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The impact of market fragmentation on European stock exchanges

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Abstract

MiFID has fostered competition between stock exchanges and alternative trading systems by removing the possibility for EU Member States to establish that equities must be traded only on regulated markets (so-called concentration rule). This paper empirically measures how market fragmentation is affecting the quality of blue chip's trading on European regulated markets. Our study evaluates the impact of fragmentation on liquidity, on information efficiency and on the price discovery process. We test the robustness of our results by applying a variety of empirical approaches. Our main findings are that fragmentation increases liquidity, but it reduces market efficiency. Moreover, primary exchanges tend to lose their leading role in the price discovery process of fragmented stocks. We show that our results are in line with some regulatory concerns which are leading to the review of MiFID.

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Contents

1 Introduction and main conclusions

MiFID has removed the so-called concentration rule, enhancing the development of new trading venues and, as a consequence, increasing the volume of trading outside primary stock exchanges. However, the debate on the effects of this phenomenon on market quality is still open. Indeed, on one side competition among trading venues can lead to more efficient and innovative services. On the other hand, the reduction of trading volume on each individual venue could make more difficult taking advantage of economies of scale and network externalities.

In Europe, the intensity of the fragmentation process has significantly increased since MiFID adoption. The share of trading on multilateral trading facilities (MTF) was approximately null at the beginning of 2008, while on February 2011 was equal to 18% of total turnover. The success of these alternative trading systems is due to several factors. First of all, trading commissions required by MTFs are significantly lower than traditional stock exchange's ones in particular for investors providing liquidity in the system. Moreover, multilateral trading facilities have adopted advanced technological facilities which reduce the latency, that is the average time between the transmission of an order and its execution. These characteristics of MTFs have attracted sophisticated investors like high frequency traders.

However, the impact of MiFID seems to have been less significant respect to what has been observed on the US market after Regulation National Market System (Reg NMS) adoption. This fact cannot be explained only on the basis of the differences between US and European market microstructures and it is mainly due to discrepancies in the ways in which NMS and MiFID regulate data consolidation and best execution.

After examining the evolution of fragmentation in Europe, we empirically analyse the impact of fragmentation on regulated markets. Main results are that fragmentation does not have negative effects on liquidity, but it reduces price information efficiency. Moreover, in some cases it leads primary stock exchanges to lose their leadership in the price discovery process.

These empirical evidences can be explained on the basis of some recent evolutions of market microstructure and some regulatory issues. In particular, the increase of liquidity could be due to the diffusion of high frequency trading which can have given rise to a trade creation phenomenon. The reduction of efficiency for highly fragmented stocks, instead, could be connected to imperfections in the consolidation process of pre-post trade information, in terms of costs and completeness of data. Moreover, high frequency trading could be driven by sophisticated strategies which tend to be correlated more with intra-day price dynamic than with fundamental values analysis. Lastly, the fact that stock exchanges tend to lose the leadership in the price discovery process for highly fragmented shares shed a new light on MTFs, which cannot be considered "passive" platforms that replicate trading price changes observed on stock exchanges.

The MiFID amendments proposed by the European Commission deals with many of the policy issues discussed in the paper. For example, the reduction in price information efficiency could be mitigated through the establishment of a mandatory consolidated tape and the adoption of measures for improving quality, format, cost and ability to consolidate market data. Moreover, a greater level playing field between regulated markets and MTFs seems appropriate, as these alternative trading systems have acquired a significant role in the financial markets and thus both competition issues and market surveillance issues need to be properly addressed. Lastly, the introduction of new safeguards for high frequency trading activities seems advisable.

The paper is structured in the following way. The first part (§2) analyses the main novelties introduced by MiFID (§2.1), the evolution of the level of fragmentation in Europe (§2.2) and the factors of success of the multilateral trading facilities (§2.3), making a comparison with the US market (§2.4). The second part (§3) proposes, on the basis of a review of the literature (§3.1) an empirical analysis which wants to measure the fragmentation impact on European blue chip's quality of trading on regulated markets.

2 MiFID and the rise in fragmentation of EU equities markets

2.1 The change in the regulatory framework after MiFID

MiFID has abolished the option for EU Member States to impose that equities must be traded on regulated markets only (so-called concentration rule), embracing the idea that competition between trading venues would bring greater advantages for investors and would foster financial integration of the European markets and would reduce transaction costs lowering issuer's funding cost[1].

The Directive recognized three types of trading venues: regulated markets, Multilateral Trading Facilities (MTF) and systematic internalizers. Transactions concluded away from regulated markets and MTF – either on systematic internalizers or elsewhere - can be considered as over-the-counter (OTC) trades.

Fragmentation of order flow can have negative effects on market liquidity and on the price discovery process. Thus, MiFID sets the basis for data consolidation, by requiring trading venues to give access to data on orders and quotations (pre-

1 Before MiFID, a strong difference was noted between transaction costs of domestic trades compared to cross-border intra-EU operations. According to a number of researches conducted during the last ten years [Giovannini Group (2001) and (2003), NERA Economic Consulting (2004), European Commission (2006a) and (2006b), Oxera (2009)], cross-border intra-UE transactions cost from 1,5 to 6 times more than domestic operations. The greater cost of cross-border transactions could hinder European issuers from raising funds in other EU countries. Some researches [London Economics (2002), European Commission (2006b)] showed that the EU GDP could increase from 0,2% to 1% if cross-border transactions would cost as the domestic ones; this increase in GDP would be achieved through the decrease in issuers' cost of capital.

trade transparency) and transactions (post-trade transparency) on a reasonable commercial basis.

Pre-trade transparency obligations are set differently according to the type of trading venue; thus, they are greater for regulated markets and MTF (even if some exemptions are allowed[2]) and they are lower for systematic internalizers; on the other side, pre-trade transparency obligations do not apply to OTC venues. Post-trade transparency rules change depending on the size of the transaction. Economic literature provides ground to transparency waivers, given the trade-off between transparency and liquidity supported by some strands of economic theory[3].

The Directive imposes a best execution rule, which requires intermediaries to send clients' orders to the trading venue where the best possible result (on a consistent basis) is obtained. For retail client, MiFID's best possible result must take into account the so-called 'total consideration' – which is the sum of transaction prices and execution costs. For professional clients, intermediaries have more choices in picking execution factors (like speed or likelihood of execution). Moreover, best execution rule can be implemented following either a 'static' or a 'dynamic' approach. The static approach involves picking ex ante the "best" trading venues and send there the clients' orders, reviewing periodically the execution quality of these venues. The dynamic approach requires usually the adoption of smart order routing systems which detect, in real time and for each order, the best trading venue[4].

Data consolidation and best execution rule are the primary tools to minimize the potential harmful effects of trading fragmentation on market liquidity and price discovery process and to boost competition between trading venues. Data consolidation allows the price discovery process to quickly incorporate information available on all trading venues, while the best execution rule drives liquidity to the most efficient trading venue.

However, after more than three years since the implementation of MiFID, industry was not able to realize an efficient and complete data consolidation system. Issues arise on information quality, costs[5] and completeness of consolidated data, as the European Commission pointed out in the course of MiFID review[6].

In this framework, European Commission proposed some important amendments to the current regulatory framework, like:

2 The so-called dark pools, which benefit from waivers granted by MiFID on pre-trade transparency, are included among exemptions. Generally, dark pools are price-taker MTFs; within these venues, transactions are closed at prices fixed in other trading venues – typically in primary stock exchanges.

3 See Lee (2002) for a review of economic literature on this topic.

4 According to Foucalt et al. (2008) and Grillet-Aubert (2010), a 'static' best execution approach could limit the flow of liquidity towards the new trading venues, undermining their competitiveness. On the other hands, the extreme heterogeneity and complexity of trading venues' fee structures could make difficult to detect, order by order, the best venue in term of total consideration. Moreover, Grob (2011) affirms that MiFID best execution rule grants intermediaries an higher flexibility compared to the approach followed by US NMS regulation.

5 CESR (2010a) and European Commission (2010) estimated that the access to consolidate data costs much more in Europe (€ 500 / month) than in the US market ($ 70 / month).

