the EC term ($\delta^{ECX}, \delta^{NP}$) and of the VAR terms $\gamma_{ij,k}$, and only report the CFWs for both markets. The coefficients' level of significance is marked by '++' or '+', which indicates that they are significantly different from 0 at the 5% or 10% level, respectively. Furthermore, the table depicts information shares for ECX. It reports the mean of the upper and lower bound and the range (difference between upper and lower bound). Remember that upper and lower bounds are obtained from changing the ordering in the Cholesky factorization. For the Dec05 contract we include 2 lags, and for Dec06/ Dec07/ Dec08 we take 8/ 1/ 3 lags, respectively.[40]

We find that for all contracts in both equations of (2.12) the coefficient of the EC term has the expected sign and is significant in at least one of the markets. Thus, price discovery takes place. Apparently, for the Dec05 and Dec06 contracts, both markets contribute to the process of price discovery. However, ECX is the clear price leader for the Dec07 and Dec08 contracts. Measuring the markets' contribution to price discovery both measures tend in the same direction. We find that for later expiration dates price

[39] As for Dec08 trading activity was very low in 2006, we start the analysis in January 2007.

[40] We applied the Schwarz information criterion for the whole sample period as well as for three-month intervals displayed in Table 2.8. As final lag-length we took the maximum.

discovery increasingly takes place on ECX. These results are in line with the development of the EUA futures market. As stated in the introduction, Nord Pool was the first platform which started to trade EUA futures and is thus expected to be the more experienced market for the first months of trading. ECX joined some time later and managed to attract more liquidity in the course of the time.

To counteract critique of analyzing a too long data sample and to account for structural breaks, we zoom into the most liquid trading phase of each contract and divide it into calendar quarters. Note that due to the lack of observations we start the analysis for the Dec05 contract with the second quarter and we remove the Dec07 contract from the quarterly analysis.[41] The results in Table 2.8 reveal the following interesting pattern for price discovery: Both measures indicate that ECX's contribution peaks in the second (Q2) and third quarter (Q3) compared to the first (Q1) and last (Q4) quarter. An exception constitutes the Dec05 contract, where in the second quarter price discovery still takes place on both platforms. To find possible explanations for this behavior, we analyze quarterly trading activity measured by the average number of daily transaction frequencies and average daily trading volume. Apparently, Table 2.8 states that the observed price discovery pattern is mostly in line with the one for trading activity: whenever liquidity is increasing ECX mostly leads the price whereas Nord Pool's contribution becomes again observable when transaction frequencies and trading volumes decline. An exception is the sharp decrease in liquidity after the second quarter for the Dec06 contract, which did not lead to a change in the common factor weights. As was stated, this behavior reflects the announcement of an considerable over-allocation of EUAs at the end of April, which led to a substantial drop in demand for EUAs and thus to a drop in spot and futures prices. Furthermore, it might be the case that findings for the last quarter are related to an earlier expiry of Nord Pool contracts compared to ECX futures. Interestingly, when comparing the observed pattern to changes in market design on ECX or Nord Pool, which we referred to in section 2.2.2, we do not find evidence that e.g. the introduction of market makers or fee reductions had an impact on results.

When interpreting our results it should be kept in mind that the construction of our data set, NP-Match, puts ECX at a disadvantage and thus favors the less liquid market Nord

[41] In case that there are less than 190 observations, the preceding month is included into the analysis as indicated at the bottom of the table.

Table 2.8: Estimation results of error correction model for a restricted sample period together with daily transaction frequencies and trading volume

Contract		EC δ^{ECX}	EC δ^{NP}	CFW [%] ECX	CFW [%] NP	IS of ECX [%] Mean	IS of ECX [%] Range	TAs ECX	TAs NP	Vol. [Mio t CO_2] ECX	Vol. [Mio t CO_2] NP
Dec05	Q2 05	+	+	0.51	0.49	0.51	0.82	11	4	79.8	34.5
	Q3		++	0.61	0.39	0.56	0.74	23	5	171.7	42.4
	Q4	++		0.13	0.87	0.45	0.90	17	3	141.4	25.8
Dec06	Q1 06			0.56	0.44	0.51	0.94	41	5	415.2	26.2
	Q2		++	0.79	0.21	0.62	0.71	57	9	517.2	68.3
	Q3		++	0.79	0.21	0.62	0.71	30	6	248.3	41.3
	Q4		+	0.69	0.31	0.55	0.87	47	5	313.0	34.0
Dec08	Q1 07			0.37	0.63	0.49	0.93	77	6	675.2	38.1
	Q2		++	0.92	0.08	0.77	0.46	145	13	966.7	78.5
	Q3		++	0.93	0.07	0.73	0.53	178	10	1296.7	71.3
	Q4	+	++	0.68	0.32	0.56	0.83	177	13	1087.4	98.1

The table presents the CFWs for both markets and for all contracts together with the information shares for ECX. We report the mean of the upper and lower bound and the corresponding range (difference between upper and lower bound). A '++' or '+' indicates that the coefficients on the error correction vector ($\hat{\delta}^{ECX}\hat{\delta}^{NP}$) are significantly different from 0 at the 5% or 10% level, respectively. In Q4 for the Dec05 and Dec06 contracts the September is included as there are less than 150 observations. TAs denotes the number of daily transactions.

Pool. Hence our results are likely to even understate the role of ECX in the process of price discovery. To check the robustness of our results we estimate the VECM of equation (2.12) also for the ECX- and Harris-Match. While results from both matches are even more in favor of ECX they also show that Nord Pool significantly contributes to price discovery in the first and last quarters of the most active trading year. We hence conclude that while ECX is the clear price leader in the EUA futures market, a null hypothesis of no contribution to price discovery by Nord Pool can be rejected.

2.5 Conclusion

In our paper we analyzed high frequency data for European Union Emission Allowance (EUA) futures for the whole first trading period from 2005 to 2007. Data has been provided by the two most liquid trading platforms ECX and Nord Pool. After giving a short market overview, we addressed the issue of market liquidity. We conducted a spread analysis by applying a trade-indicator model. Having two cointegrated price series we were able to measure the process of price discovery by estimating a vector error correction model.

Our results revealed that estimated transaction costs markedly decreased on both exchanges over time and were lower on ECX than on Nord Pool. With respect to price discovery, our paper demonstrated that for the first EUA futures contracts, Dec05 and Dec06, both exchanges contributed to price discovery. However, for the most recent contracts, Dec07 and Dec08, the more liquid market ECX became the price leader, especially in phases of high market liquidity, but Nord Pool's contribution was still present in times of lower transaction frequencies and volumes.

Obviously, our results are not only of academic interest. Our findings suggest that, in order to remain (as second competitive platform) in the market and not to lose further market share to ECX, Nord Pool should take further action to attract liquidity. The same is true for other existing and potential market competitors, especially given the large (but decreasing) extent of competition from the OTC market. The fact that we did not observe liquidity migration towards Nord Pool after the implementation of several measures to boost liquidity (section 2.2.2) is of interest for platform providers. It may be also of value for research on liquidity migration investigating which factors cause liquidity to move between trading venues.

With respect to the outlook for this recent market, the sharp increase in trading volumes over time reveals that there may be a lot of profits for other trading platforms and market participants from entering the (futures) market. The development potential of the EUA market is extremely high since the EUA can be considered as an European and – depending on future regulatory decisions with respect to additional member states – as a global asset. Low correlations with other financial assets and commodities together with an increasing range of derivative products have furthermore increased the attractiveness of EUAs as an asset class. Hence we would expect to see rapidly increasing interest from the banking as well as the mutual and hedge fund industries in the market such that in the future, compliance trading may no longer constitute the largest share of EUA trading. Summing up, together with a rapid expansion of the market for EUAs and CERs, we expect to observe an increasing number of platforms that try to participate in the growing and promising market in the near future before a phase of consolidation after which a few trading platforms will remain.

Recent developments in the carbon market support these statements. In October 2008, NASDAQ OMX completed the acquisition of Nord Pool's clearing, international derivatives and consulting subsidiaries. Given the limited success of other measures, the exposure to an increased institutional investor base as well as the fact that the platform will be the first to offer both EUA and CER trading may be keys to attract further liquidity. Besides, EEX started a cooperation with EUREX in order to increase their market share in EUA futures trading for the Phase 2 and beyond. Not only already established platforms aimed to expand, also new market platforms decided to join the market. In spring 2008 the US American Green Exchange, a cooperation of NYMEX and the environmental broker EvolutionMarkets, launched EUA and CER futures contracts for the years 2008 to 2012. BlueNext, a cooperation between NYSE Euronext and Caisse des Depots was formed in December 2007. It only specializes in carbon related products that have been acquired from Powernext. Thus, carbon indeed becomes an internationally traded commodity and there is awareness of this steadily growing market. Consequently, the existence of a well functioning market with low trading frictions is important for many parties. The instruments we are using in our analysis give evidence that after having some difficulties at the beginning, the carbon market is now able to fulfill these requirements. It is possible to track the process of price discovery with the development of the market and to identify the market platform which is informationally dominant. The study of bid-ask spreads showed that transaction costs have markedly decreased over time which indicates increasing market quality. Our analysis is the first that includes the additional trading year 2007 in which liquidity has significantly increased. We are the first to employ intraday transaction prices and, hence, we have the advantage to obtain a more detailed insight into trading and liquidity patterns compared to prior studies.

We conclude that as the design for EUA market platforms seems to work and as at least some form of "operational efficiency" has been achieved in the market, platform operators may focus on questions like reducing the scale of the OTC market. Regulatory authorities can concentrate on issues like the initial allocation process for the EU ETS that have not yet been solved for the upcoming post Kyoto trading period.

Chapter 3

Fourteen at One Blow: The Market Entry of Turquoise

This paper analyzes the market entry of Turquoise in September 2008. Turquoise started trading stocks from 14 European countries at (almost) the same time. We find that Turquoise gained higher market shares in larger and less volatile stocks, and in stocks that had excessively high pre-entry spreads. The entry of Turquoise led to a decrease in spreads but not to an increase in trading volume. Turquoise does not generally offer lower execution costs than the primary market. Taken together our results are consistent with the view that the new entrant serves as a disciplinary device that reduces rents earned by the suppliers of liquidity in the primary market.

