The Quality of Electronic Markets

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Abstract

Technical progress in information and communication technologies, increased competition through alternative trading systems, and regulatory actions have significantly changed the trading landscape during the last decade. In this paper, we first provide a conceptual framework to analyze market quality. The framework comprises of external factors, the internal market structure, and specific quantifiable market quality measures. We categorize market quality measures into activity, liquidity, and information. Second, we compare the 1997 IBIS II trading system with the 2009 Xetra system of the Deutsche Boerse Group to exemplary apply our framework. We find that trading strategies have changed, activity has increased, and liquidity has improved for the Xetra system compared to IBIS II. More generally, our case study of the German market shows that, in the context of financial market innovation, the overall market quality has improved over the last couple of years.

1. Introduction

Information and communication technology innovations have profoundly changed the design and operation of electronic markets. The automation in securities trading has been ongoing over the past three decades. Trading without the use of IT systems seems impossible today. The rise of electronic markets leaves the question of measures for a thorough analysis of market quality.

This question has to be asked in the context of rapidly changing external factors and internal market structures. One of the most important factors is the technological advancement. Technology has been at the origin of the electronic revolution which has altered almost every aspect of securities trading. In addition, traditional exchanges face more intense competition from alternative trading systems (ATS) as a result of regulatory changes and the liberalization of the landscape of trading. External factors like technology, regulation, and competition play a major part in the change of market quality, since they directly influence the internal market structure of electronic markets. [23] presents an example for the close interaction of external factors and the internal market structure, the introduction of electronic trading on the International Securities Exchange (ISE). He analyzes the successful entry of an electronic market as a result of IT advancements and a successful business model. From this area of research, a high relevance of external factors, such as regulation, competition, and technology, as well as their interaction with the internal market structure can be deducted.

In IS and finance literature, the influence of different external factors and internal market structures on market quality has been widely and thoroughly discussed and analyzed. Recent studies from [1] and [21] focus on the analysis of market quality. However, academics and practitioners refer to the term market quality in a very ambiguous way, often in terms of liquidity measures, specifically spreads and trading intensity (e.g. [1], [10], or [2]). Others also include information measures, for instance permanent price impacts and trade-correlated measures (cf. [3], [8], or [9]). Due to a missing precise definition of market quality, we provide a framework that puts several prominent measures of market quality into context with external factors and the internal market structure.

In this paper, we present a conceptual framework of market quality in the context of electronic financial markets and apply our framework in a case study. Specifically, we take measures from recent IS and finance literature and embed them in a framework of external factors and internal market structure. Our framework is applied to the German
market in order to evaluate the market quality of the two electronic markets Integriertes Boersenhandels- und Entscheidungs-system (IBIS II) and the Exchange Electronic Trading (Xetra) system. We use market data from IBIS II in 1997 and from the Xetra system in 2009 and test for differences in market quality. The case study demonstrates significant changes of equity markets over the last decade.

The remainder of the paper is structured as follows. While Section 2 describes our market quality framework, we analyze market quality of the two systems IBIS II and Xetra in Section 3. Finally, Section 4 concludes with further areas of application and research questions.

2. Market quality framework

Our proposed framework for market quality consists of three main parts which we discuss separately in the next subsections:

- The first part are the external factors encircling the market.
- The second part defines the internal market structure (cf. [11]).
- The third part describes quantifiable measures of market quality in terms of activity, liquidity, and information.

External factors influence market quality indirectly, and are not under the explicit influence of the exchanges. We cluster external influences into the factors technology, regulation, and competition, with close connections between the three factors. In contrast, internal market structure concerns how the market is designed, created, and operated.

![Market Quality Framework](image)

Figure 1. Market quality framework

There exists interaction between the internal market structure and external factors, often involving more than two factors. Interaction effects are also a popular topic in IS and finance literature. [6] propose a framework to model the impact of technology on market transparency, part of the internal market structure. The extent of this impact depends on several external and internal factors, in the case of financial markets on product complexity, competitive forces, e.g. price discrimination, and institutional or regulatory forces, like the Securities and Exchange Commission (SEC). [13] point out the relationship of IT systems and business structure, both internal factors, and external competition in the case of the London Stock Exchange (LSE) and competitive new entrants. They conclude that by making use of IT, the LSE as incumbent exchange could preserve its business model for some time, but it finally had to give way to more innovative business models of new entrants. We define market quality measures in the context of this dynamic, interconnected environment of external factors and internal market structure.