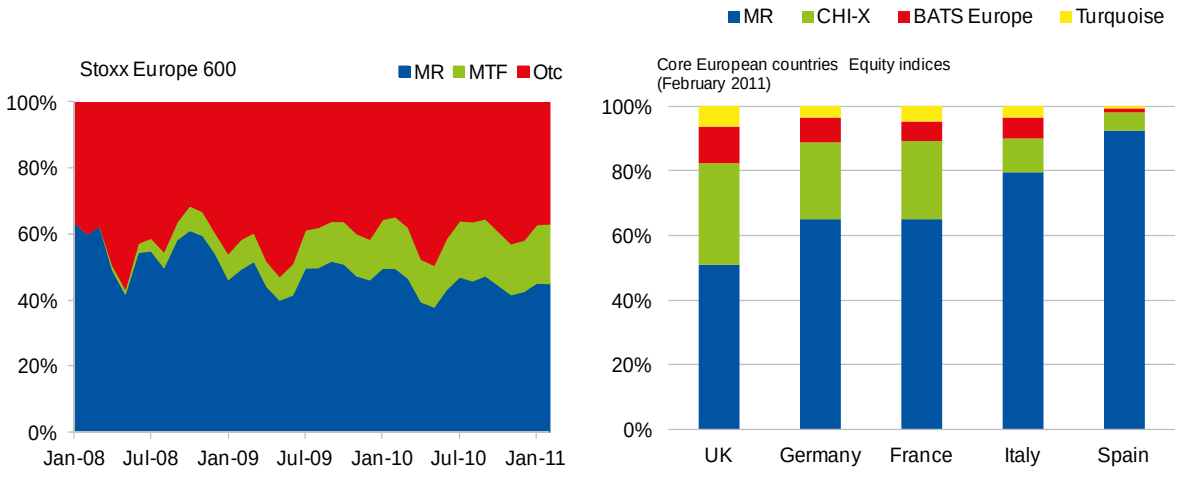
6 European Commission (2010).

- an harmonization in the organisational and market surveillance requirement of regulated markets and MTFs, in order to achieve a greater level playing field between these two types of trading venues;
- the introduction of new safeguards for high frequency trading activities and the requirement for venues to adopt appropriate risk controls to ensure the resiliency of their platforms;
- the establishment of a mandatory consolidated tape managed by authorized data providers, as well as measures for improving quality, format, cost and ability to consolidate market data.

2.2 A landscape of EU market fragmentation

In this section we analyse the evolution of trading fragmentation among regulated markets, MTFs and OTC trades for the 600 stocks constituents the Stoxx Europe 600 index[7] from January 2008 to February 2011. At the beginning, the market share of MTFs was nearly zero, while in February 2011 about 18%[8] of total turnover was traded on these new exchange platforms. At the opposite, regulated market's trading share has shrinked from 64% of total turnover in January 2008 to 45% in February 2011. Lastly, OTC trades accounted for about 40% of total turnover for all the period of time, although their market share seems to be quite volatile (Figure1).

Figure 1 Fragmentation of EU equities markets



Computations on Thomson Reuters data. The left-side figure represents the total turnover, traded on the stocks included in the Stoxx Europe 600 index, on a monthly basis from January 2008 till February 2011. The right-side figure shows the turnover on the shares included in the primary national equity indices (FTSE100, DAX30, CAC40, FTSEMIB, IBEX35); the trading activity taken into consideration refers to the primary regulated markets (LSE, Euronext, Deutsche Borse, Borsa Italiana, Bolsa de Madrid) and the three main European MTFs (Chi-X, Bats Trading, Turquoise).

7 The volume traded on these 600 stocks represents about 85% of total volume on European equities.

8 The 18% market share of MTFs includes a 2% related to dark pools.

OTC trades include transactions carried out by systematic internalizers or concluded on other venues not clearly defined under MiFID (like broker crossing network[9]). However, according to some surveys, the market share of these OTC venues should not be significant[10]. Part of OTC trades is also referable to wholesale transactions, carried out for various reasons (for example dividend arbitrage operations).

According to a 2011 AFME research, at least one half of OTC trades does not represent "real" transactions, but rather "duplication" of trades carried out on other trading venues. Reasons for this duplication could lie in some industry practices[11]. Obviously, this could bring to a sharp overestimation of OTC trades.

The increase in market fragmentation and the rise of MTFs' importance has not had the same intensity in all European countries and has been particularly significant above all in UK. Thus, it appears that MiFID impact has been conditioned by the specific characteristics of the various national financial systems. Grob (2011), for example, affirms that the level of dissatisfaction with the pre-MiFID situation was higher in UK, where many US broker firms have their European branches, than anywhere else; this dissatisfaction was due to trading fee and execution costs, which appeared to be higher in UK than in US. At the opposite, according to Grob, the low level of fragmentation in Spain could be caused by a rule which requires trades executed on MTFs to be registered on the primary Spanish stock exchange.

Rise in market fragmentation is also a consequence of IT improvements like the development of high frequency trading[12]; it appears that MTFs were able to propose to this kind of market participants better solutions than those offered by regulated markets. Generally speaking, MTFs were able to expand their market share by adopting sophisticated IT technologies and implementing aggressive fee policies, as it is better explained in the following paragraph.

2.3 The reasons for the success of MTFs

Chi-X, Turquoise and Bats Trading were the first MTFs to enter the market; they are also by now the alternative trading venues which appear to have achieved the greater success. These MTFs have adopted market microstructures similar to those of regulated markets, that are characterised by a visible or "light" order-book, by the

9 According to CESR (2010a), broker crossing networks are 'internal electronic matching systems operated by an investment firm that execute client orders against other clients orders or house account orders'.

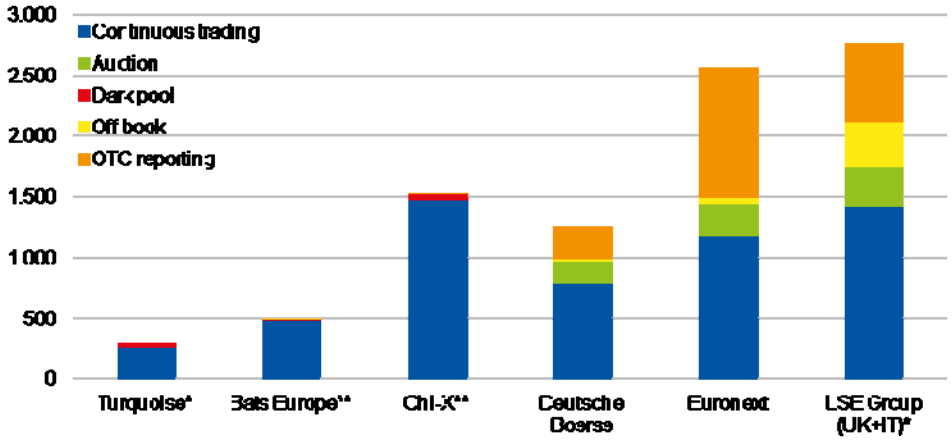
10 According to CESR (2010a), broker crossing networks held a 1% market share of total EU equities turnover in the period from 2008 till first quarter 2010. Systematic internalizers held a 2% market share of total EU equities turnover in 2009, according to FESE (2010), and their market share in 2010 was on the same level according to Grob (2011).

11 Like the so-called riskless principal, agency cross, and chain of transactions practices. For example riskless principal is a situation where an investment firm acts on its own account (on the primary market) and on behalf of a client (typically OTC) and simultaneously executes a buy (on the market) and a sell (OTC) transaction without any change in price. Although no risk arises for the investment firm, these practice create an OTC trade for each transaction carried out on the market. See CESR (2010b).

12 The use of computers in securities trading is not an innovation by itself. The novelty in high frequency trading lies in the use of innovative software and hardware architectures for creating, placing and modifying numbers of orders, without any human intervention, following trading strategies focused on very short timeframe (usually intraday).

absence of an auction phase, and by the presence of a central clearing counterparty. MTFs have tried to divert order flow from regulated markets by adopting lower fees and technologically advanced trading platforms. Moreover, MTFs offer trading on all the most-liquid EU equities, while regulated markets specialize in their "domestic" stocks[13]. This is the reason why the overall volume traded on the main MTFs is close to the turnover of the national regulated markets (Figure 2).

Figure 2 Turnover traded on primary EU trading venues
(2010, €billion)



Computations on Thomson Reuters data. Total turnover (€ billion) on Stoxx Europe 600 shares from January 2010 till December 2010. For 'off-book' we mean trades carried out away from the order book and according to special rules set up by trading venues; 'OTC-reporting' stands for transactions carried out over-the-counter and published by trading venue, which acts as reporting channel. (*) In December 2009 LSE Group announced the acquisition of a majority stake in Turquoise. (**) In February 2011 Bats Trading declared the acquisition of Chi-X.

Moreover, some MTFs decided to propose themselves as multi-service providers, for example by offering their customers the use of smart order routing softwares, which are able to catch the best trading opportunities[14].

Most MTFs adopted a 'make/take' fee structure. According to this type of fee structure, a market participant providing liquidity to the order book (so-called 'liquidity provider') will receive a rebate from the MTF; at the opposite, a market participant which absorbs liquidity (so-called 'liquidity taker') will pay fees to the MTF, which are, however, lower than the trading fees requested by regulated markets.

Table 1 shows the average fee levied by primary European MTFs and regulated markets[15]. The net trading fees collected by MTFs, calculated as the difference

13 European Commission recognizes that there are now greater opportunities for pan-European trading, as investors can trade on the most liquid shares across the EU by accessing only one venue. Given the success of alternative trading system, the main regulated markets have launched their own MTFs or have acquired existing ones.