3.1 Introduction

Situations in which several trading venues compete for order flow in the same instruments are by now the rule rather than the exception. In the US, alternative trading systems (ATS) exist since more than a decade and have gained significant market share in NYSE- and NASDAQ-listed stocks. Recent regulatory changes, in particular the Markets in Financial Instruments Directive (MiFID) of the European Union, have spurred competition in Europe.[1] The inception of new pan-European trading platforms like Chi-X and Turquoise puts established exchanges under pressure. Although some alternative trading systems entered the market successfully, others failed. A case in point is NASDAQ Europe which was unable to attract sufficient order flow. Consequently, the platform was closed in 2003, only about a year after the launch of SuperMontage Europe.

[1]Descriptions of the regulatory environment in Europe and in the US can be found in Petrella (2009).

Competition for order flow raises several interesting and important questions. What determines the success of a new entrant? Does a new entrant attract volume only at the expense of incumbent trading venues or does the total trading volume increase? Does the increased level of competition increase market quality? From a theoretical point of view the answers to these questions are not straightforward because of the existence of network externalities. These externalities create barriers to entry. Consequently, a market entry may fail even though the entrant has superior technology. Because fragmentation of the order flow may be detrimental to liquidity, increased competition for order flow does not necessarily increase liquidity.

In the present paper we analyze the market entry of Turquoise in the summer of 2008. The entry of Turquoise is a particularly interesting event for at least two reasons. First, Turquoise was founded by nine large investment banks. These banks, through their own trading activity and their brokerage business, can direct significant order flow to the new trading venue. This arguably increases the odds for a successful entry. Second, Turquoise started trading stocks from 14 different European markets at roughly the same time. In this respect the entry of Turquoise is close to a natural experiment and allows us to analyze the extent to which the success of Turquoise depends on characteristics of the home market.

We collected intraday data for Turquoise and the home markets from Bloomberg. Our sample comprises 266 stocks from 14 different markets and covers three months prior to the entry of Turquoise and three months post-entry. We use this data to answer the three questions raised above. We analyze cross-sectional determinants of the Turquoise market share, considering both firm-specific and market-specific variables. We use a panel approach to investigate whether changes in market design by primary exchanges had an impact on market shares. We further test whether the entry of Turquoise has led to an increase in total trading volumes and/or liquidity in the home market, and we analyze the determinants of changes in transaction volume and liquidity using a panel approach. Obviously, when analyzing changes in volume and liquidity, we need to control for any other factors that may have contributed to changes in these variables. We achieve this by measuring both volume and liquidity relative to matched control samples of Spanish and Italian stocks. Spanish stocks were not traded on Turquoise during our sample period (trading started in February 2009) whereas trading of Italian stocks started on October 13 and 20, about six to seven weeks later than trading of stocks from the other 13 countries.

Our main results are that both stock and market characteristics are determinants of Turquoise market shares, the most important variables being measures of liquidity, volatility, firm size and market capitalization of the primary markets. We find ambiguous evidence as to whether overall market quality changed after the entry of Turquoise. Our data furthermore suggest that average best bid-ask spreads on Turquoise exceeded those of the primary markets in the period between November 2008 and January 2009.

Our paper is closely related to other papers analyzing competition for order flow. Hendershott and Mendelson (2000), Parlour and Seppi (2003) and Degryse et al. (2009) have developed theoretical models of competition for order flow. Despite the different modeling approaches these papers agree in the conclusion that the introduction of an additional market has an ambiguous effect on overall welfare.

A famous episode that has spurred a host of empirical research is the "battle of the Bund". The London International Financial Futures Exchange (LIFFE) started trading in futures contracts on German government bonds in 1988. About two years later, the Deutsche Terminbörse (DTB), an electronic derivatives exchange founded in January 1990, launched an almost identical contract. The two markets co-existed for about eight years. The LIFFE had the larger market share until 1997. After that date, trading volume on the LIFFE deteriorated and it abandoned the Bund contract soon thereafter. For a detailed account of this episode see Cantillon and Yin (2008).

Lee (1993) analyzes trading of New York Stock Exchange (NYSE)-listed securities at different trading venues and finds that execution costs differ significantly across venues. Conrad et al. (2003) demonstrate that execution costs are lower for trades executed in ATS than for trades executed via traditional brokers. Boehmer et al. (2007) show that differences in execution costs indeed affect investors' future order routing decisions. Batallio (1997) compares execution costs before and after Madoff Investment Securities started to selectively purchase order flow. He finds that spreads decreased upon the entry of Madoff. Boehmer and Boehmer (2003) analyze the entry of the NYSE in the market for exchange traded funds (ETFs). The NYSE started trading of some ETFs which were listed on the American Stock Exchange in 2002. Upon entry of the NYSE spreads decreased significantly. Foucault and Menkveld (2008) analyze the rivalry between Euronext and the London Stock Exchange (LSE) in the Dutch equity market. They conclude that the consolidated limit order book after the entry of the LSE is deeper than the Euronext order book prior to the entry. Mayhew (2002) confirms the result that competition decreases execution costs. He finds that options which are listed on multiple exchanges have narrower spreads than those listed on only one exchange.

Taken together, the extant empirical literature yields the conclusion that competition is "good". Our own results are somewhat ambiguous but point in the same direction. Pairwise comparison of matched samples (Turquoise stocks versus Spanish and Italian stocks) do not reveal a significant decrease of the bid-ask spreads after the introduction of Turquoise. The comparison with the Italian stocks indicates that volume may have increased after the introduction of Turquoise. When we use a weekly panel instead we find evidence that spreads have declined and volume has increased after the introduction of Turquoise. These results are consistent with a positive impact on market quality of competition between trading venues.

From a methodological point of view our paper is also related to previous papers analyzing the impact of changes in market structure on market quality (e.g. Boehmer et al. (2005) who analyze a change in transparency on the NYSE and Foucault et al. (2007) who analyze a change in anonymity on Euronext). A common problem in this type of analysis is that the structural change affects all sample stocks at the same time. It is thus necessary to control for other factors that may have affected market quality around the event day. Boehmer et al. (2005) and Foucault et al. (2007) achieve this by including control variables in their analysis. We also included appropriate control variable. In addition, we implemented the control sample approach described above.

The remainder of the paper is organized as follows. Section 3.2 introduces the reader to the history of Turquoise. Section 3.3 includes the description of the data set and summary statistics. Section 3.4 covers the analysis of determinants of relative success of Turquoise. Section 3.5 investigates changes in liquidity and trading volumes after the entry of Turquoise while section 3.6 compares these parameters on Turquoise and the primary exchanges. Section 3.7 concludes.

3.2 The Launch of Turquoise

In November 2006, seven of the largest investment banks in Europe announced their plans to found a new pan-European equity trading platform. The stated objective of the member banks Citigroup, Credit Suisse, Deutsche Bank, Goldman Sachs, Merrill Lynch, Morgan Stanley and UBS was to be able to execute orders for their clients at markedly lower costs compared to those paid to existing exchanges.[2] The new platform was intended to compete with existing markets and attract liquidity from them. The creation of the venture became possible because of changes in European regulation, specifically the European Union's Markets in Financial Instruments Directive (MiFID) which came into force in November 2007. A stated objective of MiFID was to promote competition in equity trading in Europe, e.g. by allowing the creation of new trading platforms (*Multilateral Trading Facilities*, MTFs) to challenge incumbent equity markets.

The nine founding members (the seven investment banks listed above and BNP Paribas and Société Générale Corporate & Investment Banking who joined the consortium in 2007) are the owners of Turquoise Services Limited, a regulated entity authorized to operate a Multilateral Trading Facility by the Financial Services Authority. Turquoise is independently managed. The Swedish firm Cinnober provided the platform technology. The European Central Counterparty Ltd (EuroCCP), a subsidiary of the Depositary Trust & Clearing Corporation (DTCC) serves as the central counterparty for all trades and provides clearing and settlement services.

While the launch of Turquoise's trading platform was originally scheduled for the end of 2007, the system finally started to operate with 5 sample firms per exchange (so-called soft launch) between August 15 and August 22, 2008. In September 2008, trading was extended to about 1270 firms from 13 European stock exchanges.[3] Italian firms started trading in October 2008, Spanish stocks were added on February 16, 2009, after the end of our sample period. On November 1, 2008 (the beginning of our post-entry period) 311 stocks from 14 countries were traded in the integrated order book described in more

[2] All information on Turquoise is obtained from the official website www.tradeturquoise.com.

[3] The exchanges are London Stock Exchange (United Kingdom), Deutsche Börse (Germany), NYSE Euronext Paris (France), NYSE Euronext Amsterdam (Netherlands), NYSE Euronext Brussels (Belgium), NYSE Euronext Lisbon (Portugal), OMX Copenhagen (Denmark), OMX Stockholm (Sweden), OMX Helsinki (Finland), Oslo Bors (Norway), Wiener Börse (Austria), Swiss Exchange (Switzerland) and Irish Stock Exchange (Ireland).

detail below. The remaining stocks were only traded in the dark pool.

Turquoise initially offered two different trading systems, an integrated order book and a dark pool. In March 2009 (after the end of our sample period) stocks traded in the dark pool thus far were migrated to the integrated order book. Our empirical analysis only considers stocks traded in the integrated order book.

The integrated order book is a hybrid trading facility that combines a transparent open limit order book with a hidden order book (dark pool) within the same matching engine and order book. It is designed to "increase execution and price improvement for small orders, whilst minimizing information leakage and market impact for larger, institutional-size orders."[4] Orders in the open book enjoy time priority over hidden volume. A feature that distinguishes Turquoise's dark pool from traditional hidden orders is the fact that orders submitted to the dark pool do not have a visible part.[5] Therefore, there may be hidden liquidity inside the visible spread. Consequently, the quoted spread visible on the trading screens may overstate the actual cost of executing an order. Another distinguishing feature of the trading system is the possibility to submit limit orders with a price limit that is pegged to the best bid or ask quote. To provide an example, a trader can submit a buy order such that the price limit is always one tick below the best bid. When the best bid changes the price limit will be automatically adjusted. Obviously, the order in the example will only execute when a large market sell order that walks up the book is submitted.