2.1. External factors

As depicted in Fig. 1, external factors can be categorized into technology, regulation, and competition:

The external factor technology comprises technological developments, falling into the categories information dissemination, information processing, and communication technology. The last thirty years have seen an unprecedented development in computing power and network systems linking computers globally. The ubiquity with which computers are present in our everyday life, personally and professionally, could not have been imagined even two decades ago. This radical development has profoundly influenced financial markets and enabled new applications like algorithmic trading systems, the automation of the trading process, as well as high-speed news dissemination that provides information faster and more reliably than ever.

Due to the technological advancements of electronic markets, regulatory authorities have tried to keep pace by adapting new regulation. During the last years, one of the regulatory changes with the biggest impact on trading in Europe includes Markets in Financial Instruments Directive (MiFID). MiFID became effective in November 2007 to create a harmonized trading landscape in the 27-nation European Union. It abolished the concentration rule which favored one single dominating exchange in each country. Instead, MiFID promotes competition between traditional exchanges and multilateral trading facilities (MTF) and the order processing under best execution. Best execution under MiFID relies on multiple factors, for instance prices, trading costs, speed, or likelihood of execution and
settlement. The introduction of MiFID allowed MTFs to offer trading in European equities, which led to fierce competition between trading venues in Europe. The till then monopoly-like status of traditional exchanges has crumbled ever since which resulted in a more fragmented European equities market.

As described, there is a close relationship of regulatory changes and the competition between trading venues. Literature is inconclusive about the impact of competition on market quality and price discovery. [1] explore the competition of Electronic Communication Networks (ECNs), a form of ATS in the US, and Nasdaq market makers. They report that trades are more likely to be executed on ECNs in case of high information asymmetry, high trading volume and stock-return volatility. However, ECNs possess higher execution costs, since Nasdaq market makers can preferenate or internalize less informed trades. These results put market quality aspects into the context of competing trading venues and what kind of traders and orders they attract. [17] analyze the market quality of the LSE and competing MTFs. They provide evidence that the LSE offers more liquidity and contributes more to trade-based price discovery whereas MTFs contribute more to quote-based price discovery.

2.2. Internal market structure

In contrast to external factors, the internal market structure directly influences market quality. External factors provide general conditions which affect the internal market structure, i.e. the design, creation, and operation of electronic markets. Following [11], the internal market structure can be decomposed into business structure, market microstructure, and IT systems.

Depending on the customer target group, trading venues coordinate their model by defining a business structure. Among others, it specifies a target group of customers that the market should attract and provide products and services for. According to [7], different types of traders are attracted by different market models, making the choice of market model and the knowledge of trader types extremely relevant. Types of traders can be further characterized by the degree of informedness of each trader. [4] examine the benefits of a risk-based pricing for exchanges in an intermediated market. Depending on the level of informedness, investors pose different levels of risk for the exchange and its intermediaries. These different risk groups of investors have become difficult to distinguish by the introduction of anonymous alternative trading systems. They state that the use of IT in risk signaling and risk-based pricing depending on the risk group of investors can lead to slightly reduced transaction costs, lower ones for uninformed investors and higher ones for informed investors. Therefore, the analysis links aspects of business structure, specifically target groups of customers as well as the pricing of services with market quality.