14 This paper examines competition on secondary markets only. For competition issues on listing after MiFID, see Lazzari et al. (2011).

15 To set the average variable trading fee we made some hypothesis: we suppose to have an investment firm of small-medium size, with 21-30 traders, not acting in a market maker capability, which trade a total annual turnover of 16,5 €/billion, execute 1,1 million of trades for an average value of each trade of €15.000; we make the hypothesis that trading refers only to the most liquid equities (so-called blue chips), during the continuous trading session and without taking advantages of fee discounts offered by some venues for automatic orders. Therefore, we fall into DB's "high volume" fee scheme, Euronext's "Tier2" scheme, Borsa Italiana's "princing 2" and Bolsa de Madrid top pricing.It

between fees paid by liquidity takers and rebates granted to liquidity providers, are lower than the net trading fees levied by traditional regulated markets. In particular, MTFs' net trading fees are around 0,1 basis point of value of transaction, against an average of 1 bp for the primary regulated markets. Moreover, statistics reported in table 1 puts on evidence that all regulated markets adopt "traditional" fee structures, where liquidity providers and liquidity takers pay the same trading fees. However, given that regulated markets often apply lower fees when established thresholds of trading volume are exceeded, MTFs should have a greater competitive advantage for investors with lower trading activity.

Moreover, MTFs use technologically advanced trading platforms, which allow to minimize the so-called latency, namely the time between the transmission of an order and its execution. Recently, the average latency of the main MTFs has been gradually diminished and it has reached a scale of few milliseconds. Also main regulated markets have adopted advanced trading systems to not loose competitiveness respect the new trading venues[16].

It's clear that the race for latency mainly attracts high frequency traders. Profit opportunities for this kind of trading activities can, indeed, be significantly affected by differences in latency. At the opposite, if trading activity is human-driven, differences in latency of fractions of second are irrelevant compared to the overall time needed for placing an order.

Thus, MTFs base their competitive strategies on acquiring order flow of sophisticated investors and high frequency traders, offering advanced IT solutions and fees structures that award liquidity providers.

Table 1 Variable trading fee (basis point respect to the value of transaction) and fixed annual costs (€/thousand)

Trading venue	Liquidity taker	Liquidity provider	Net trading fee	Fixed annual costs
Chi-X	0.30	-0.20	0.10	0
Turquoise	0.28	-0.20	0.08	0
Bats Europe	0.28	-0.18	0.10	0-6.00
LSE	0.31	0.31	0.62	75.00
Deutsche Borse	0.48	0.48	0.96	28.00
Euronext	0.65	0.65	1.30	12.00
Borsa Italiana	0.40	0.40	0.80	177.00
Bolsa de Madrid	0.40	0.40	0.80	19.00

Source: trading venues' price list (November 2010); Chesini et al (2010).

must be pointed out that most regulated markets apply lower fees or grant discounts when the volume traded by the client exceeds established thresholds, but we do not consider such discounts or other special offers. There are other peculiarities of fee structures which makes this exercise even more complex: for example, DB applies different fee for automatic-generated orders, while Euronext diversifies trading fee according to the trading phase and the stock's level of liquidity.. Regarding annual fixed costs, the main component is usually the connectivity charge, which is greatly influenced by the number of links to the trading platform and their speed. Finally, we use the currency rate €/£ of 0,86675.

16 Primary MTFs and regulated markets now offer new services aimed at minimizing the latency, like co-location – which means allowing investment firms to locate their computers in close physical proximity to the trading platform's matching engine.

2.4 The US experience

The comparison among post-MiFID European situation and US market may help highlight the effects of different regulatory choices[17]. In 2005, the SEC enacted the Regulation National Market System (Reg-NMS), which has increased competition between the traditional stock exchanges and the new alternative trading venues[18]. However, main differences between Reg-NMS and MiFID are related to two crucial issues: data consolidation and best execution. On these topics, Reg-NMS provides for:

- the establishment of a central data consolidation system for pre and post trade transparency information, which is mandatory fed by the main trading venues; this system is managed by a consortium formed by the exchanges and the Financial Industry Regulatory Authority (FINRA); data fees requested by the consortium for accessing the consolidation system are subject to SEC's approval;
- a dynamic best execution rule, where only price of execution matters; according to this rule, marketable orders will receive at least the best price displayed in the data consolidation system; the rule also captures the amount of access fee for execution, so that quotations are quite comparable among trading venues[19].

Thus, Reg-NMS seems to apply, respect to MiFID, a more severe approach on data consolidation and best execution. The EU framework, as already mentioned, left data consolidation in the hands of the industry and allowed for a 'static' best execution approach based on many factors (price, costs, speed, etc.).

Since Reg-NMS introduction, NYSE market share has dropped from 79% of total trading volume in US listed equities in 2005 to 25% in 2009; also NASDAQ has experienced a decrease in market share, although less relevant than the NYSE one (Figure 3)[20].

In September 2009 the US equities market was highly fragmented, with 5 exchanges, which accounted for about 63,8% of total traded volume, 5 ECNs which executed about 10,8% of total volume, 32 dark pools with 7,9% of total volume, and more than 200 over-the-counter intermediaries which accounted for the remaining 17,5% of total volume[21].

Fragmentation was accompanied by a deep increase in total traded volume, which could be explained on the basis of both the 'trade creation' phenomenon and significant diffusion of high frequency traders (Figure 4)[22].

17 See among others Petrella (2010), Davies (2008), Lanoo (2007).

18 Alternative trading venues in the US landscape are ATSs, which can be further distinguished in ECNs and dark pools, and over-the-counter dealers. However, it should be noticed that before NMS entered into force there had been already a significant level of competition among trading venues in US. For example, in 1998 SEC estimated that ATS executed about 20% of trading volume on NASDAQ listed stocks.

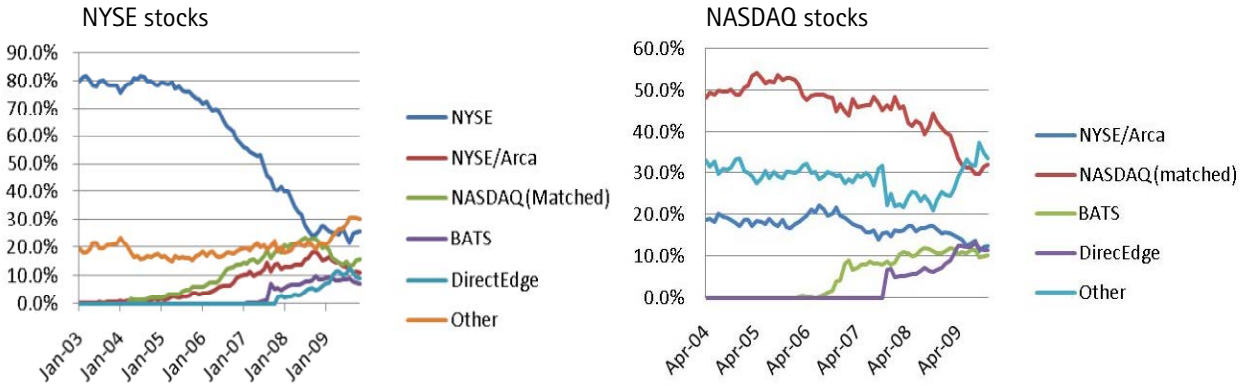
19 SEC requires trading venues to publish monthly statistics on execution quality and impose to intermediaries to make public information on their order transmission policy.

20 SEC (2010), Angel et al (2010).

21 SEC (2010).

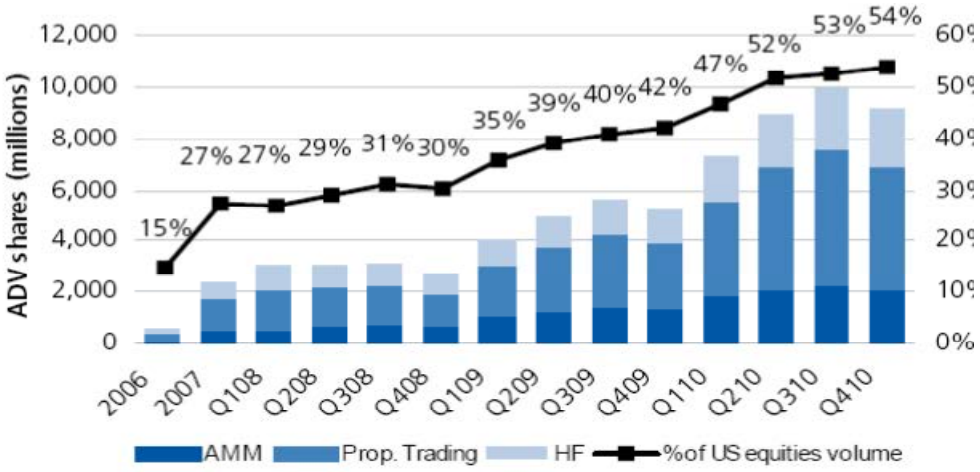
22 The relevance of high frequency trading phenomenon can be only indirectly estimated. However, Grillet-Aubert (2010) and SEC (2010) broadly agree on a 50% share of total US equities volume. Regarding the European market,

Figure 3 Market share in US listed equities trading



Source: Angel *et al.* (2010).