Trading in Turquoise starts with a pre-opening phase from 08:40:00 CET to 08:59:30, followed by an opening call auction which takes place between 08:59:30 and 09:00:00. The exact time of the matching is determined randomly. The continuous trading session begins at 09:00:00 and extends until 17:30:00. There is no closing call auction.

According to the Turquoise rule book the minimum tick size is the same as in the home market unless the Turquoise management specifies a different tick size. For most of our sample stocks (217 out of 260) the minimum tick sizes in Turquoise and the home market

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[4]See www.tradeturquoise.com/tq_about.shtml.

[5]Several markets, e.g. Xetra and NYSE allow the submission of hidden orders (iceberg orders). These orders must, however, have a visible part. Therefore, there can be no hidden liquidity inside the quoted spread. NYSE Euronext has recently launched Smart Pool, a dark pool for block trades. It is not part of the main order book but is rather operated and regulated as an independent MTF.

were equal. Nine stocks (all from Germany) have a lower tick size in Turquoise. 34 stocks (from Sweden and Switzerland) have (at least in parts of the sample period) a larger tick size in Turquoise.

During our sample period five potentially important changes in market structure occurred.[6] On November 24, 2008, Deutsche Börse introduced Xetra MidPoint, a dark pool integrated into the Xetra order book.[7] On January 14, 2009, Euronext introduced the single order book for the Amsterdam, Brussels and Paris market. Prior to that date some stocks were traded in more than one of Euronext's markets. The resulting fragmentation may have adversely affected liquidity. Also in January 2009, the LSE introduced Member Authorised Connection, a facility which provides faster access to trading for members' customers via direct connection to the electronic trading system TradElect. Other changes were the introduction of a new real-time data feed on the OMX exchanges in January 2009 and the migration of Italian stock market segments to the LSE TradElect trading platform in November 2008. In our empirical analysis we controlled for the effect of these events.

3.3 Data Set and Descriptive Statistics

Our initial data set consists of all 311 firms from 14 European countries that started trading in Turquoise's integrated order book between August 15, 2008 and October 20, 2008. We obtained intradaily data from Bloomberg. The data covers both the home markets and Turquoise and consists of one-minute snapshots. Variables include the aggregated trading volume and the number of trades over the previous minute, the last bid, ask and transaction price of the one-minute interval, depth at the ask and at the bid, and the number of quote updates within the minute. The trading volume and the number of transactions in Turquoise includes transactions involving hidden orders. The best bid

[6]Besides these changes in market structure, there were several fee reductions. Fees on Euronext, the LSE, Oslo Bors and Xetra were reduced on September 1, 2008; in Switzerland on October 1, 2008, and Clearstream reduced its fees on November 1, 2008. All these reductions were already in place at the beginning of our post-entry period. Therefore we cannot assess the extent to which they may have affected the success of Turquoise. Turquoise itself reduced its fees after trading volume fell markedly in March 2009 (after the end of our sample period) when a market making agreement between Turquoise and the founding members expired.

[7]Xetra MidPoint matches orders at the quote midpoint of the Xetra order book. MidPoint orders are completely hidden, and they are only matched with other MidPoint orders.

and ask quotes, on the other hand, are based on visible orders only.

We had to discard 41 firms from the initial data set because of missing or incomplete Bloomberg data. Four firms were listed on two incumbent markets but we only include them once in our sample.[8] This reduces the sample to 266 firms. In our regression analyzes we include additional control variables (e.g. market capitalization and free float). For six firms this data was unavailable. Therefore, we include 260 firms in our baseline regressions.

As noted in the previous section, trading in Turquoise started with a "soft launch" in August 2008. During the soft-launch period, only a small number of stocks were traded in Turquoise. The market share of Turquoise was below 1%. It stayed at that level through September 2008. Market shares increased markedly in October. The Italian stocks included in our sample started trading in Turquoise only in October 2008. The intraday data for Turquoise available from Bloomberg includes information on best bid and ask quotes only from November 2008 onwards. We therefore consider the three-month period from May to July 2008 as our pre-Turquoise benchmark period and the three-months period from November 2008 to January 2009 as our post-entry period. Summary statistics for the sample stocks, sorted by the country of the primary listing, are depicted in Table 3.1.

The United Kingdom accounts for the largest share of our sample firms, followed by France, Italy, Sweden and Germany. The Turquoise market share (defined as trading volume in Turquoise divided by the sum of trading volume in Turquoise and the home market) spans a wide range. It is highest for the Netherlands (7.1%) and lowest for Ireland (0.15%).

The changes in market capitalization, trading volume, quoted spreads and depth between the pre-Turquoise and the post-entry period reflect the deteriorating market environment in the fall of 2008. Market capitalizations fell significantly, in some countries to less than half their initial level. Trading volume also fell, albeit to a much lesser extent. The increased spreads and the decreased depth indicate that liquidity deteriorated. Obviously,

[8] Consider Royal Dutch Shell as an example. The stock is listed on the London Stock Exchange and on Euronext Amsterdam. We kept the data from Euronext Amsterdam because trading volume in this market was higher in the pre-Turquoise period. The other three stocks with double listings are Nokia (data from Finland retained, data from Sweden discarded), ABB (Switzerland retained, Sweden discarded) and AstraZeneca (UK retained, Sweden discarded).

Table 3.1: Summary statistics

Country	Obs.	TQ Share in %	MarketCap *Pre*	MarketCap *Post*	Trading Volume *Pre*	Trading Volume *Post*	Spread in % *Pre*	Spread in % *Post*	Depth *Pre*	Depth *Post*
UK	90	6.10	18,565	12,185	12.54	10.91	0.04	0.19	30.35	25,631
Germany	24	4.94	26,811	18,792	4.53	4.84	0.07	0.15	4,829	9,947
France	36	6.03	28,227	21,039	4.15	3.92	0.08	0.13	13,226	6,379
Netherlands	16	7.10	16,268	10,685	5.96	5.59	0.09	0.15	17,559	8,087
Belgium	4	1.53	15,249	7,033	2.27	1.27	0.12	0.23	7,692	3,897
Portugal	4	0.53	9,978	6,390	8.26	5.01	0.18	0.18	150,078	24,487
Denmark	3	0.33	20,636	10,180	1.21	1.46	0.19	0.34	11,241	9,900
Sweden	25	4.13	9,791	5,847	6.39	5.61	0.30	0.38	108,838	55,578
Finland	4	1.48	25,845	16,246	8.75	8.44	0.13	0.18	27,214	25,045
Norway	5	0.42	26,066	11,997	6.42	7.26	0.15	0.21	28,428	18,840
Ireland	4	0.15	8,068	3,275	3.91	5.65	0.36	1.34	6,444	15,824
Switzerland	19	3.33	29,854	24,789	4.80	4.03	0.12	0.20	17,171	15,755
Austria	4	5.93	12,263	4,683	1.16	1.03	0.11	0.27	3,039	3,331
Italy	28	3.30	17,171	11,014	25.51	17.77	0.12	0.17	13,251	35,604

The table presents summary statistics aggregated on a country-wide level. Unless otherwise stated, *Pre* indicates the average of the respective variable over the period May to July 2008 and *Post* indicates the average from November 2008 to January 2009. MarketCap denotes market capitalization in million Euro. Trading volume depicts average daily trading volume in million shares. Spread depicts the quoted bid-ask spread in percentage terms. Depth stands for the sum of average bid and ask volume available at best quotes. TQ share denotes the share of trading volume transacted on Turquoise relative to the volume transacted on Turquoise and the incumbent exchange. Obs. stands for the number of observations.

thus, the impact of the introduction of Turquoise on market quality cannot be assessed by simply comparing measures of market quality for the pre- and the post-entry period. Rather, we will include appropriate control variables in our analysis and, in addition, use a control sample.

3.4 Cross-Sectional Determinants of Market Shares

In this section we analyze the determinants of the Turquoise market shares. We start with a cross-sectional analysis and then turn to a panel approach. The variable of interest, $Market\ Share\ TQ$, is defined as the number of shares traded on Turquoise between November 2008 and January 2009 divided by the number of shares traded on Turquoise and the home market in the same period. We regress $Market\ Share\ TQ$ on a number of stock and market characteristics. $LnMcap$ denotes the natural logarithm of market capitalization measured in Euro[9] as of July 31, 2008. $FreeFloat^{Pre}$ denotes the average free float of a share in the period from May to July 2008, expressed as a fraction of the total number of shares outstanding. $Volume^{Pre}$, $Spread\ in\ \%^{Pre}$ and $Depth^{Pre}$ denote the average daily trading volume in shares, the average percentage quoted spread and the average quoted depth in the pre-Turquoise period. $Std.Dev.Return^{Pre}$ is the standard deviation of daily returns in the same period. The indicators $\mathbf{1}_{NYSE}$ and $\mathbf{1}_{DJEUROSTOXX50}$ are set to 1 if a stock is cross-listed on the NYSE or is included in the DJ Euro Stoxx 50 index and is set to 0 otherwise. Market-related variables include $TickSize^{Pre}$,[10] the average absolute tick size of a stock in the period between May and July 2008 as well as $LnMcapExchange^{Pre}$, the overall market capitalization on the respective exchange as of July 2008 in Euro.

Results are presented in Table 3.2. Model (1) is a baseline specification that includes stock and market characteristics. Model (2) adds four dummy variables $\mathbf{1}_{EURONEXT}$, $\mathbf{1}_{OMX}$, $\mathbf{1}_{LSE}$ and $\mathbf{1}_{XETRA}$. They identify stocks listed in markets belonging to the institutional groups NYSE Euronext, OMX, London Stock Exchange and Xetra.[11] Model (3) is analogous to specification (1) but additionally includes indicator variables for the national stock markets (coefficient estimates are not reported in the table). As documented in Table 3.1, UK stocks are by far the largest group in our sample. To make sure that our results are not driven by the UK stocks, we repeated the analysis after exclusion of the UK stocks. We obtain similar results (not shown but available upon request). All t-statistics are based on robust Huber/White standard errors.