The close connection of business structure and IT systems can be demonstrated by the example of algorithmic trading systems. Algorithmic traders became and are becoming more and more dominant. Today, algorithmic traders submit about 52 % of all trades in German DAX 30 stocks. Algorithmic trading is defined as the use of computer algorithms to manage the trading process (cf. [10]). Their applications are manifold. They are often used for “slice and dice” algorithms as described by [10]. In consequence, these algorithms split large orders into smaller ones in order to minimize impact and transaction costs and to hide information and trading strategies. Algorithmic trading systems with short-term strategies, called high frequency trading systems, intensify this effect even more. High frequency trading strategies sometimes involve the submission and an immediate cancellation in case of non-execution of an order, both within milliseconds. As a result, we can see increased trading activity, and a rising demand for speed and anonymity. With this changing group of customers, exchanges adapted their IT system and business structure accordingly. However, ECNs und MTFs often meet the described needs of traders for anonymous low latency systems better than traditional exchanges. Literature shows that even small reductions in latency can have significant effects on market quality in terms of information and liquidity. For instance, [16] and [22] analyze the introduction of Xetra Release 8.0 in 2007 on the German market which reduced system latency from 50 to 10 milliseconds per roundtrip. [19] report that information is more quote-based after the introduction of the new release. The combination of fast trading platforms and new order types enabled through IT systems results in a competition among trading venues. This resembles a systems’ arms race in terms of both business structures and IT systems.

At the heart of market design, the microstructure is established. Market microstructure is “the study of the process and outcomes of exchanging assets under explicit trading rules” ([15], p. 1). In order to determine the market microstructure, the execution system, the market model, and the role of intermediaries have to be defined, as well as the degree of transparency. Market microstructure may have a direct effect on market quality. An abundance of market microstructure research papers, linking
changes in market microstructure to market quality, have been published during the last two decades.

The market model determines the auction model of the market, for example a call auction or a continuous double auction, which also are the two most important ones for financial markets. The execution system, i.e. the matching of buyers and sellers, can be either quote-driven, brokered or order-driven, or a hybrid form of those. Quote-driven and brokered markets involve intermediaries, e.g. in the form of brokers or liquidity providers. One prominent example for a comparison of execution systems is presented by [12]. They analyze differences in liquidity of the Nasdaq, and the NYSE. During their observation period, the NYSE operated a floor-based order-driven trading system, but also engaged liquidity providers in the form of specialists. Those are more common in quote-driven systems. The Nasdaq, on the other hand, was a fully quote-driven market at that time, with dealers acting as intermediaries for every trade. [12] compare both execution systems and find that transaction costs on the Nasdaq are larger than on the NYSE.

Another aspect of market microstructure is the degree of transparency, i.e. the extent to which information is disclosed before, during, and after the trading process plays a vital role. [3] examine the introduction of the NYSE's OpenBook, the dissemination of the whole order book instead of only the best bid and ask prices. This increase in pre-trade transparency has led to changes in market quality: smaller order sizes, more order cancellations, less order book depth, liquidity improvements, and a decline in the participation of specialists. This gives an indication for the different dimensions of market quality that have to be considered for a complete evaluation of an electronic market. The most prominent are presented in the next section.

2.3. Measures

We identify the most prominent and important dimensions of market quality with a focus on quantifiable measures. We further classify these measures into three categories of market quality: activity, liquidity, and information.

Activity can be measured using daily measures like the number of trades (Trade Count), the trading volume (Turnover), or the average trade size (Trade Size) (cf. [1] and [10]). Trading intensity measures are usually calculated on a daily basis per instrument. The first three measures are closely related. An increase in the number of trades does not unconditionally imply an increase in trading volume, since trade sizes also have to be taken into account. While all three measures can be classified as trading intensity, quote updates can be considered as a measure for the mere market activity of traders.

Liquidity is a better measure for the attractiveness of a market for traders than activity, since it indicates "the ability to trade large size quickly, at low cost, when you want to trade" (cf. [7], p. 394). It also affects external factors, i.e. regulation as well as competition: "Everyone likes liquidity. Traders like liquidity because it allows them to implement their trading strategies cheaply. Exchanges like liquidity because it attracts traders to their markets. Regulators like liquidity because liquid markets are often less volatile than illiquid ones." (cf. [7], p. 394) Liquidity as a central measure for market quality is therefore the main criterion for the success and attractiveness of a trading venue.

Spread measures for liquidity are very common in finance literature. The most prominent ones are quoted spreads, effective spreads, and realized spreads (e.g. in [3] and [12]). Spread measures are commonly reported on a daily basis per instrument in basis points (bps).