Figure 4 Share of equity trading volumes due to HFT flows in the US



Source: Grillet-Aubert (2010). The author tried to distinguish the high frequency traders between market makers (AMM), proprietary trading (Prop. Trading) and hedge funds (HF).

Sec has observed that, in order to attract high frequency traders, by 2009 also regulated markets had adopted advanced trading platforms, which minimize latency and had also embraced 'make/take' fee structures. In particular, NYSE has tried to recover the lost market share by adopting a better, automated trading system, and by acquiring one of its new competitors (Achipelago – Arca). The LSE, followed a similar strategy as well; by implementing a new trading platform (Millennium) and by acquiring Turquoise.

CESR (2010a) estimates that high frequency trading accounts for 13%-40% of total EU equities volume. According to Grob (2011), who makes reference to estimations from the Tabb Group, the market share of high frequency trading should be nearly 60% in the US and 40% on European markets.

An additional reason which helps explaining the greater level of trading fragmentation in the US respect to Europe lies in the different post-trading systems. In Europe (Petrella 2010, Grob 2011) a dozen of central counterparties are active, and everyone of them is linked to a specific trading venue. This means that an intermediary executing transactions on different trading venues needs to reconcile internally the clearing flows stemming from the various central counterparties; this brings to an increase in back office complexity and costs. At the opposite, in the US the low number of central counterparties has helped preventing the fragmentation of clearing flows.

3 Measuring fragmentation impact on stock exchange

Competition among trading venues can reasonably improve broker and institutional investor's operability because it brings down the average level of fees and because it enlarges exchange services offer. However, it is difficult to exactly quantify investor's net benefits because the spreading out of dark pools and high frequency trading could weaken market efficiency and could raise transparency issues (Sec, 2010).

Fragmentation's effect on the quality of trading is hardly predictable without doing an empirical analysis. Indeed, economic theory puts on evidence advantages and disadvantages of the competition among exchange platforms. Indeed, even if network externalities and economy of scale phenomena become less frequent, the efficiency of the services offered by exchange platforms can increase. At the same time, the efficiency of the price discovery process could take advantage of the competition among trading venues, but it could also be weakened by information asymmetry issues and opaqueness problems.

In this section, we will report the results of an empirical analysis which tries to measure the effects of fragmentation on: a) level of liquidity, b) price information efficiency, c) price discovery process. In particular, we will focus on how fragmentation affects the quality of trading on stock exchanges. Our research work begins with a review of the financial literature (§3.1); then we will describe the statistical indicators applied in the paper (§3.2). Lastly, after a brief description of our sample data-set (§3.3), results of the empirical analysis will be discussed (§3.4, §3.5, §3.6).

3.1 Review of the literature about market fragmentation's impact on stock exchanges

The impact of fragmentation on the quality of trading has been examined by several theoretical and empirical works. However, results reported in research works are not always consistent with each others.

Theoretical research papers try to establish how long-run equilibrium conditions varies with the level of competition among trading venues and with the wideness of exchange services offered. Pagano (1989) puts on evidence that, if the technological infrastructure does not vary among venues, investors tend to concentrate the trading on the biggest exchange platforms by taking advantage of economies of scale and of network externalities. Chowdry and Nanda (1991) show that competition among trading venues make more opaque the price discovery process and can lead to information asymmetries and adverse selection problems. Mendhelson(1987) and Madhavan (1995) argue that fragmentation could reduce liquidity, weaken information efficiency and increase volatility. Biais (1993) underlines, instead, that under transparency conditions, stock exchange's level of liquidity does not significantly change.

Some empirical studies put on evidence the negative effects of fragmentation. Bennett and Wei (2006), for example, find that bid-ask spread decreases for stocks which move from NASDAQ (market in which orders are highly fragmented) to NYSE (market in which orders are, instead, consolidated in only one trading book). Analogously, Sec (2001) demonstrates that liquidity is higher for stocks listed on NYSE than for NASDAQ shares. Lastly, some empirical studies (Cohen *et al.* 1982 and 1985; Porter and Thatcher 1998, Easley *et al.* 1996) find that fragmentation make more opaque the price discovery process and set back the application of best execution rules.

Other empirical research papers, instead, underline the positive effects of market fragmentation. Battalio (1997) shows, for example, that even if there are adverse selection problems, the level of market efficiency increases. De Fountnouvelle, Fishe and Harris (2003) and Myhew (2002) underline that liquidity of options is enhanced when the wideness of exchange platform's services is increased. Moreover, O'Hara and Ye (2011) put on evidence that fragmentation does not reduce liquidity and does not weaken market information efficiency. Pagano and Roell (1991) argue that the launch of Seaq International platform at the end of '80, did not lead to a reduction of trade volume on Borsa Italiana. Foucalt and Menkveld (2008) show that the competition between LSE-Eurosets and Euronext has had a positive effect on liquidity above all, because new technological infrastructures (like smart order routing) make easier the application of best execution rules.

Some recent research papers focuses on the impact of MiFID on the level of liquidity by considering the financial system as a whole. Much less attention is paid on changes of liquidity for specific categories of trading venues and in particular for stock exchanges (Grillet-Aubert, 2010 and Idier *et al.*, 2009). Both Gresse (2011), and Gomber *et al.* (2011) find that fragmentation has had mainly a positive effect on the average level of liquidity on European stock markets.

3.2 Indicators of fragmentation, liquidity and information efficiency

We compute the level of fragmentation as the inverse of the Herfindhal concentration index, that is for stock *i*:

$$F_i = \frac{1}{\sum_{j=1}^{N} q_{i,j}^2}$$

where $\boldsymbol{q_{i,j}}$ is the share of trading volume on exchange platform *j* for the share *i* [23] This indicator ranges from 1 (if the whole trading is concentrated on only 1 trading venue) and *N* (if trading is equidistributed among all the platforms). To compute F_i we take into consideration data of stock exchanges and of multilateral trading facilities with visible order books.

The liquidity indicators, which will be applied in the next sections, are standard measures which are frequently used in the literature of market microstructure[24]. A first indicator is given by the relative quoted spread (*RQS*), which is based on the spread between bid and ask and measures roundtrip transaction costs. That is for the share *i* and at time *t*, we have:

$$RQS_{i,t} = \frac{(ask_{i,t} - bid_{i,t})}{\frac{(bid_{i,t} + ask_{i,t})}{2}} * 100.$$

We compute *RQS* on a daily basis by applying two methodologies that rely on different types of data. Indeed, in a first case we use end of the trading day data and we carry on a long run analysis of liquidity. In a second case, we measure liquidity in a less approximate way by using infra-day data which, however, cover a time period of only 6 months, that is by computing the daily average of the 5-minute *RQS*:

$$\overline{RQS}_{i,t} = \frac{\sum_{m=1}^{M} RQS_{i,m}}{M}$$

where *M* is the number of *bid/ask* observations for the share *i* in the day *t*.

A second indicator of liquidity is, instead, given by the so-called *price impact* indicator *(PI)*, proposed by Amihud (2002), which is based on the ratio between daily return and trading volume, that is:

$$PI_{i,t} = \frac{|r_{i,t}|}{trading\ volume_{i,t}}$$

in which $r_{i,t}$ is the log-return $\left(r_{i,t} = log_e\left(\frac{P_{i,t}}{P_{i,t-1}}\right)\right)$. The rationale of this indicator is that if the level of liquidity is high, large trading orders should not lead to significant price changes.