Turning to results we find that, although significance levels and magnitude of the estimated coefficients vary, the results are qualitatively similar across specifications. The market share of Turquoise tends to be larger for firms with higher market capitalization

[9]Exchange rates used for conversion were obtained from the website of the European Central Bank.

[10]Note that using relative tick size, defined as average tick size over average midpoint in the pre-entry period, yields qualitatively similar results. Since the correlation between relative tick size and some country indicator variables as well as the predicted spread component as described below exceeds 60%, we use the absolute tick size in our estimations.

[11]NYSE Euronext comprises the primary markets of France, the Netherlands, Belgium and Portugal. OMX covers the Danish, Swedish and Finnish markets. Borsa Italiana is a member of the London Stock Exchange group and migrated equity trading to the LSE TradElect platform in November 2008. Xetra is not an institutional group but a trading platform. It is used in Germany, Ireland and Austria.

and firms with higher free float. The respective coefficients are positive and significant in all cases. The sign of the indicator variable standing for index membership in the Dow Jones Euro Stoxx 50, however, is negative in all specifications, partly reducing size effects since index membership is largely a function of market capitalization.[12] A cross-listing on the NYSE does not affect the Turquoise market share.

Firms with high execution costs in the pre-entry period (as measured by the quoted bid-ask spread) have a higher market share on Turquoise. Similarly, Turquoise market shares tend to be higher for firms with lower quoted depth and lower trading volume in their home markets. These results are consistent with the notion that liquidity in the home market determines the attractiveness of an alternative trading venue.

The relation between volatility (measured in the pre-entry period) and the Turquoise market share is negative. This indicates that the alternative trading venue may be relatively more attractive for less volatile stocks. Firms with lower absolute tick size in the pre-Turquoise period tend to have higher market shares on Turquoise. This is a somewhat surprising result because the tick sizes in Turquoise and in the home market are in most cases the same.

Stocks from countries with a higher aggregate market capitalization tend to be traded more actively on Turquoise. This is consistent with the descriptive statistics presented in the previous section. A possible explanation is that the portfolios and trading activities of the nine investment banks that founded Turquoise (among them four US-based institutions) are tilted towards larger markets.

When we add dummy variables for the institutional groups (model (2)) we find that the market share of firms with a primary listing on Euronext, LSE or Xetra is higher as compared to firms listed on an OMX member exchange or one of the other exchanges. Using country dummies instead of the institutional group dummies (model (3)) increases the explanatory power of the model significantly (the adjusted R^2 increases from 0.40 to 0.51[13]) but yields otherwise similar results. Only the tick size variable loses its significance.

[12] It might be the case that the relation between Turquoise market share and size is nonlinear and that the Euro Stoxx dummy picks up this nonlinearity. To check that we included the square of the size variable as an additional regressor. The Euro Stoxx dummy retained its sign and significance. Note that multicollinearity is not an issue here; the pairwise correlations between the independent variables do not exceed 40%.

[13] The country dummies alone explain 18.7% of the cross-sectional variation of the market shares.

Turquoise was designed to cater to the needs of institutional investors. We therefore expect its market share to be higher for firms with larger institutional shareholdings. Unfortunately, we did not have access to full ownership data at the firm level. However, Thompson Reuters Datastream provides some ownership information as of May 2008. With respect to institutional ownership data, it features information on shareholdings of investment companies with a strategic focus, shareholdings by foreign institutional investors and by pension funds. While the latter group is non-zero in only 6 out of 260 observations, there is more variation in the other two sub-groups. We hence use the variables $InvestmentHoldings$ and $ForeignHoldings$ which indicate the percentage of shares in issue held by investment companies or, respectively, foreign institutions. Repeating estimations of models (1) to (3) including these variables, we expect a positive sign for both variables. Estimation results from specifications (4) to (6) show that as expected, $InvestmentHoldings$ is significantly positive in all cases. Contrary to expectations, $ForeignHoldings$ (which may include holdings by foreign investment banks) is significantly negative. Without having detailed access to ownership data, we can only speculate about the reasons for this finding which may relate to the origin of the foreign institution or to its strategic interest in the company. Using ownership data on a country level as a robustness check, results indicate a positive impact of institutional ownership on Turquoise market shares.[14]

Our results suggest that firms with high spreads tend to have higher Turquoise market shares. Spreads can be large for two reasons. First, the characteristics of the firm (e.g. its size, the volatility of its returns) may be such that the equilibrium spread is large. Second, the spread may be high because suppliers of liquidity earn rents or because structural features of the stock market lead to operational inefficiencies. In the second case the spread is above its equilibrium level. We expect that high equilibrium spreads do not result in a higher Turquoise market share whereas above-equilibrium spreads do. To test this conjecture we decompose the pre-Turquoise average spreads into two components. To this end we first regress average quoted spreads from the pre-Turquoise period on the natural logarithm of market capitalization in Euro as of July 31, 2008, the average free float in percentage of shares outstanding, the average daily trading volume in shares, the

[14]Information at the country level is obtained from the publication *Share Ownership Structure in Europe*, Final Version, December 2008, available on the homepage of the Federation of European Securities Exchanges FESE. The information relates to the year 2007. Results are available upon request.

standard deviation of returns and average relative tick size in the pre-Turquoise period. Coefficient estimates of this regression (not shown) are in line with expectations,[15] the adjusted R^2 amounts to 18.04%.

We use the predicted values from this regression, $Pred.\ Spread\ in\ \%^{Pre}$, as an estimate of the equilibrium spread and the residual, *Spread Residual*, as an estimate of the deviation from the equilibrium spread. We then use these two variables as regressors in the market share regression. We estimate the same six specifications as above. The results are shown in Table 3.3. The coefficient on the spread residual is always positive and significant, as expected. The coefficient on the predicted values is positive but is only significant in the two models that include country dummies. Thus, the results of our cross-sectional market share regressions confirm the intuition that the new entrant, Turquoise, gains market share particularly in those cases where pre-Turquoise spread levels were excessively high.

3.4.1 Panel analysis of market share determinants

The analysis so far considered the average Turquoise market share in the post-entry period. This approach is well suited to uncover the cross-sectional determinants of the Turquoise market shares, but it does not exploit the time-series variation in the market share data. In order to include the time-series dimension we construct a daily panel data set. The sample period is the post-entry period from November 2008 to January 2009. The panel includes the explanatory variables introduced in the previous section as well as further variables that incorporate information about changes in the market model that occurred during the sample period. The model we estimate has the following form:

$$y_{it} = x'_{it}\alpha + w'_{it}\beta + v_i + u_{it}, \quad i = 1, ..., N, \quad t = 1, ..., T. \tag{3.1}$$

x_{it} is a vector of strictly exogenous covariates, possibly including time constants. w_{it} is a vector of potentially endogenous covariates, all of which might be correlated with v_i, the unobserved individual heterogeneity. w_{it} might include lagged values of the dependent variable y_{it}. u_{it} is the i.i.d. error term. The list of explanatory variables includes the logarithm of the market capitalization in Euro at the end of the previous day, $LnMcap_{t-1}$, the logarithm of the trading volume on the previous day, $LnVolume_{t-1}$, the average

[15] Spreads are negatively related to the free float, firm size and trading volume. They are positively related to return volatility, relative tick size and depth.

Table 3.2: Cross-sectional determinants of Turquoise market shares

	Market Share TQ					
Specification	OLS (1)	OLS (2)	OLS (3)	OLS (4)	OLS (5)	OLS (6)
Variable	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.
$LnMcap^{Pre}$	0.009**	0.012***	0.014***	0.010***	0.014***	0.015***
	(2.52)	(3.36)	(4.84)	(2.83)	(3.76)	(5.54)
$FreeFloat^{Pre}$	0.029***	0.042***	0.047***	0.020**	0.033***	0.036***
	(3.15)	(3.99)	(4.16)	(2.13)	(3.13)	(3.19)
$Volume^{Pre}$	-7e-11	-1e-10*	-1e-10*	-7e-11	-1e-10*	-1e-10*
	(0.91)	(1.80)	(1.79)	(0.92)	(1.95)	(1.91)
$Spread\ in\ \%^{Pre}$	17.889*	21.996**	26.527***	18.200*	22.675***	27.413***
	(1.88)	(2.53)	(4.24)	(1.93)	(2.68)	(4.71)
$Depth^{Pre}$	-6e-08*	-5e-08*	-5e-08**	-6e-08*	-5e-08*	-5e-08**
	(1.92)	(1.89)	(2.39)	(1.87)	(1.82)	(2.27)
$Std.Dev.Return^{Pre}$	-7e-04***	-3e-04**	2e-04*	-7e-04***	-3e-04**	2e-04
	(3.99)	(2.32)	(1.83)	(4.06)	(2.16)	(1.45)
$TickSize^{Pre}$	-4e-04***	-3e-04***	-8e-05	-4e-04***	-3e-04***	-1e-04*
	(3.82)	(3.56)	(1.34)	(4.01)	(3.76)	(1.87)
$LnMcapExchange^{Pre}$	0.024***	0.019***	0.042***	0.024***	0.019***	0.043***
	(4.01)	(4.19)	(7.11)	(4.01)	(4.13)	(7.62)
$InvestmentHoldings$				6e-04**	6e-04***	7e-04***
				(2.34)	(2.64)	(2.89)
$ForeignHoldings$				-4e-04**	-5e-04***	-5e-04***
				(2.29)	(2.83)	(2.74)
$\mathbf{1}_{NYSE}$	4e-04	-0.003	-0.003	6e-04	-0.003	-0.003
	(0.10)	(0.67)	(0.72)	(0.15)	(0.69)	(0.75)
$\mathbf{1}_{DJEUROSTOXX50}$	-0.012***	-0.019***	-0.019***	-0.012***	-0.019***	-0.019***
	(2.61)	(4.00)	(4.26)	(2.61)	(3.87)	(4.23)
$\mathbf{1}_{EURONEXT}$		0.036***			0.036***	
		(6.69)			(6.60)	
$\mathbf{1}_{OMX}$		-0.003			-0.004	
		(0.33)			(0.51)	
$\mathbf{1}_{XETRA}$		0.020**			0.020**	
		(2.10)			(2.14)	
$\mathbf{1}_{LSE}$		0.031***			0.033***	
		(4.55)			(4.74)	
Const.	-0.725***	-0.663***	-1.297***	-0.737***	-0.667***	-1.317***
	(3.69)	(4.40)	(6.85)	(3.75)	(4.49)	(7.39)
Country Dummies	no	no	yes	no	no	yes
Group Dummies	no	yes	no	no	yes	no
Obs.	260	260	260	260	260	260
R^2	0.34	0.43	0.55	0.37	0.46	0.58
Adj. ^{2}	0.32	0.40	0.51	0.33	0.42	0.53

Remark: ***, ** and * denote significance at the 1%, 5%, and 10% level, respectively. t-statistics are based on robust standard errors. Variable definitions are given in section 3.4. Terms in brackets denote absolute t-statistics.