Quoted spreads are ex-ante measures of liquidity. This means they can be calculated directly from order book data on a tick-by-tick basis without any trade information. However, they only measure the transaction costs of small trades on the upper level of the order book. Quoted spreads can also be calculated as trade-time quoted spreads (Quoted Spread Trade), i.e. the prevailing quoted spreads at the time when a trade occurred. Quoted spreads at trade are usually smaller than quoted spreads since traders usually monitor the market and trade when it is cheap to trade. Let \( Ask_i \) denote the ask price for a stock \( i \) at time \( t \), \( Bid_i \) the respective bid price, and \( Mid_i \) the mid quote. The quoted spread is then calculated as follows:

\[
Quoted\ Spread_i = (Ask_i - Bid_i)/(2* Mid_i)
\]

The effective spread is an ex-post measure and can be obtained from actual trade and quote data. It represents the actual transaction costs paid when an incoming market order is executed against a limit order. With most data sets, the trade direction of the order has to be inferred from a heuristic (e.g. by [14]). Let \( Price_i \) denote the execution price and \( D_i \) the trade direction, with -1 for a market sell and +1 for a market buy order, then the effective spread is calculated as follows:

\[
Effective\ Spread_i = D_i*(Price_i - Mid_i)/Mid_i
\]

The effective spread can be decomposed into the realized spread, i.e. liquidity suppliers’ revenue, and the price impact. According to Bessembinder and
Kaufman, 1997 it equals losses to better informed traders and is defined as follows:

\[ \text{Realized Spread}_{i,t} = D_{i,t} \times \frac{(\text{Price}_{i,t} - \text{Mid}_{i,t})}{\text{Mid}_{i,t}} \]

Usually, a time interval \( x \) of 5 to 30 minutes is used, with 5 and 15 minutes being the most common.\(^1\)

While spread measures account for the width of liquidity, depth is another dimension of liquidity. It measures the quoted volume of limit orders in the order book at a given price (cf. [1]). Let \( \text{Vol.Bid}_{i,t} \) and \( \text{Vol.Ask}_{i,t} \) denote the volume at the best bid and ask, respectively. Depth at the best bid and ask can then be measured as:

\[ \text{Depth}_{i,t} = \frac{\text{Vol.Bid}_{i,t} + \text{Vol.Ask}_{i,t}}{2} \]

Information models, e.g. [5], explain how information is translated into market prices through order flow. Informed trades submit a market order when they believe that their information justifies a price different from current quotes. After a trade, market makers adjust their prices according to their beliefs about the probability of trading with an informed or uninformed trader. In order to approximate the information content of a trade, the price impact can be used, calculated as the price adjustment after a trade (cf. [10]):

\[ \text{Price Impact}_{i,t} = D_{i,t} \times \frac{(\text{Mid}_{i,t} + x - \text{Mid}_{i,t})}{\text{Mid}_{i,t}} \]

The price impact only serves as an indication of information content. More robust measures are information measures introduced by [8] and [9]. [8] suggests focusing on the trade innovation, the unexpected part of a trade. The information content of a trade is derived from the trade innovation. [9] further proposes to decompose the price variance into a trade-correlated and quote-correlated part.

The application of our framework is not restricted to financial electronic markets. In this paper, we concentrate on electronic markets with a continuous double auction as the auction mechanism. Other research applications are subject to further research.

3. Case study: IBIS II vs. Xetra

For an exemplary application of our market quality framework, we apply the framework to a comparative analysis of IBIS II and the Xetra system, two predominant financial electronic markets in the history of German exchanges. IBIS II had been the trading system for German DAX 30 securities between April 1991 and November 1997. It has been replaced by the Xetra system in November 1997. Our analysis provides an exemplary application of our framework from Section 2.

3.1. Institutional details

The “Inter-Banken-Informations-System” (IBIS I) was originally designed as a quotation and settlement support system for the Deutsche Boerse Group. The Deutsche Boerse Group is one of the largest stock exchange operators in the world. In the early days between December 1989 and April 1991, trading took place from 8:30 a.m. to 5 p.m. (local time) by phone. IBIS I was replaced by the “Integriertes Boersenhandels- und Entscheidungssystem” (IBIS II), a fully automated trading system organized as an anonymous continuous open limit-order book with price-time priority. However, it was only possible to trade round lots of 100 or 500 shares (cf. [18] and [19] for details). Orders were directly transferred to the DWZ, the German securities clearing service.