23 For a description of this methodology see Fidessa Group plc.

24 For a review of the indicators most frequently applied in the literature see Grillet-Aubert (2010).

Lastly we compute the book depth (*D*):

$$D_{i,m} = \frac{ask_{i,t} + bid_{i,t}}{2} * \left(quantity\ ask_{\ i,m} + quantity\ bid_{i,m}\right)$$

where $quantity\ ask_{\ i,t}$ and $quantity\ bid_{i,t}$ are the quantities of stocks potentially available for trading corresponding to the best bid and the best ask observed in the minute *m*. The daily measure is the average of $D_{i,m}$[25] :

$$\overline{D}_{i,t} = \frac{\sum_{m=1}^{M} D_{i,m}}{M}.$$

As a consequence, a comparison among two trading venues A and B can be made by computing :

$$RD_{i,t} = \frac{\overline{D_{i,t}^{A}}}{\overline{D_{i,t}^{B}}}.$$

Lastly, to measure information efficiency, we apply two indicators which test the significance level of return serial correlation. Indeed, if markets are efficient, prices should be close to being a random walk and returns should not be serially autocorrelated (weak information efficiency). In particular, the *R²delay*[26] indicator is based on the estimation of the following two equations which respectively represent the restricted and extensive market model:

$$r_{i,t} = \alpha_i^R + \beta_i^R r_{m,t} + \varepsilon_{i,t}^1$$

$$r_{i,t} = \alpha_i^E + \beta_{i,0}^E r_{m,t} + \beta_{i,1}^E r_{m,t-1} + \beta_{i,2}^E r_{m,t-2} + \varepsilon_{i,t}^2$$

where r_i is the return of the share *i*, while r_m is the market return. The indicator (for the share *i* in the estimation period of time *k*) is given by

$$delay_{i,k} = 1 - \frac{R_R^2}{R_E^2}$$

where R_R^2 and R_E^2 are the coefficients of determination respectively of the restricted and the extensive market models. If return serial correlation was equal to zero, R_R^2 should be equal to R_E^2 and the indicator should be approximately equal to zero. As a consequence, if the indicator's value is higher, the level of return serial correlation is more significant (the level of information efficiency is lower)[27].

25 See Gresse (2011).

26 See Hou et al. (2005).

27 By construction, the coefficient of determination of the extensive model cannot be lower than the coefficient of determination of the restricted model and, then, $\frac{R_R^2}{R_E^2}$ must be less or equal to 1.

Lastly, the variance ratio indicator of Lo and Mac Kinley (1988) is computed on high frequency trading data

$$VR_{i,t} = \left| \left(\frac{var_{i,t}^{30\ minute}}{2 * var_{i,t}^{15\ minute}} \right) - 1 \right|$$

where $var_{i,t}^{30\ minute}$ is the 30 minute return variance, while $var_{i,t}^{15\ minute}$ is the 15 minute return variance. Under the hypothesis of market efficiency, this indicator should be close to zero, because if returns are not serially correlated, on the basis of the variance additivity rule, the 30 minute variance should be approximately equal to two times 15 minute variance.

3.3 Descriptive analysis of the sample

Empirical analysis has been carried on a sample composed of the 50 stocks included in the Stoxx Europe 50 index (see Tab. A.1 in the Annex).

Our analysis draws on several data sources:

a) Fidessa group plc (trading volume data aggregated on the basis of exchange platforms);

b) Thomson Reuters (end of the day trading prices, bid and ask quotations and trading volume);

c) Bloomberg (infra-day data-each 5 minute on prices and on the quantity of shares available for trading, corresponding to the best bid and ask).

We carry on a descriptive analysis by making a distinction among shares on the basis of the fragmentation level. We compute the quartiles of the distribution of F_i: the first quartile corresponds to a low level of fragmentation; the second quartile corresponds to a medium-low level of fragmentation, the third quartile to a medium-high level of fragmentation; the fourth quartile to a high level of fragmentation (see Table A in the Appendix). For each group of stocks, we compute the mean of the capitalization, trading volume and volatility.

Fragmentation level deeply varies among European primary regulated markets: it is on average higher for blue chips negotiated on the London Stock Exchange and approximately null on Bolsa de Madrid. Secondly, the level of fragmentation seems to be positively correlated with capitalization and negatively with trading volume and volatility (Fig.5). An increase of the uncertainty about trading prices probably leads investors to be more risk adverse and concentrate trading activity on the primary regulated markets. Indeed, since 2008 the fragmentation index has declined only during periods of market turbulence (Lehman and sovereign debt crisis; Figure 6).

Then, we examine the relationship between fragmentation and liquidity, by computing for each quartile of F_i average values of the relative quoted spread (*RQS*) and of the price impact indicator (*PI*; Figure 7). On the basis of *RQS*, fragmented stocks are at the same time the most liquid shares. However, the average value of the

price impact indicator seems not to significantly change among quartiles of F_i. Moreover, fragmented shares can be characterized by the highest values of relative quoted spread just because they are the most capitalized stocks in the sample. As a consequence, descriptive analysis is not able to give consistent results about the impact of competition among trading venues on the level of liquidity.

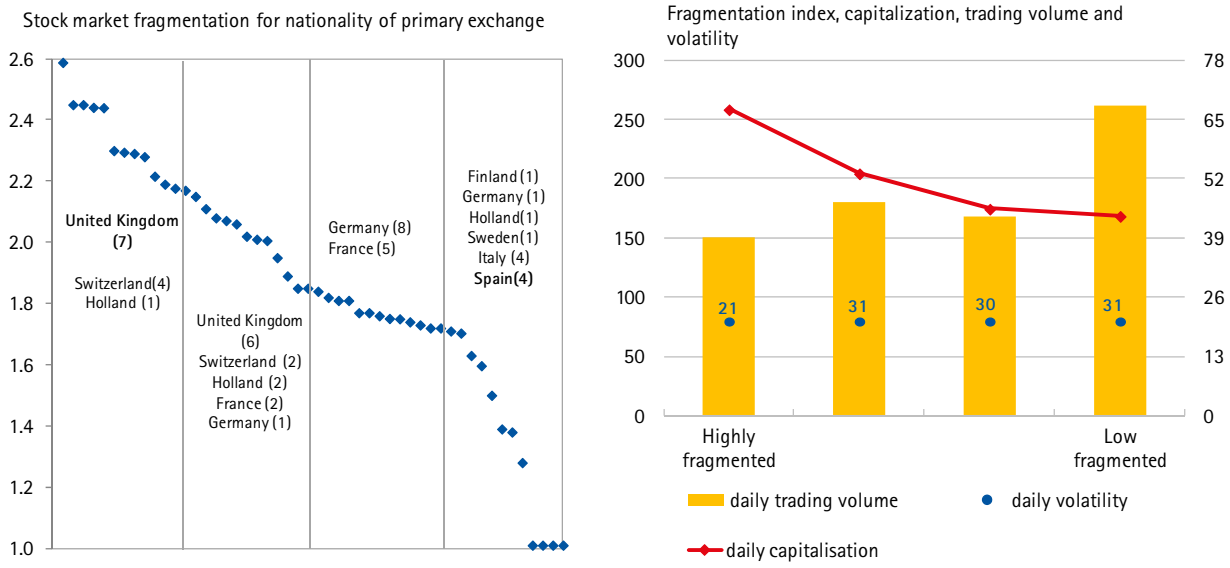
Lastly we compare primary stock exchanges and Chi-X (the most important European MTF) by taking into consideration infra-day data on prices and trading volume, in the period between September 2010 and February 2011 (Figure 8). Main result is that the level of liquidity is higher on primary stock exchanges respect to Chi-X on the basis both of bid-ask spread and book depth. This discrepancy, however, gradually decreases during the trading day.

In conclusion, the just illustrated descriptive analysis shows that:

a) the explicative variables of liquidity (capitalization, volatility, trading volume) are correlated with the level of fragmentation;

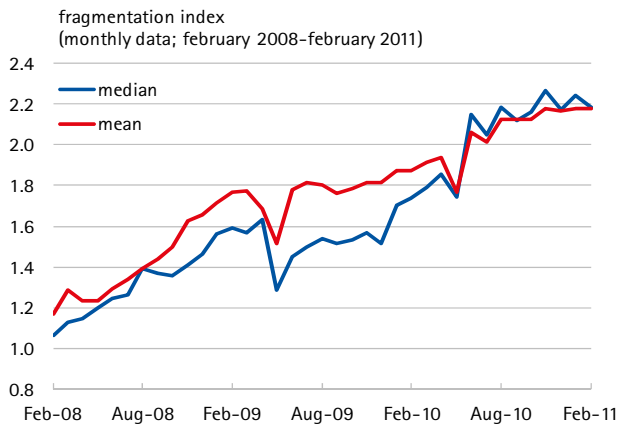
b) on average primary stock exchanges keep being more liquid than Chi-X.