Table 3.3: Determinants of Turquoise market shares using predicted spreads and residuals

	Market Share TQ					
Specification	OLS (1a)	OLS (2a)	OLS (3a)	OLS (4a)	OLS (5a)	OLS (6a)
Variable	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.
$LnMcap^{Pre}$	0.004	0.003	0.012***	0.005*	0.005	0.014***
	(1.40)	(0.99)	(4.01)	(1.88)	(1.47)	(4.58)
$FreeFloat^{Pre}$	0.020**	0.029***	0.042***	0.012	0.021**	0.033***
	(2.48)	(3.40)	(3.73)	(1.45)	(2.37)	(2.81)
$Volume^{Pre}$	-1e-10*	-2e-10***	-1e-10**	-1e-10	-3e-10***	-2e-10**
	(1.65)	(2.88)	(2.04)	(1.62)	(2.98)	(2.08)
$Pred.\ Spread\ in\ \%^{Pre}$	1.450	-6.652	19.993***	2.287	-6.141	22.359***
	(0.24)	(0.87)	(2.99)	(0.37)	(0.79)	(3.23)
Spread Residual	18.646**	24.836***	26.558***	18.898**	25.484***	27.435***
	(2.07)	(3.51)	(4.25)	(2.11)	(3.76)	(4.72)
$Depth^{Pre}$	-7e-08**	-5e-08*	-5e-08**	-7e-08**	-5e-08*	-5e-08**
	(2.03)	(1.84)	(2.39)	(1.97)	(1.77)	(2.26)
$Std.Dev.Return^{Pre}$	-4e-04***	5e-04*	3e-04**	-4e-04***	5e-04*	3e-04*
	(2.85)	(1.80)	(2.19)	(2.94)	(1.88)	(1.86)
$TickSize^{Pre}$	-4e-04***	-2e-04***	-7e-05	-4e-04***	-2e-04***	-1e-04*
	(4.08)	(3.58)	(1.32)	(4.24)	(3.74)	(1.86)
$LnMcapExchange^{Pre}$	0.022***	0.015***	0.038***	0.022***	0.015***	0.039***
	(4.10)	(3.30)	(6.14)	(4.08)	(3.18)	(6.14)
$InvestmentHoldings$				6e-04**	7e-04***	7e-04***
				(2.40)	(2.94)	(2.88)
$ForeignHoldings$				-4e-04**	-4e-04***	-5e-04***
				(2.12)	(2.65)	(2.73)
$\mathbf{1}_{NYSE}$	0.001	-0.002	-0.003	0.001	-0.003	-0.003
	(0.30)	(0.59)	(0.79)	(0.35)	(0.62)	(0.80)
$\mathbf{1}_{DJEUROSTOXX50}$	-0.012***	-0.021***	-0.019***	-0.012***	-0.021***	-0.019***
	(2.77)	(4.28)	(4.23)	(2.75)	(4.15)	(4.21)
$\mathbf{1}_{EURONEXT}$		0.038***			0.038***	
		(6.84)			(6.77)	
$\mathbf{1}_{OMX}$		-0.010			-0.011	
		(1.17)			(1.34)	
$\mathbf{1}_{XETRA}$		0.029***			0.029***	
		(2.75)			(2.79)	
$\mathbf{1}_{LSE}$		0.037***			0.039***	
		(5.13)			(5.34)	
Const.	-0.608***	-0.425***	-1.146***	-0.622***	-0.426***	-1.201***
	(3.56)	(2.82)	(5.76)	(3.63)	(2.82)	(5.79)
Country Dummies	no	no	yes	no	no	yes
Group Dummies	no	yes	no	no	yes	no
Obs.	260	260	260	260	260	260
R^2	0.36	0.48	0.55	0.38	0.50	0.58
Adj. ^{2}	0.33	0.44	0.50	0.35	0.47	0.53

Remark: ***, ** and * denote significance at the 1%, 5%, and 10% level, respectively. t-statistics are based on robust standard errors. Variable definitions are given in section 3.4. Terms in brackets denote absolute t-statistics.

quoted depth and the average percentage quoted spread on the previous day, $Depth_{t-1}$ and $Spread\ in\ \%_{t-1}$, respectively, the average intraday midpoint volatility on day $t-1$, $Std.Dev.Return_{t-1}$, the average absolute tick size $TickSize_{t-1}$ on the previous day, and time fixed effects. We use first lags in order to avoid endogeneity problems.

When estimating model (3.4), we have to account for unobserved firm heterogeneity v_i and potential endogeneity of the regressors in w_{it}. We remove heterogeneity by first differencing and obtain the following model:

$$\Delta y_{it} = \Delta x'_{it}\alpha + \Delta w'_{it}\beta + \Delta u_{it}, \quad i = 1, ..., N, \quad t = 1, ..., T, \tag{3.2}$$

where $\Delta a_{it} = (a_{it} - a_{it-1})$. Note that first-differencing eliminates explanatory variables without time-series variation (e.g. the institutional group dummies) from the model. If a variable is endogenous (i.e., depends on y_{it}) lagged first differences of that variable are not strictly exogenous. Therefore we use second and further lags as instruments in order to obtain consistent estimators. We estimate the model by GMM.

As noted in section 2, five potentially important changes in the trading protocols of Euronext, LSE, OMX and Xetra occurred during our sample period. We include indicator variables in order to capture any impact these changes may have had on market shares. The indicator variable is set to one for stocks affected by the change from the day of the change onwards, and is set to zero otherwise.

Results from a static specification (P1) and a dynamic specification (P2) which includes the lagged Turquoise market share as an additional regressor are presented in Table 3.4. In model (P1) the Turquoise market share is positively related to the lagged spread in the home market. Thus, when execution costs in the home market increase, traders switch to Turquoise. The relation between Turquoise market share and lagged volume in the home market is negative.[16] This is surprising at first sight but may be explained by serially correlated trading activity in the home market. If the order flow of retail investors (who typically do not have access to Turquoise) is serially correlated then low trading activity in the home market on day $t-1$ predicts low activity on day t which, in turn, results in a higher Turquoise market share on day t. The coefficients on the change-in-market-structure dummies indicate that the introduction of Xetra MidPoint lowered the market

[16]Note that this is not a spurious relation because the Turquoise market share is measured on day t and the volume in the home market on day $t-1$.

Table 3.4: Determinants of Turquoise market shares: panel estimations

	Market Share TQ	
Specification	GMM (P1)	GMM (P2)
Variable	Coef. ($\|z - stat\|$)	Coef. ($\|z - stat\|$)
$LnMcap_{t-1}$	-0.005	-0.011**
	(1.10)	(2.54)
$LnVolume_{t-1}$	-0.010***	-0.005***
	(6.15)	(4.59)
$Spread\ in\ \%_{t-1}$	0.619**	0.548
	(2.14)	(1.50)
$Depth_{t-1}$	-1e-09	-1e-09
	(0.23)	(0.25)
$Std.Dev.Return_{t-1}$	5e-07	5e-07
	(1.00)	(1.09)
$TickSize_{t-1}$	-0.009	-0.005
	(1.17)	(0.57)
$\mathbf{1}_{ChangeEuronext}$	0.015***	0.014***
	(3.51)	(3.10)
$\mathbf{1}_{ChangeXetra}$	-0.009**	-0.010**
	(2.20)	(2.08)
$\mathbf{1}_{ChangeLSE}$	-0.004	0.001
	(0.60)	(0.21)
$\mathbf{1}_{ChangeBorsaItaliana}$	-0.003	0.009
	(0.41)	(1.16)
$\mathbf{1}_{ChangeOMX}$	2e-04	-9e-04
	(0.05)	(0.16)
$Market\ Share\ TQ_{t-1}$		0.205***
		(4.47)
Obs.	14,886	14,874

Remark: ***, ** and * denote significance at the 1%, 5%, and 10% level, respectively. z-statistics are based on robust standard errors. Instruments for GMM specifications are lag $t-2$ to lag $t-5$ of averages of quoted depth, quoted bid-ask spreads and log daily trading volume in stocks on the primary exchange. $LnMcap_{t-1}$ stands for the logarithm of stock market capitalization in Euro at day $t-1$. $LnVolume_{t-1}$, $Spread\ in\ \%_{t-1}$ and $Depth_{t-1}$ stand for the average daily trading volume in logarithms, average percentage spread and average depth on trading day $t-1$. $Std.Dev.Return_{t-1}$ is the standard deviation of intraday returns on day $t-1$. $TickSize_{t-1}$ denotes the average tick size on the primary exchange on day $t-1$. $Market\ Share\ TQ_{t-1}$ is the relative market share of Turquoise in terms of trading volume on the prior trading day $t-1$. $\mathbf{1}_{ChangeXY}$ is an indicator variable equal to one if the primary exchange XY has introduced a change in the market model or technology in the estimation period from the day of change onwards and zero otherwise. Daily time indicator variables are not depicted.

share of Turquoise. This trading platform was explicitly targeted at investors making use of non-displayed liquidity (as e.g. the dark pool on Turquoise) for large trading volumes and our results indicate that it was successful in attracting liquidity.