The Deutsche Boerse Group replaced IBIS II with the Xetra system in November 1997, the prevailing trading system for all German securities ever since, which has undergone several releases and changes. The Xetra system is a fully-electronic trading system, with trading hours from 9:00 a.m. (local time) to 5:30 p.m. (local time) in our chosen sample. Like IBIS II, it is order-driven, anonymous, and is organized as an open limit-order book. It follows a flexible market model, specifically a continuous double auction. There is an opening call auction at 9:00 a.m. (local time) in the morning, a two-minute intra-day call auction at 1:00 p.m. (local time) and a closing call auction at 5:30 p.m. (local time), all three with a random ending. In our study we focus on the continuous trading periods.

The external factors, i.e. regulation, competition, and technology significantly changed over time. In contrast, the basic market microstructures of IBIS II and the Xetra system as described above are quite similar: Both enable fully automated continuous trading with price-time priority within same time durations. Our analysis primarily focuses on the comparison of both markets with regard to our specified market quality measures and to the external factors and internal market structure of our market quality framework.

Our data samples consist of DAX stocks traded on IBIS II between January 1st, 1997 and March 31st, 1997 and on the Xetra system for the same time

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\(^1\) The SEC uses the five-minute mark for their analyses. SEC, Release No. 34-43590 (cf. [http://www.sec.gov/rules/final/34-43590.htm](http://www.sec.gov/rules/final/34-43590.htm)).
The period in 2009. Table 1 shows our data samples, with each consisting of 29 DAX stocks. We exclude companies that are not continuously traded during our observation period. The companies in Table 1 are ranked by their average daily trading volume over the specific observation periods.2 While Sample 1 consists of stocks traded on IBIS II, Sample 2 comprises Xetra stocks.

3.2. Results

Despite the similar market microstructure of both markets, internal and external factors have significantly changed. We highlight the most important differences based on our framework.

The external factors regulation and competition have profoundly changed from 1997 to 2009 particularly after the introduction of MiFID. As a result of the concentration rule, national markets have often operated as a de facto monopolist. After MiFID, the introduction of multilateral trading facilities has started a fierce competition for order flow between incumbent exchanges in Europe and alternative trading venues. For instance the London Stock Exchange (LSE) lost over 30 percent of its market share between 2007 and 2009. Deutsche Boerse has been able to maintain a higher fraction of market shares but they have also seen a significant drop lately.

As to the technological changes, we can see an immense increase in the speed of both information and communication technology. The electronic revolution has also greatly affected the German trading landscape, with the use of computerized high speed trading systems, geographically dispersed market participants, anonymization of trading, and a greater choice of trading platforms.

The change in external factors has triggered a substantial transformation of exchanges’ internal market structures consisting of business structures, IT systems, and market microstructures.

The customer target group as an aspect of the internal business structure has changed (cf. section 2.2). Particularly institutional investors aim for more sophisticated trading strategies and a higher degree of automation, e.g. by using algorithmic trading systems. With the introduction of the Automated Trading Program (ATP) in December 2007, Deutsche Boerse directly targets to attract algorithmic traders. As mentioned for example in [10], algorithmic traders have a different trading behavior than human

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2 In order to transform measures given in Deutsche Mark (DM) in the IBIS data to Euros, we use the exchange rate at which the currency entered the Euro (1.95583 Euros per DM).
Table 2. Descriptive statistics

The table provides market activity, liquidity, and information measures for DAX stocks traded on IBIS II between January 1st, 1997 and March 31st, 1997 (Sample 1) and on the Xetra system for the same time period in 2009 (Sample 2). We report the mean, the standard deviation as well as minimum and maximum values of all measures on a daily basis per instrument. **Turnover** is the average daily trading volume in million Euros, **Trade Count** the average number of trades per day, **Trade Size** the average trading volume in Euros per trade, and **Quote Frequency** the total number of price and volume updates per day. In order to transform measures given in Deutsche Mark from Sample 1 to Euros, we use the exchange rate at which the Deutsche Mark entered the Euro.