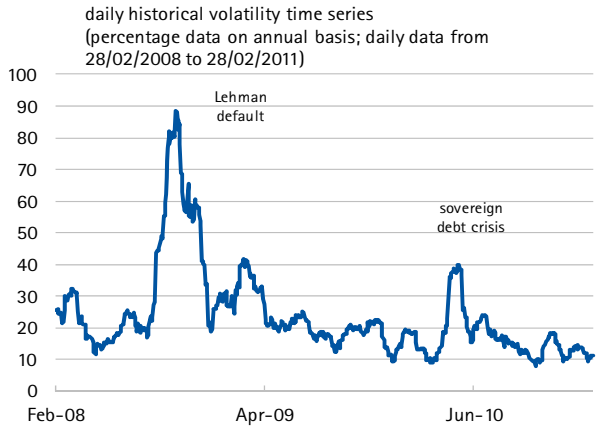
Figure 5 Market Fragmentation of the constituent shares of the Stoxx Europe 50 index
(average on the period between 31 May 2009 and 31 May 2010)



Computations on Thomson Financial Datastream and Fidessa Group plc. data between 31 May 2009 and 31 May 2010 . On the left side graph: the vertical grid represents the four quartiles of the fragmentation index's distribution; in parentheses the number of shares is reported. On the right graph the means (for each quartiles) of the median daily capitalization and of the median daily trading volume are reported; the volatility is expressed on an annual basis. The shares which belong to the group of the "highly fragmented shares" are included in the IV° quartile of the fragmentation index' s distribution; shares which belong to the group of the "low fragmented shares" are included in the I° quartile of the fragmentation index' s distribution.

Figure 6 Fragmentation and volatility



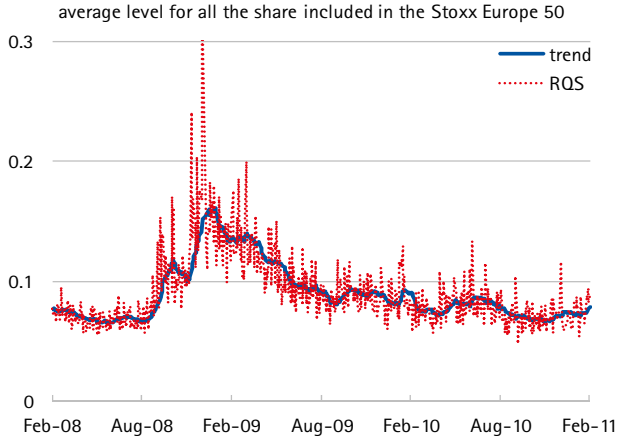


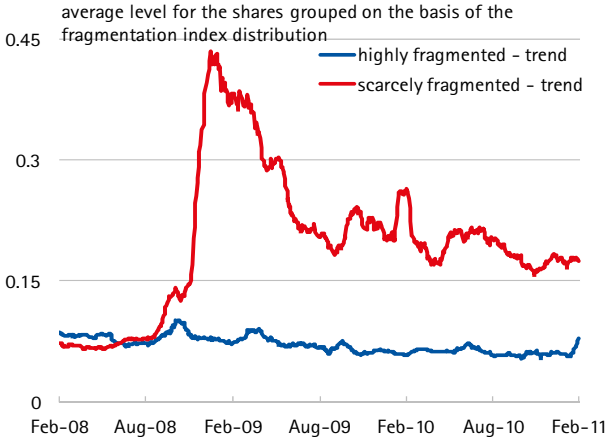
Computations on Thomson Financial Datastream data.

Figure 7 Fragmentation and liquidity

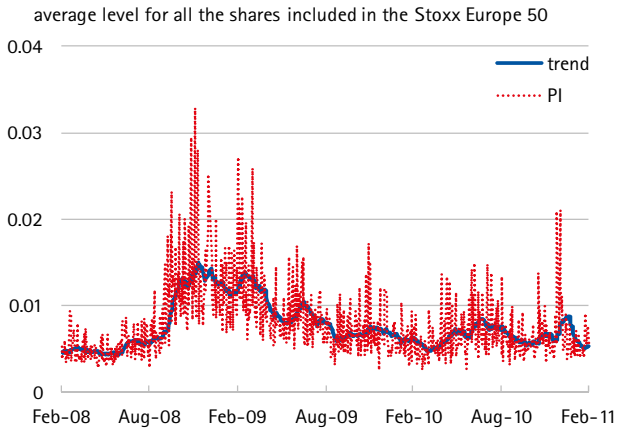
(daily data from 28/02/2008 to 28/02/2011)

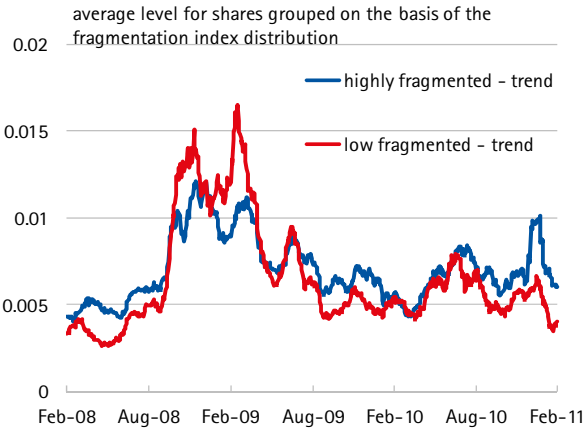
Relative quoted spread (%)





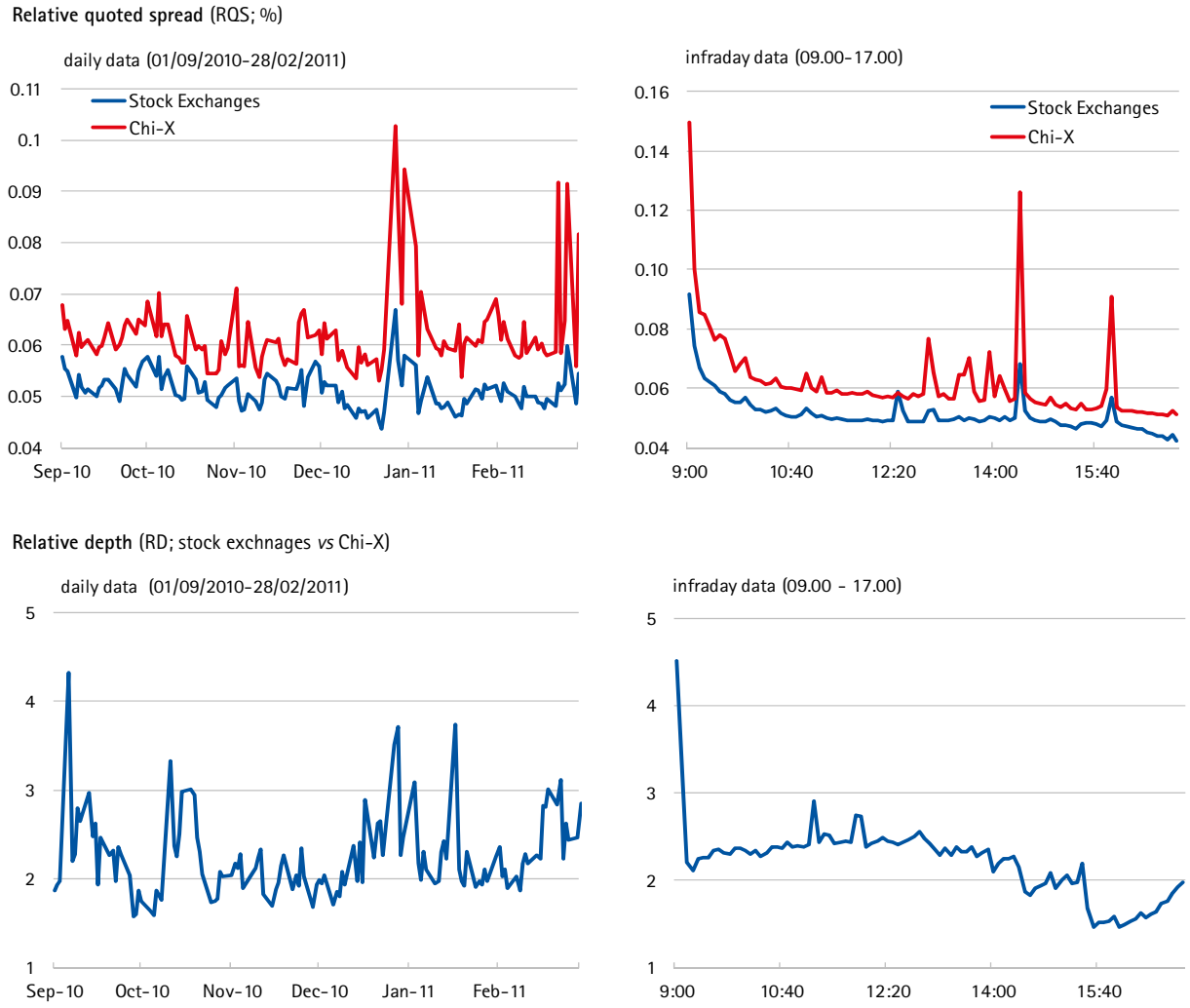
Price impact





Computations on Thomson Reuters data. The indicator of *price impact* has been multiplied by 10^8 (see. Hasbrouck, 2006). The *trend* has been computed as 20 day moving average. The aggregate indicator for each group of shares is computed as weighted average, with each share's weight given by the ratio between its capitalization and the whole capitalization of the group of stocks to which it belongs.