In contrast, the introduction of the single order book in Euronext led to a higher Turquoise market share. This is a surprising result because one would expect that the consolidation of the order flow improves market quality. We do not have a good explanation for this result. The other changes in market structure (i.e., the introduction of LSE Member Authorized Connection, the introduction of the OMX real time data feed, and the migration of Italian stocks to the LSE TradElect platform) did not significantly affect Turquoise market shares.

In model (P2) the coefficient on the lagged Turquoise market share is positive and significant, implying that market shares are persistent even after controlling for the other explanatory variables. The other results are similar, except that the lagged spread in the home market, although retaining its sign, loses significance.

3.5 Spread and Volume Changes after the Entry of Turquoise

As can be seen from Table 3.1 the post-entry period has been characterized by an uncertain market environment and a significant decrease in liquidity due to the world-wide financial crisis. In assessing the question of whether measures of market quality such as the bid-ask spreads or trading volume have improved due to the market entry of Turquoise, it is therefore important to control for the general changes in market quality. We accomplish this by including appropriate control variables and by using two control samples of stocks that are not traded in Turquoise. The first control sample consists of Spanish stocks which were not traded on Turquoise during our entire sample period. The second control sample consists of Italian stocks which could not be traded on Turquoise prior to mid-October 2008.

3.5.1 The first control group

As noted above, Spanish stocks started trading on Turquoise in February 2009, after the end of our sample period. Therefore, we can benchmark changes in market quality that those stocks experienced, which were traded on Turquoise, against the change in market quality of Spanish stocks between the pre- and the post-entry period. In doing so we have to control for the characteristics of the stocks. To this end we use a matched-sample approach. Our sample of Spanish stocks consists of the component stocks of the IBEX 35 index as of July 2008. These are the most liquid Spanish stocks. We match each IBEX 35 stock with a stock of our Turquoise sample based on average market capitalization in Euro in the pre-Turquoise period and average price in Euro in the pre-Turquoise period (for guidance on how to use matched samples see Davies and Kim (2009)).[17] Unfortunately, we do not have intraday data for the Spanish stocks. Rather, we obtained daily data on trading volume, closing prices, and closing bid-ask spreads. For consistency we use the same data for the Turquoise sample. We lose one observation because of lacking data. We are thus left with 34 pairs.

The results are depicted in Tables 3.5 and 3.6. We first note that the two groups of stocks are similar with respect to market capitalization. The matched Turquoise stocks have a median pre-Turquoise market capitalization of 7.1 billion Euro, as compared to an average of 7.2 billion Euro for the Spanish stocks. They indicate that median quoted spreads of the Turquoise stocks and the Spanish stocks are very similar in the pre-Turquoise period. We define the relative spread increase as $Spread\ Increase = 1 - (Spread\ in\ \%^{Post}/Spread\ in\ \%^{Pre})$. The relative increase is larger for the Turquoise stocks than for the Spanish stocks when we consider the mean and larger for the Spanish stocks when we consider the median. However, a Wilcoxon signed rank test as suggested by Davies and Kim (2009) does not reject the null hypothesis of equality of the median between the groups.

Figures on trading volume (measured in million Euro) are shown in Table 3.6. In the pre-Turquoise period the mean trading volume is higher for the Spanish stocks whereas the median is larger for the Turquoise stocks. For both groups trading volume is markedly lower in the post-entry period. The decline is slightly more pronounced for the Spanish

[17] We match stocks without replacement and choose the match as to minimize the sum of relative squared deviations over the whole sample.

Table 3.5: Changes in percentage quoted spreads over time - Turquoise sample versus Spanish stocks

		Quoted Spreads in %				Spread Increase		
		TQ Sample		Spain		TQ Sample	Spain	
	Obs.	*Pre*	*Post*	*Pre*	*Post*	(i)	(ii)	(i)-(ii)
Mean	34	0.29%	0.42%	0.16%	0.24%	61.23%	58.35%	2.88%
Median	34	0.17%	0.25%	0.14%	0.21%	38.41%	64.97%	-25.30%

Table 3.6: Changes in turnover over time - Turquoise sample versus Spanish stocks

		TQ Sample		TQ Sample incl. TQ	Spain	
	Obs.	*Pre*	*Post*	*Post*	*Pre*	*Post*
Mean	34	102	53	55	135	90
Median	34	44	24	25	33	18

		Percentage Change				
		TQ Sample	incl. TQ	Spain		
	Obs.	(a)	(b)	(c)	(a)-(c)	(b)-(c)
Mean	34	-44.09%	-41.47%	-44.63%	0.54%	3.17%
Median	34	-48.97%	-45.81%	-47.24%	-1.81%	-0.13%

Remark: Turnover is depicted in million Euro.

sample but a Wilcoxon test does not reject the null hypothesis of equality. To summarize, when we compare bid-ask spreads and trading volume before and after the introduction of Turquoise and use Spanish stocks as a control sample we do not find a positive effect of increased competition on market quality.

3.5.2 The second control group

In order to check whether the results are sensitive to the choice of the control group we chose a second control group, consisting of highly liquid Italian stocks. These stocks could not be traded on Turquoise prior to October 20.[18] We therefore redefine the post-entry

[18]Note that two Italian firms were traded from October 13, 2008 onwards. For these firms and their matches we compute data based on a post-entry period lasting until October 10, 2008. Results remain unchanged when we exclude these two firms from the analysis.

Table 3.7: Changes in percentage quoted spreads over time - Turquoise sample versus Italian stocks

		Quoted Spreads in %				Spread Increase		
		TQ Sample		Italy		TQ Sample	Italy	
01.09.08-17.10.08	Obs.	*Pre*	*Post*	*Pre*	*Post*	(i)	(ii)	(i)-(ii)
Mean	25	0.25%	0.30%	0.13%	0.20%	40.07%	50.17%	-10.11%
Median	25	0.15%	0.24%	0.12%	0.20%	24.91%	46.68%	-20.84%
22.09.08-17.10.08								
Mean	25	0.25%	0.36%	0.13%	0.24%	66.31%	75.35%	-9.04%
Median	25	0.15%	0.27%	0.12%	0.23%	45.86%	77.02%	-24.26%

period. It now extends from September 1 to October 17. Even though all stocks we use in our analysis could be traded on Turquoise on September 1, the official Turquoise market opening only occurred on September 22. Therefore, we use a second post-entry period extending from September 22 to October 17 as a robustness check. We again use a matched-sample approach. Each of the 25 Italian stocks in the sample is matched with a Turquoise stock using the matching procedures described in the previous section.[19] The selected groups are larger in terms of market capitalization. The Turquoise stocks have a median pre-Turquoise market capitalization of 9.2 billion Euro, as compared to an average of 8.3 billion Euro for the Italian stocks.

Results on percentage quoted spreads are depicted in Tables 3.7. We find that the median percentage bid-ask spreads are similar whereas the mean percentage spread is markedly higher for the Turquoise stocks. In the post-entry period percentage quoted spreads are higher for both Italian and Turquoise stocks, irrespective of which post-entry period is considered. The increase is less pronounced for the Turquoise stocks. However, the difference is (based on a Wilcoxon signed rank test) not significant.

Table 3.8 shows the results on trading volume. The Italian stocks are more actively traded than the Turquoise stocks. Trading volume for the Turquoise stocks increased between the pre-entry and the post-entry period. The trading volume of the Italian stocks, on the

[19]The Italian stocks we consider here correspond to the 25 out of 28 stocks those in our Turquoise sample which we also use in our cross-sectional estimations. For summary statistics, compare 3.1

Table 3.8: Changes in turnover over time - Turquoise sample versus Italian stocks

01.09.08-17.10.08		TQ Sample		TQ Sample incl. TQ	Italy	
	Obs.	*Pre*	*Post*	*Post*	*Pre*	*Post*
Mean	25	65	71	73	130	121
Median	25	45	45	45	47	42
22.09.08-17.10.08						
Mean	25	65	68	71	130	113
Median	25	45	45	48	47	39

		Percentage Change				
		TQ Sample	incl. TQ	Italy		
01.09.08-17.10.08		(a)	(b)	(c)	(a)-(c)	(b)-(c)
Mean	25	16.14%	20.90%	-6.38%	22.52%	27.28%
Median	25	16.15%	16.29%	-11.08%	26.42%	32.52%
22.09.08-17.10.08						
Mean	25	7.49%	12.43%	-16.47%	23.96%	28.90%
Median	25	3.08%	11.05%	-18.46%	39.69%	41.45%

Remark: Turnover is depicted in million Euro.

other hand, decreased. The null hypothesis no difference in differences is rejected by a Wilcoxon signed rank test.

To summarize, when we consider changes in liquidity benchmarked against a control sample of Italian stocks we find that the introduction of Turquoise did not materially affect quoted bid-ask spreads but did result in an increase in trading volume.

3.5.3 Panel estimations

In this section we use an alternative procedure to measure the impact the introduction of Turquoise had on bid-ask spreads and trading volumes. We construct a weekly panel data set that spans the period from May 1, 2008 to January 31, 2009. The panel thus includes both the pre- and the post-entry period. In the cross-sectional dimension we include all Turquoise stocks analyzed previously (including the Italian stocks) as well as the Spanish stocks which were not traded on Turquoise during the entire sample period.

The dependent variables are two measures of liquidity, the quoted bid-ask spread and the trading volume. We include explanatory variables that are known to be related to liquidity. Specifically, we include lagged values of the log of market capitalization in Euro, trading volume (only in the spread regression), the bid-ask spread (in the volume regression), volatility, and the relative tick size. Lags are used in order to avoid endogeneity problems.

As noted previously we do not have access to intraday data for the Spanish stocks. Therefore, the analysis is based on daily data obtained from Bloomberg. The quoted spread is measured by the percentage closing spread. Market capitalization and relative tick size are calculated based on closing prices. The daily values for all variables are then averaged over the days of the week. We obtain an estimate of daily volatility from the daily high, low, opening and closing price as proposed by Garman and Klass (1980).[20]

In order to capture the impact of Turquoise on the spread we include the variable $Market\ Share\ TQ_{it}$ as a regressor. This variable is zero whenever a stock i is not traded on Turquoise in week t and is set to the Turquoise market share in week t otherwise. If increased competition leads to reduced spreads we should expect a negative coefficient. In order to allow for a non-linear effect of the Turquoise market share on spreads we also include the square of $Market\ Share\ TQ_{it}$.