As liquidity and information measures we report different spread measures as relative measures in basis points. While the **Quoted Spread** is calculated on a tick-by-tick basis per instrument, **Quoted Spread Trade**, **Effective Spread**, **Realized Spread 5**, and **Realized Spread 15** are reported trade-by-trade. For **Realized Spread 5** (Realized Spread 15), we use the midpoint in \( t \) plus 5 minutes (\( t \) plus 15 minutes) as reference point. **Depth** gives the daily average quoted volume at the best bid and ask in Euros for all data set entries. We calculate daily average price impacts using midpoints as reference points in \( t \) plus 5 minutes (\( t \) plus 15 minutes) for **Price Impact 5** and **Price Impact 15**, respectively.

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>Std. Dev.</td>
</tr>
<tr>
<td><strong>Trading Intensity</strong></td>
<td></td>
</tr>
<tr>
<td>Turnover [Mio.]</td>
<td>30.983 35.543 0.972 464.663 79.746 70.764 5.983 672.762</td>
</tr>
<tr>
<td>Trade Count</td>
<td>228 202 10 3,060 4,314 2,779 632 25,228</td>
</tr>
<tr>
<td>Trade Size</td>
<td>124,993 67,479 29,293 386,888 16,295 6,090 5,302 38,504</td>
</tr>
<tr>
<td>Quote Frequency</td>
<td>654 418 74 5,243 43,301 28,105 4,601 265,501</td>
</tr>
<tr>
<td><strong>Liquidity</strong></td>
<td></td>
</tr>
<tr>
<td>Quoted Spread</td>
<td>14.386 8.784 2.996 66.990 6.440 2.461 2.447 18.758</td>
</tr>
<tr>
<td>Quoted Spread Trade</td>
<td>11.333 6.808 2.506 53.125 5.179 2.028 2.011 18.055</td>
</tr>
<tr>
<td>Realized Spread 5</td>
<td>2.588 4.929 -14.140 34.588 1.284 1.507 -5.864 11.994</td>
</tr>
<tr>
<td>Depth</td>
<td>151,261 69,601 38,513 414,371 31,579 18,507 12,783 144,444</td>
</tr>
<tr>
<td><strong>Information</strong></td>
<td></td>
</tr>
<tr>
<td>Price Impact 5</td>
<td>8.814 5.099 1.251 42.955 2.701 1.552 -1.683 11.914</td>
</tr>
</tbody>
</table>

traders as well as competitive advantage with respect to speed and computation. Therefore, the importance of latency and availability have changed. Nowadays, trading venues compete for customers by offering co-location services and faster systems.

The aforementioned development has been enabled by increasingly automated IT systems and it has also been accompanied by a shift from floor to electronic trading. In 1997 floor trading still played an important role, leaving IBIS II with about 40 percent of the total trading volume in DAX stocks. The situation in 2009 was quite different. Xetra now accounts for more than 90 percent of turnover in the DAX shares. IBIS II and Xetra are based on different IT systems. Xetra was originally developed to attract order flow from non-institutional investors and from outside of Germany by providing a decentralized access. Since it was accessible for all market participants, it also provided improved transparency, which is part of the market microstructure.

All these changes in the business structure and in IT systems led to an anonymous and highly automated market which has been faster in processing trades and trade information. We have not seen a change in the main characteristics of the market microstructure. However, main drivers of a market differences between Xetra and IBIS II can be attributed to the internal factors business structure and IT structure strongly driven by changes in external factors.

In order to evaluate and compare the market quality of both markets, we calculate measures of market quality as specified in Section 2. 3 Descriptive statistics are reported in Table 2.

In contrast, the number of trades has shown an 18-fold increase, from 228 trades per day to 4,314 trades. The explanation comes with the analysis of

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3 For trade measures, we correct time-stamps of quotes for -1.5 seconds to account for a recording lag of quote and trade values.
Table 3. Evolution in liquidity and information measures over time