Figure 8 Comparison between primary exchanges and Chi-X liquidity levels



Computations on Bloomberg data. Indicators have been calculated on the basis of prices and quantities observed during stock exchange's continuous trading sessions (from 09.00 to 17.00). In Figure the sample mean of RQS and RD are reported.

3.4 Results of the empirical analysis

3.4.1 Market fragmentation's impact on liquidity

Measuring the impact of fragmentation on liquidity raises some issues on a methodological point of view. First of all, it is necessary to exactly identify the effect of market fragmentation without confusing it with shocks which can have had an impact on the financial system as a whole (i.e. sovereign debt crisis and Lehman default). Secondly, descriptive analysis puts on evidence that market fragmentation is an endogenous variable, because it is correlated with other explanatory variables of liquidity (capitalization, trading volume and volatility). Applying an econometric model, without taking into consideration this endogeneity problem, leads to biased and not reliable estimates of the coefficients. For example, highly capitalized stocks

generally have lower trading costs. If trading in such stocks is also more likely to fragment, then a finding of lower trading costs for fragmented stocks may be spurious due to the failure to control for firm size.

We try to overcome these problems and test the robustness of the results by taking into consideration a variety of empirical approaches. The first applied statistical technique consists of a comparison among fragmented and not fragmented stocks (so-called control sample) on the basis of "counterfactual" assumptions: if market fragmentation's impact was null, after MiFID the liquidity level of the control sample should have varied in the same way as the liquidity level of fragmented stocks.

One possible way to apply counterfactual logic assumptions is comparing changes in liquidity level within couples of shares which are similar in all the characteristics except for the level of fragmentation (matched sample technique; Davies and Kim 2008; O'Hara and Yee 2011). In our specific case, however, the level of fragmentation significantly varies among trading venues; in particular Spanish stocks are almost not fragmented, while English stocks tend to be significantly fragmented. As a consequence, matched sample techniques cannot be applied, because it is difficult to find several couples of not fragmented shares (i.e. Spanish stocks) and highly fragmented shares (i.e. English stocks) which are similar in all the characteristics (capitalization, trading volumes and volatility).

As a consequence, we decide to apply a statistical methodology called "difference in difference", which compares fragmented and not fragmented shares by taking into consideration also other discrepancies in terms of capitalization, trading volume and volatility. Indeed, the fragmentation's impact is implicitly measured by finding residual differences, between fragmented and not fragmented stocks, which are not due to dissimilarities in other characteristics.

The "difference and difference" method requires the detection of two groups of shares (fragmented and not fragmented) and of two periods of time (before and after the beginning of the fragmentation process). In particular, our control sample is composed of the first (for capitalization) 30 IBEX35 shares. The group of fragmented stocks, instead, includes the first (for capitalization) 30 FTSE100 shares. We compare both groups in two different periods of time: 2007 and 2010, that is first and after the beginning of the "market fragmentation process". Indeed, in 2007 also English blue chips could be considered as not fragmented.

Dependent variables of the model are the yearly average of the relative quoted spread and price impact indicators[28].These measures are computed by considering end of the trading day regulated market data ($RQS_{i,t}$ and $PI_{i,t}$). We include into the model the following explanatory variables: the capitalization, the volatility, the trading volume and two dummy variables which measure respectively the impact of 2007 each stock's conditions and of exogenous shocks. As a consequence, the effect of fragmentation is measured as the change in liquidity level which is related only to

28 See Meyer(1995) and Bertrand et al. (2003) for this kind of application in which a comparison is made between two cross-sections of yearly average values.

fragmented stocks and which is not due to variations of the other just mentioned explicative factors.

In Table 2 some descriptive statistics of the two groups of stocks (fragmented *vs* control sample) are reported and a comparison between 2007 and 2010 data has been made. The stocks included in the control sample are characterized by a lower level of liquidity, and, at the same time, are more volatile and less capitalized.

Table 2 Sample decriptive statistics – *difference in difference* method

	Relative Quoted Spread (%)	Price impact	Volatility (% annual basis)	Daily average of trading volume (mln. of euro)	Daily average of capitalisation (bln of euro)
2007					
Control sample	0.142	0.049	26.987	132.714	20.274
Fragmented stocks	0.112	0.007	25.399	309.263	54.870
2010					
Control sample	0.083	0.086	31.749	132.565	20.243
Fragmented stocks	0.061	0.018	26.987	301.284	54.287

In the Table annual average of the variable are reported. The price impact indicator has been multiplied by 10^8 (see Hasbrouck, 2006).

The applied econometric model is composed of the following equations:

$$RQS_{i,a}^{PE} = a_1 + b_1 market_{i,a} + c_1 period_{i,a} + d_1 market_{i,a} * period_{i,a} + e_1 X_{i,a}$$

$$PI_{i,a}^{PE} = a_2 + b_2 market_{i,a} + c_2 period_{i,a} + d_2 market_{i,a} * period_{i,a} + e_2 X_{i,a}$$

where:

a) a is equal to 2007 or to 2010;

b) $RQS_{i,a}^{PE}$ is the mean of $RQS_{i,t}^{PE}$ in the year a computed on primary stock exchange;

c) $PI_{i,a}^{PE}$ is the mean of PI_{it}^{PE} in the year a computed on primary stock exchange;

d) $market_{i,a}$ is a *dummy* variable which is equal to 1 if the share is fragmented (English stock) and 0 otherwise (Spanish stock - control sample);

e) $period_{i,a}$ is a *dummy* variable which is equal to 1 in 2010 and 0 in 2007;

f) $X_{i,a}$ is the vector of the mean of the explanatory variables (logarithm of daily capitalization, logarithm of stock exchange daily trading volume[29], daily volatility and the inverse of price[30]) in the year a.

The coefficient of the variable *market* measures the impact of the initial conditions, given that its value influences the level of liquidity only in 2007; the

29 We consider the component of trading volume which is not correlated with the capitalization (Gresse; 2011).

30 See Harris (1994).

dummy variable *period* can be considered, instead, as a *proxy* for exogenous shocks which have had an impact on the financial system as a whole. Lastly the interaction variable (*market * period*) is different from zero only for fragmented shares in 2010 (*market=1* and *period=1*). Therefore, the corresponding coefficient *d* is an implicit measure of the fragmentation effect, because it detects residual changes of fragmented stock's liquidity level which are not due to standard explicative variables of liquidity. As a consequence, *difference in difference* method overcomes the endogeneity problem because it does not require the introduction in the model of a proxy of the fragmentation's level.

Our results suggest that the *d* coefficient is not significantly different from zero in the equation of the relative quoted spread, while it is negative and significant in the price impact equation (Table 3). As a consequence, fragmentation seems not to have a negative impact on the level of liquidity. The effects of the other explanatory variables are in line with the economic theory: the level of liquidity increases with trading volume and with the capitalization, while diminishes with the volatility.

Table 3 Estimates of the "difference in difference" model – Impact of fragmentation on the liquidity level

	Relative Quoted Spread	Price impact
Market	0.017* (0.009)	0.007 (0.009)
Period	-0.088*** (0.012)	0,005 (0.009)
Market * Period	**0.005 (0.013)**	**-0.033*** (0.011)**
Volatility	0.166*** (0.036)	0.204*** (0.050)
Log(capitalization)	-0.029*** (0.003)	-0.028*** (0.003)
Log(trading volumes)	-0.026*** (0.008)	-0.037*** (0.006)
$(Price)^{-1}$	0.016 (0.015)	-0.009 (0.008)
Constant	0.766*** (0.084)	0.648*** (0.066)
R^2	0.700	0.749
N° observations	120	120

Estimates are obtained by applying OLS estimation method with a robust estimator of the variance and covariance matrix. In parenthesis standard errors of the estimates are reported: (***) corresponds to a 1% significance level, (*) corresponds to 10% significance level. Daily volatility is expressed on an annual basis.

We test the robustness of these results by applying also another approach, that is the Heckman correction[31] model. In this case, the dependent variables are $\overline{RQS}_{i,t}$ and $\overline{D}_{i,t}$, which are daily average of infraday data (see §3.2) and are less approximative liquidity measures, even if related to a more restricted period of time (from the 1st of September 2010 to the 28th of February 2011).

The Heckman correction model allows to overcome the endogeneity problem by explicitly estimating the relation between fragmentation and the other explicative variables. Indeed, the dependent variable of the first equation is the probability that shares are fragmented:

31 See O'Hara and Yee (2011) for an application of Heckman(1979) model on US data.

$$Prob(\text{share i is fragmented}) = (1 - q_{i,m}^{PE}) = \Phi(Z_{i,m}\gamma) =$$

$$= \Phi(\gamma_0 + \gamma_1 log(cap_{i,m}) + \gamma_2 log(volume_{i,m}) + \gamma_3 United\ Kingdom_{i,m} + \gamma_4 Spain_{i,m})$$

where $q_{i,m}^{PE}$ is the primary stock exchange market share in the month m for the stock i, Φ is the standard normal cumulative distribution function and $Z_{i,m}$ is the vector of monthly average of the liquidity's explanatory variables[32]. Moreover, "United Kingdom" is a dummy variable equal to 1 if the share is listed on the London Stock Exchange and 0 otherwise; lastly "Spain" is a dummy equal to 1 for all the listed shares on Bolsa de Madrid and 0 otherwise[33].