We further allow for time fixed effects and include two stock-specific indicator variables. $\mathbf{1}_{SoftLaunch}$ is equal to one for stocks that were listed on Turquoise during the soft launch test period when only a limited number of stocks was tradable on Turquoise. For all countries except for Italy, the soft launch took place on differing dates between August 15 and 31, 2008. For Italian stocks the soft launch consisted of the trading week from October 13 to 17, 2008. Spanish stocks were not traded on Turquoise during the sample period. Therefore, the soft launch indicator is always zero for Spanish stocks. The second indicator variable $\mathbf{1}_{Post^{TQ}}$ is set to one for all stocks except the Italian and Spanish ones from September 22, 2008 (the official launch date) onwards. For Italian stocks it is set to one from October 20, 2008 onwards, for Spanish stocks it is always zero. These indicator variables are used to investigate whether the mere existence of an alternative trading

[20] $Volatility^{OHLC} := \sqrt{1/n[(log(H_t/L_t))^2 - (2log(2)-1)(log(C_t/O_t))^2]}$, where n is the number of observations (days), H_t is the daily high, L_t is the daily low, O_t is the daily opening and C_t is the daily closing price.

venue has an impact on spreads. They thus complement the variable $Market\ Share\ TQ_{it}$ which measures the impact that actual trading activity in the new trading platform has on spreads.

The results from GMM estimation are reported in Table 3.9. We consider the results for the spread first. We estimated two models. Model (P3) is the baseline specification, in model (P4) is a dynamic specification where the lagged spread is added as a regressor. In both specifications we find that the coefficient of $Market\ Share\ TQ$ is significantly negative while the coefficient of $Market\ Share\ TQ^2$ is significantly positive. Hence, using standard control variables, we find that spreads decrease (in a non-linear way) when the Turquoise market share increases. Thus, competition appears to increase liquidity as measured by the spread. Note that while the sign of the soft launch and post Turquoise indicator variables is negative as expected, only one out of four coefficients is significantly different from zero. The negative sign and significance of market capitalization and trading volume are in line with expectations.

In models (P5) and (P6) the trading volume is the dependent variable. Here, the Turquoise market share is only significant at the 10% level in specification (P5). Both the soft launch and the post-Turquoise indicators are insignificant. These results provide, at best, weak evidence that the introduction of Turquoise has led to an increase in trading volume.

3.6 Turquoise versus Primary Markets

As the last part of our analysis we compare how the incumbent home markets and Turquoise fare with respect to trading parameters like bid-ask spreads, quoted depth and trading volumes. Therefore, we depict the differences between average parameters over the post-entry period between Turquoise and the respective home market in Tables 3.10 and 3.11.

Looking at Table 3.10, it can be seen that for all home markets except for Austria and Ireland, the average spread across sample firms from November 2008 to January 2009 is lower in the primary market compared to Turquoise. 8 out of 14 countries have firms in which the average spread of at least one firm is below that of the home market. The overall number of firms with lower spreads is 24. Regarding the lower panel of Table 3.10, it can be seen that the average trade size on Turquoise is significantly below that of the

Table 3.9: Determinants of bid-ask spreads and turnovers: weekly panel estimations

	Spread in %		*LnTurnover*	
Specification	GMM (P3)	GMM (P4)	GMM (P5)	GMM (P6)
Variable	Coef. ($\|z-stat\|$)	Coef. ($\|z-stat\|$)	Coef. ($\|z-stat\|$)	Coef. ($\|z-stat\|$)
$Market\ Share\ TQ_{t-1}$	-0.006**	-0.007**	1.011*	0.525
	(2.00)	(2.51)	(1.86)	(1.13)
$Market\ Share\ TQ^2_{t-1}$	0.018**	0.021***	-2.367	-1.590
	(2.38)	(3.37)	(1.24)	(0.96)
$LnMcap_{t-1}$	-0.001*	-0.001	0.301***	0.130
	(1.78)	(1.45)	(2.65)	(1.03)
$LnVolume_{t-1}$	-5e-04***	-6e-04***		
	(3.32)	(3.01)		
$Volatility^{OHLC}_{t-1}$	0.002	0.003	-1.314***	-2.409***
	(0.60)	(1.01)	(5.46)	(5.72)
$TickSize_{t-1}$	-6e-04	-7e-04	-0.015	0.012
	(0.73)	(0.81)	(0.14)	(0.08)
$\mathbf{1}_{SoftLaunch}$	-8e-05	-3e-04**	-0.018	-0.020
	(1.12)	(2.39)	(0.44)	(0.49)
$\mathbf{1}_{Post^{TQ}}$	-2e-04	-1e-04	-0.021	-0.019
	(0.96)	(0.69)	(0.48)	(0.63)
$Spread^{Last}\ in\ \%_{t-1}$		-0.047*	-7.791*	-6.139
		(1.81)	(1.66)	(1.51)
$LnTurnover_{t-1}$				0.267***
				(6.85)
Obs.	11,190	11,186	11,186	11,186

Remark: ***, ** and * denote significance at the 1%, 5%, and 10% level, respectively. z-statistics are based on robust standard errors. $Market\ Share\ TQ_{t-1}$ is the average relative market share of Turquoise in terms of trading volume in the prior trading week, $Market\ Share\ TQ^2_{t-1}$ is its square. $LnMcap_{t-1}$ stands for the average logarithm of stock market capitalization in week $t-1$ in Euro, $LnVolume_{t-1}$ denotes the logarithm of average daily trading volume in week $t-1$. $Volatility^{OHLC}_{t-1}$ is lagged weekly volatility, computed as described in section 3.5.3. $TickSize_{t-1}$ is the average daily absolute tick size in week $t-1$. $\mathbf{1}_{SoftLaunch}$ is equal to one if the stock is traded in the soft launch period and zero otherwise. $\mathbf{1}_{Post^{TQ}}$ is zero before and during the soft launch period and equal to one afterwards if the stock is traded on Turquoise. Weekly time dummies are not depicted. Instruments for GMM specifications are lag $t-2$ to lag $t-4$ ($t-6$ in (P5) and (P6)) of $LnVolume$, $Market\ Share\ TQ$, $Market\ Share\ TQ^2_{t-1}$ and the average of last quoted spreads lagged one week $Spread\ in\ \%_{t-1}$ in model (P4) and the lagged logarithm of turnover $LnTurnover_{t-1}$ in model (P6).

Table 3.10: Difference between Turquoise and primary markets (part 1)

	Difference Spread in %			
Country	*Mean*	*Std.Dev.*	*Min*	*Max*
UK	0.142***	0.102	-0.125	0.477
Germany	0.080***	0.120	0.021	0.592
France	0.008***	0.019	-0.039	0.052
Netherlands	0.031***	0.023	0.003	0.088
Belgium	0.089	0.077*	0.047	0.231
Portugal	0.050*	0.059	-0.031	0.103
Denmark	0.027**	0.011	0.014	0.034
Sweden	0.383***	0.167	-0.019	0.758
Finland	0.165**	0.076	0.108	0.276
Norway	0.147**	0.208	-0.155	0.421
Ireland	-0.129	0.165	-0.444	0.023
Switzerland	0.103***	0.071	-0.117	0.238
Austria	-0.181	0.123	-0.356	-0.091
Italy	0.156***	0.056	0.065	0.286
	Difference Trading Volume			
Country	*Mean*	*Std.Dev.*	*Min*	*Max*
UK	-2054.58***	4113.00	-30814.70	-116.89
Germany	-1651.87***	1133.75	-4664.14	-290.72
France	-51.60**	148.98	-215.06	788.49
Netherlands	-91.63***	131.63	-269.63	294.34
Belgium	-56.36	115.36	-136.14	110.71
Portugal	-1073.62*	1111.89	-2636.79	-222.13
Denmark	-284.61	349.12	-674.59	-1.16
Sweden	-59.14	401.38	-1333.31	729.23
Finland	-373.29**	177.88	-622.35	-223.48
Norway	-858.61***	312.90	-1293.72	-548.05
Ireland	-13144.99***	5715.30	-19934.74	-6143.06
Switzerland	-27.07	168.64	-330.72	520.23
Austria	-803.17***	246.43	-1070.12	-518.09
Italy	-4591.22***	8459.71	-30721.12	-154.21

The table presents country averages of differences between trading parameters on Turquoise and the primary market. Trading volume stands for average trading volume in shares. Spread in % relates to the best quoted bid-ask spread in percentage terms. ***, ** and * denote rejection of the null-hypothesis in one-sided t-tests that the spread on Turquoise is higher than on the incumbent exchanges (upper panel) or, respectively, that average trade size on Turquoise is smaller than in the primary markets (lower panel). The asterisks correspond to significance levels of 1%, 5% and 10%, respectively.

home market in 10 countries which may be not surprising given the fact that the overall transacted volume is markedly lower, too. Table 3.11 shows that average depth at best quoted bid and ask prices is markedly lower on Turquoise compared to the home market. However, due to the existence of hidden volumes in the dark pool, actual depth may differ from visible depth.