The table reports test for differences between quoted spreads, effective spreads, realized spreads, and price impacts for DAX stocks traded on IBIS II between January 1st, 1997 and March 31st, 1997 and on the Xetra system for the same time period in 2009. The trading volume categories are obtained by ranking the firms in the DAX by their average daily trading volume for the IBIS II and Xetra sample. The first category contains the first 15 firms with the highest trading volume (High) and the second the next 14 firms (Low). While Quoted Spread is calculated on a tick-by-tick basis per instrument, Effective Spread, Realized Spread 5, and Price Impact 5 are calculated on a trade-by-trade basis. All measures are given on a daily basis per instrument and calculated as relative measures in basis points. In addition, we report trade based measures for trades with less than 4,000 shares and equal or greater than 4,000 shares separately. To test for differences between the IBIS II and Xetra sample, we match stocks according to their average daily trading volume over the sample periods, i.e. the two DAX stocks with the highest trading volume build the first stock pair, the second pair consists of the stocks with the second highest trading volume, and so on. We use Thompson clustered standard errors to test for differences in measures between IBIS II and the Xetra system and report the corresponding t-statistics and significance levels. 'a' denotes significance at the 1% level and 'b' at the 5% level.

<table>
<thead>
<tr>
<th>Trade Size Category</th>
<th>High Volume Stocks</th>
<th>Low Volume Stocks</th>
<th>t-stat.</th>
<th>t-stat.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IBIS II</td>
<td>Xetra</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>9.313</td>
<td>5.363</td>
<td>3.950</td>
<td>4.100</td>
</tr>
<tr>
<td></td>
<td>19.821</td>
<td>7.595</td>
<td>12.226</td>
<td>6.311</td>
</tr>
<tr>
<td>Quoted Spread</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>7.411</td>
<td>3.353</td>
<td>4.058</td>
<td>5.756</td>
</tr>
<tr>
<td>&lt; 4000</td>
<td>7.359</td>
<td>3.352</td>
<td>4.008</td>
<td>5.605</td>
</tr>
<tr>
<td>&gt;= 4000</td>
<td>6.419</td>
<td>4.346</td>
<td>2.073</td>
<td>4.505</td>
</tr>
<tr>
<td>Effective Spread</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>15.557</td>
<td>4.560</td>
<td>12.226</td>
<td>6.311</td>
</tr>
<tr>
<td>&lt; 4000</td>
<td>15.541</td>
<td>4.567</td>
<td>10.974</td>
<td>6.698</td>
</tr>
<tr>
<td>Realized Spread 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>0.362</td>
<td>1.163</td>
<td>-0.801</td>
<td>-3.261</td>
</tr>
<tr>
<td>&lt; 4000</td>
<td>0.595</td>
<td>1.174</td>
<td>-0.579</td>
<td>-2.369</td>
</tr>
<tr>
<td>&gt;= 4000</td>
<td>-0.393</td>
<td>1.017</td>
<td>-1.410</td>
<td>-2.723</td>
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<tr>
<td>Price Impact 5</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>7.090</td>
<td>2.235</td>
<td>4.855</td>
<td>7.765</td>
</tr>
<tr>
<td>&lt; 4000</td>
<td>6.804</td>
<td>2.223</td>
<td>4.581</td>
<td>6.900</td>
</tr>
<tr>
<td>&gt;= 4000</td>
<td>6.863</td>
<td>3.761</td>
<td>3.102</td>
<td>4.495</td>
</tr>
</tbody>
</table>

average trade sizes, which are in 2009 less than one seventh of the sizes they were in 1997.

This accounts for the small increase in turnover relative to the immense increase in the number of trades. The standard deviation is 67,479 Euros compared to 6,090 Euros, indicating that the main part of the order flow concentrates in the dimension of small orders. We conclude that the behavior of traders has dramatically changed within the time period between 1997 and 2009.

Market activity in general is reflected by quote updates, which occur with every cancellation of an order, a change of best bid, ask or volume, as well as the execution of an order over one or more levels in the order book. Quote updates have increased with the factor 65, from 654 updates to 43,300 updates.

A large proportion of these changes in activity can be attributed to recent technological developments like algorithmic trading and low latency networks. Today, large orders are often split into smaller ones in order to minimize their impact and to hide the trading strategy, as explained in section 2.2. This leads to more frequent and smaller trades.

Regarding the liquidity measures, we observe a decrease of up to 65 percent, from 11.34 bps to 3.94 bps for average effective spreads and from about 11.33 bps to around 5.18 bps in the case of average quoted spreads at trades, with smaller standard deviations and therefore a lower variability in the availability of liquidity. This increase in liquidity might be explained by higher competition between liquidity suppliers in the order book. On the other hand, depth has fallen quite sharply, from 151,261 to 31,579 Euros on average per day and instrument. However, this development can be explained by changes in trading behavior and strategies. As stated before, order sizes have decreased on average, thus we might infer smaller orders at the best bid and asks.

Our results imply that we have an improvement of liquidity in spread measures, but we do not see a definite improvement of the overall liquidity. Spreads
increase, implying a higher liquidity, depth on the other side decreases, implying a lower liquidity. Such results are also reflected in MiFID's best execution policy which requires intermediaries to consider multiple dimensions of market quality (see section 2.1).

The information content of trades, measured by the price impact, decreased between 1997 and 2009, with a simultaneous increase of realized spread. The results show that the price impact at the five minute mark decreases from 8.814 bps to in 1997 only 2.701 bps in 2009. As expected, information per trade decreases as a result of smaller order sizes and increased activity as shown in our descriptive results for market activity. However, in order to get more robust results and insight into the price discovery process, we need more sophisticated measures like trade- and quote-based information measures as developed in [8]. In order to test for the statistical significance of the differences, we apply robust Thompson clustered standard errors (cf. [20]). We split each sample into high and low volume stocks and test these categories individually. The results shown in Table 3 are statistically significant at the 1% level for quoted, effective and realized spreads and price impacts at the 5-minute mark. Individual trades have a larger price impact both in 1997 and 2009 for low volume stocks. Differences between trades of less than 4000 shares and more than 4000 shares are generally more pronounced on the Xetra system.

In conclusion, we can infer from the results of quantitative measures and qualitative aspects of our framework that certain aspects have tremendously changed. While the landscape of external factors, regulation, competition, and technology have necessarily changed due to the electronization of financial markets, the internal market structure has also been adopted, by providing higher transparency and focusing more on the needs of algorithmic and high frequency traders.

Overall, we find a significant increase in activity. Our liquidity results overall are inconclusive but effective spreads, actual transaction costs, have significantly decreased from 1997 to 2009. Per trade price impacts show an enormous decrease from the last version of IBIS II to the 2009 Xetra System. For the change of quantitative measures, we can give reasons from the qualitative factors of our market quality framework. The main reasons are the change of trading strategies and market participants, and the automation of the trading process.

4. Conclusion

In this paper, we develop a framework to assess the quality of electronic financial markets. Market quality is influenced by external factors and the internal market structure. We discuss quantitative measures to evaluate market quality in terms of activity, liquidity, and information. External factors are clustered into technology, regulation, and competition. These external factors directly influence the internal market structure which consists of business structure, IT systems, and market microstructure. The internal market structure again influences the market quality directly. With our framework, we provide a guideline for academics and practitioners to evaluate electronic financial markets. Since no universal measure for market quality exists, our framework includes multiple dimensions of market quality embedded in different interacting factors and measures which build a complete picture of the quality of an electronic market.

We apply our framework in a comparative case study to the two at their time predominant electronic market platforms in Germany, IBIS II in 1997 and Xetra in 2009. Our case study demonstrates an application of our market quality framework and additionally provides evidence on how the nature of electronic financial markets has changed over the last years. Our measures generally show that the overall market quality has increased. Despite the improvement of market quality, the implications of the technological change have also led to criticism. The use of low latency system makes it harder for human traders to compete on speed especially with high frequency strategies. This may also discriminate against smaller investors who do not have the immense resources necessary to invest into innovative trading systems. Regulators are also concerned about the destabilization of the market. One recent instance could be observed on May 6, 2010 during the flash crash. Although the causes are still unknown, investigators suspect the use of high frequency traders as one of them.

Further research includes the usage of more sophisticated measures, e.g. Hasbrouck information measures (cf. [8] and [9]) as introduced in Section 2.3. We also limited our work to quantifiable measures within one market. Further case studies can be conducted to compare different market structures and different external factors, e.g. in the spirit of [21], who made a comparative analysis of the Paris Bourse and the NYSE. In addition, the framework can be applied to different countries and markets that have different structures but trade the same instruments.
References