Table 3.11: Difference between Turquoise and primary markets (part 2)

	Difference Depth Ask			
Country	*Mean*	*Std.Dev.*	*Min*	*Max*
UK	-8104.23***	19902.13	-141479.30	-277.13
Germany	-1888.88	7632.99	-37711.70	-81.48
France	-2249.61***	2335.71	-10629.82	-308.00
Netherlands	-2223.44***	2223.00	-6907.99	-146.47
Belgium	-1226.57*	965.90	-2633.15	-448.44
Portugal	-10470.28	11928.83	-27810.68	-2537.22
Denmark	-4929.76	6070.76	-11722.71	-34.63
Sweden	-10308.83***	9308.44	-32805.97	9006.04
Finland	-9334.86*	6494.12	-18050.16	-3240.13
Norway	-8582.17***	3740.09	-13570.05	-4860.07
Ireland	-6825.33**	4059.71	-10872.06	-1329.94
Switzerland	-6861.68***	9094.96	-27162.12	-392.73
Austria	-1019.66***	243.46	-1320.54	-724.24
Italy	-8242.17**	18512.06	-89664.47	81.74
	Difference Depth Bid			
Country	*Mean*	*Std.Dev.*	*Min*	*Max*
UK	-9887.72***	28159.25	-209201.50	-295.56
Germany	-1644.33	6392.71	-31624.41	-72.21
France	-2199.03***	2295.30	-11065.50	-285.63
Netherlands	-2305.93***	2308.77	-7344.72	-83.10
Belgium	-1198.06*	824.10	-2386.74	-509.65
Portugal	-9961.76	10188.07	-24632.71	-2954.29
Denmark	-4500.15	5545.78	-10707.09	-32.48
Sweden	-9831.84***	10171.34	-42152.89	7477.23
Finland	-9104.46*	6295.98	-17481.07	-3027.64
Norway	-8052.23***	3471.94	-12582.76	-4530.32
Ireland	-7513.64*	5233.85	-13840.05	-1379.17
Switzerland	-6651.35***	8784.47	-25584.75	-417.62
Austria	-1032.78***	280.78	-1269.65	-633.0 7
Italy	-7996.55**	18683.66	-90944.63	1079.35

Depth ask and bid stand for the average ask and bid volume available at best quotes. ***, ** and * denote rejection of the null-hypothesis in one-sided t-tests that depth at the ask on Turquoise is lower than on the incumbent exchanges (upper panel) or, respectively, that depth at the bid on Turquoise is smaller than in the primary markets (lower panel). The asterisks correspond to significance levels of 1%, 5% and 10%, respectively.

3.6.1 Traded spreads

The finding that average quoted spreads on Turquoise are in most cases higher than on the primary markets is somehow at odds with the observation that firms with high spreads in the pre-entry period tend to be more actively traded on Turquoise compared to firms with low spreads in the pre-Turquoise period. Note, however, that a marked extent of liquidity on Turquoise stems from a dark pool in which best quotes are posted inside the midpoint, leading to observed quoted spreads that are biased upwards in comparison to incumbent exchanges. The Turquoise platform operator estimates that the average spread improvement from the dark pool is about 4 ticks. In order to examine whether we find evidence of this statement in our snapshot data, we compute a measure of traded spreads as follows: We define "effective" spreads from our one-minute data to be the 2 times the absolute value of the difference between the transaction price P_t in a given minute t and the last quoted midpoint M_t in that minute ($S^{'effective'} = 2|P_t - M_t|$). If traded spreads are below quoted spreads (and for timing reasons), we would expect that this measure of traded spreads is smaller than average quoted spreads. Results from spread comparisons are shown in Table 3.12 where we subtract computed "effective" spreads from average quoted spreads in absolute terms and depict both medians and averages across countries. Focusing on median values, the last column shows that our measure of traded spreads is below quoted spreads in 13 of 14 primary exchanges which is conform to our expectations. Median spread improvements are however often below one Euro Cent (or the national equivalent) which may be related to the fact that we do not dispose of real transaction data. Note, however, from comparing the last two columns that for 5 of 14 exchanges, the difference between quoted and "effective" spreads is higher on primary markets which tends to offset effects on Turquoise.

The last table indicates that the relative spread improvement on Turquoise does in general not suffice to obtain "effective" spreads below those of the primary market. This can be seen by considering columns 4 and 10 of Table 3.13 in which "effective" spreads on Turquoise and primary markets are compared both in absolute and percentage terms. For all markets, the mean and median value of this difference is positive, although the latter is often not statistically significant from zero. Results relating the transaction price to the midpoint established in the last snapshot M_{t-1} are qualitatively similar and available upon request.

We conclude that, considering averages and median values across stock markets, average bid-ask spreads (trading volumes) are in most cases higher (lower) on Turquoise compared to home markets. Computing a proxy for traded spreads, we find that the difference to primary markets decreases, but does not disappear on average. Hence, it seems that trading a broad sample of stocks, implicit transaction costs cannot be systematically reduced by switching to the new MTF Turquoise. The observation that the market

Table 3.12: Difference between quoted and "effective" spreads on Turquoise and the primary markets

	Difference Quoted vs. "Effective" Spreads					
	Mean			Median		
	Home Market		Turquoise	Home Market		Turquoise
Country	*Pre*	*Post*	*Post*	*Pre*	*Post*	*Post*
UK	0.381	0.265	-0.750	0.282	0.227	0.206
Germany	0.005	0.007	-0.009	0.004	0.004	8e-04
France	0.004	0.011	-0.010	0.003	0.009	-0.001
Netherlands	0.004	0.005	0.020	0.004	0.004	0.002
Belgium	0.005	0.007	0.005	0.005	0.007	0.009
Portugal	2e-04	2e-04	0.004	2e-04	9e-05	0.003
Denmark	5.602	4.176	9.559	0.064	0.041	0.144
Sweden	0.042	0.214	0.198	0.012	0.010	0.218
Finland	0.002	0.002	0.008	0.002	0.002	0.007
Norway	0.018	0.018	0.071	0.014	0.015	0.036
Ireland	0.006	0.006	0.003	0.004	0.004	0.002
Switzerland	0.035	0.033	0.029	0.020	0.022	0.032
Austria	0.001	-0.004	-2.437	0.001	-0.002	8e-04
Italy	0.004	0.002	0.002	0.003	0.001	0.002

share of Turquoise is negatively correlated with the difference in effective spreads between Turquoise and the primary exchange (and the fact that this correlation is stronger for subsets with higher Turquoise market shares) indicates, however, that for some stocks, there may be scope for spread improvements by switching to Turquoise. Further research may formally assess this question.[21]

3.7 Conclusion

This chapter analyzes the market entry of the pan-European MTF Turquoise in August 2008. The fact that Turquoise covered shares of 14 European countries by November 2008 enables us to investigate its launch in a setup which is close to a natural experiment.

We first examine the market share of Turquoise and its determinants. Results from cross-

[21] One can imagine that relative spread differences between Turquoise and the primary markets depend upon the intraday trading time, weekday effects or situations related to the state of the order book and volatility.

Table 3.13: Difference between effective spreads on Turquoise and the primary markets

	Difference "Effective" Spreads Turquoise vs. Home Markets					
	$2\|P_t - M_t\|$			$\|200(P_t - M_t)/M_t\|$		
Country	*Mean*	σ	*Median*	*Mean*	σ	*Med.*
UK	1.64	8.62	0.40	0.28	0.91	0.08
Germany	0.05	0.14	0.02	0.08	0.06	0.05
France	0.02	0.03	0.02	0.07	0.07	0.05
Netherlands	0.16	0.59	7e-03	0.07	0.07	0.06
Belgium	0.07	0.08	0.05	0.33	0.39	0.14
Portugal	0.01	7e-03	0.01	0.22	0.02	0.22
Denmark	41.31	70.83	0.63	0.31	0.08	0.32
Sweden	0.06	0.08	0.06	0.08	0.07	0.09
Finland	0.02	0.01	0.02	0.18	0.07	0.20
Norway	0.24	0.17	0.20	0.30	0.07	0.28
Ireland	0.02	0.02	0.01	0.09	0.21	0.08
Switzerland	0.09	0.11	0.05	0.18	0.31	0.07
Austria	2.48	4.87	0.06	5.25	10.14	0.33
Italy	3e-03	3e-03	3e-03	0.06	0.05	0.05

sectional regressions indicate that market shares of Turquoise are particularly high for large stocks with a high relative free float and a low level of volatility, hence for stocks that pose a relatively low risk for market makers. Furthermore, the market share is c.p. high for firms with higher levels of illiquidity as measured by the bid-ask spread and depth at the best quotes before the entry of Turquoise. Decomposing bid-ask spreads into a predicted component (the predicted value from a regression of the spread on a set of explanatory variables, performed for the pre-Turquoise period) and an unpredicted component (the residual from that regression), it turns out that market shares are particularly high for firms the spreads of which were "too high" relative to the set of explanatory variables used. Regarding market characteristics, firms from a market with a larger overall market capitalization tend to have relatively higher market shares, as do firms from markets in which the share of investment bank ownership is relatively high or the share of ownership by foreign institutions is relatively low. Finally, the market share of firms with a low tick size is higher. Results of a panel analysis of daily changes in market shares provide additional evidence that high spreads in the home market lead to higher Turquoise market share. They also show that organizational changes by some primary exchanges had an impact on Turquoise market shares while others had not.

We further analyze whether market quality improved after the entry of the new trading venue. We consider the bid-ask spread and trading volume as measures of liquidity. To control for changes in the market environment (in particular the crisis which culminated in the month of the official launch of Turquoise) we use control variables and control samples. The results are somewhat ambiguous. Pairwise comparison of matched samples (Turquoise stocks versus Spanish and Italian stocks) do not reveal a significant decrease of the bid-ask spreads after the introduction of Turquoise. The comparison with the Italian stocks indicate that volume may have increased after the introduction of Turquoise. When we use a weekly panel instead we find evidence that spreads have declined and volume has increased after the introduction of Turquoise. These results are consistent with a positive impact on market quality of competition between trading venues.

Finally, we compare trading characteristics of Turquoise and the primary markets. We find that average quoted spreads and a measure of traded spreads are higher on Turquoise compared to the home market in the period between November 2008 and January 2009.

Our results draw a differentiated picture of competition between exchanges. Turquoise was able to attract order flow without generally offering higher liquidity than the primary market. At the same time, Turquoise gained higher market shares in stocks for which spreads in the home market are "too" high relative to fundamentals. Higher Turquoise market shares, in turn, lead to lower spreads and thus to an improvement of market quality. All in all, our results are consistent with the new entrant serving as a disciplinary device which reduces rents earned by the suppliers of liquidity in the primary market. Whether the post-entry revenue to the suppliers of liquidity and the operators of the trading systems are sufficient is a question we are unable to answer. The fact that trading volume did not generally increase upon the entry of the new competitor is, however, an indication that the overall revenue has decreased.

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