In line with O'Hara and Yee (2011), the first equations is estimated by applying the following linear regression[34]

$$\Phi^{-1}(1 - q_{i,m}^{PE}) = \gamma_0 + \gamma_1 log(cap_{i,m}) + \gamma_2 log(volume_{i,m}) + \gamma_3 United\ Kingdom_{i,m} + \gamma_4 Spain_{i,m}\ .$$

The estimate of the coefficient γ_1 is significant and positive: if the capitalization increases, the probability of market fragmentation increases as well (Table 4).

Table 4 Estimates of Heckman model- first equation (probability of a stock to be fragmented)

Cefficients	Estimates
γ_1 (logharitm of capitalization)	0.029** (0.015)
γ_2 (logharitm of trading volume)	-0.009* (0.005)
γ_3 (United Kingdom)	0.347*** (0.016)
γ_4 (Spain)	-1.627*** (0.019)
γ_0	-1.245*** (0.373)
R^2	0.931
N° observations	300

Estimates are obtained by applying OLS estimation method with a robust estimator of the variance and covariance matrix). In parenthesis *standard errors* of the estimates are reported: (***) corresponds to a 1% significance level, (*) corresponds to 10% significance level.

In the second equation of the model, the impact of fragmentation on liquidity is directly estimated:

$$\overline{RQS}_{i,m}^{PE} = \alpha_1\ (1 - q_{i,m}^{PE}) + \alpha_2 \sigma_{i,m} + \alpha_3 \hat{\lambda}_{i,m}$$

$$\overline{D}_{i,m}^{PE} = \beta_1\ (1 - q_{i,m}^{PE}) + \beta_2 \sigma_{i,m} + \beta_3 \hat{\lambda}_{i,m}$$

32 We consider the component of trading volume which is not correlated with the capitalization (Gresse; 2011).

33 On the basis of several estimation trials, the volatility coefficient is not significantly different from zero and for this reason the volatility has not be included in the set of explicative variables.

34 The direct application of the probit econometric model requires, indeed, that the dependent variable is dycotomic variable with only two values: one and zero. In this case, instead, the dependent variable is a market share.

where $\sigma_{i,m}$ is the monthly average volatility of stock exchange's trade price, while $\hat{\lambda}_{i,t} = \frac{\varphi(Z_{i,t}\hat{\gamma})}{\Phi(Z_{i,t}\hat{\gamma})}$ is the Mills *ratio* in which φ is the standard normal density function[35] and $Z_{i,m}$. is the vector of explicative variables already described in the previous equation. The Mills ratio is an adjusting factor explicitly put into the model to overcome the endogeneity problem of the fragmentation variable. Results of the estimation process are reported in Table 5. The signs of α_1 and β_1 coefficients put on evidence that an increase of the level of fragmentation leads to a reduction of the relative quoted spread and to an increase of the book depth.

Results reported in this section consistently show that fragmentation has a positive effect on liquidity, in line with O'Hara and Yee (2011). This result is coherent also with empirical evidences reported in other research papers applied on European data, which, however, focuses on the impact of fragmentation on the global level of liquidity in European stock markets (Gresse, 2011; Gober, 2011).

Table 5 Estimates of Heckman model– second equation (impact of fragmentation on the level of liquidity)

	Relative Quoted Spread (α)	Depth (β)
$(1 - q^{SE})$	**-0.035*** (0.008)**	**5.257*** (0.733)**
Volatility	0.001*** (0.000)	0.070*** (0.016)
Mills ratio	0.051*** (0.003)	-1.407*** (0.234)
R^2	0.890	0.454
N° observations	300	300

Estimates are obtained by applying OLS estimation method with a robust estimator of the variance and covariance matrix). In parenthesis *standard errors* of the estimates are reported: (***) corresponds to a 1% significance level. Daily volatility is expressed on an annual basis.

3.4.2 Market fragmentation's impact on information efficiency

Fragmentation's impact on price information efficiency has been measured by applying both econometric models described in the previous section.

In this case the application of the *difference in difference* method require the estimation of the following equations:

$$delay_{i,a} = a_2 + b_2 market_{i,a} + c_2 period_{i,a} + d_2 market_{i,a} * period_{i,a} + e_2 X_{i,a}$$

where the dependent variable $delay_{i,a}$ is the mean of $R^2 delay$ indicator computed for the share *i* in the year *a* (with *a=2007* or *a=2010*), while the explanatory variables are the ones already described in §3.4.

The Heckman correction model, instead, includes the following equations:

$$Prob(\text{share i is fragmented}) = (1 - q_{i,m}^{PE}) = \Phi(Z_{i,m}\gamma) =$$

$$= \Phi(\gamma_0 + \gamma_1 log(cap_{i,m}) + \gamma_2 log(volume_{i,m}) + \gamma_3 United\ Kingdom_{i,m} + \gamma_4 Spain_{i,m}) \quad (1)$$

35 Mills ratio allows to take into consideration first equation's estimates.

$$VR_{i,m}^{PE} = \theta_1 \left(1 - q_{i,m}^{PE}\right) + \theta_2 \sigma_{i,m} + \theta_3 \hat{\lambda}_{i,m} \qquad (2)$$

where the explanatory variable $VR_{i,m}^{PE}$ is the monthly average of the daily variance-ratio indicator (computed on primary exchange data), while the explanatory variables are the ones already described in §3.4. Our estimates suggest that market fragmentation has a negative effect on information efficiency. An increase of the fragmentation level, indeed, leads to a significant increase of both R^2*delay* and *variance ratio* given that the coefficients of (*market * period*) and $(1 - q_{i,m}^{PE})$ variables are both significant and positive (see Table 6 and Table 7).

Table 6 Difference in difference coefficient estimates – impact of fragmentation on information efficiency

	Estimates
Market	-0.040 (0.139)
Period	-0.180*** (0.046)
Market * Period	**0.165*** (0.047)**
Volatility	0.027 (0.165)
Log(capitalization)	-0.043 (0.034)
Log(trading volume)	-0.020 (0.026)
Constant	0.831* (0.494)
R^2	0.260
N° observations	300

Estimates are obtained by applying an OLS estimation method with a robust estimator of the variance and covariance matrix. In parenthesis coefficient estimates *standard errors* of the estimates are reported: (***) corresponds to a 1% significance level; (*) corresponds to a 10% significance level. Daily volatility is expressed on an annual basis.

Table 7 Estimates of Heckman model– second equation (impact of fragmentation on information efficiency)

	Estimates
$(\mathbf{1 - q^{PE}})$	**0.352*** (0.015)**
Volatility	0.000 (0.000)
Mills ratio	0.098*** (0.005)
R^2	0.973
N° observations	300

Estimates are obtained by applying an OLS estimation method with a robust estimator of the variance and covariance matrix. In parenthesis coefficient estimates *standard errors* of the estimates are reported: (***) corresponds to a 1% significance level; (*) corresponds to a 10% significance level. Daily volatility is expressed on an annual basis.

3.4.3 Market fragmentation's impact of fragmentation on the price discovery process

In this section we try to establish which is the role of stock exchanges in the price discovery process. We apply a statistical methodology based on specific economic hypotheses which are illustrated in Hasbrouck (1995). Main assumption is that,

at time *k* and for each share *i*, discrepancies between equilibrium efficient price and observed trade prices are temporary and should converge to zero in the long-run. More formally we have:

$$p_{i,k}^{PE} = p_{i,k}^{*} + s_{i,k}^{PE}$$

$$p_{i,k}^{ChiX} = p_{i,k}^{*} + s_{i,k}^{ChiX}$$

where $p_{i,k}^{*}$ is the unique efficient equilibrium price (which does not change with the trading venue) for the share *i* and the gap "*s*" is a stationary process which converges to zero in the long run. On the other hand, $p_{i,k}^{PE}$ and $p_{i,k}^{ChiX}$ are trade prices observed respectively on primary stock exchange and on Chi-X. The difference between observed trading prices is, then, a stationary process:

$$p_{i,k}^{PE} - p_{i,k}^{ChiX} = s_{i,k}^{PE} - s_{i,k}^{ChiX}.$$

As a consequence, on an econometric point of view, it is possible to say that the two price time series should be cointegrated (Engle and Granger, 1987). As a consequence, the *Vector Error Correction Model* (VECM) allows to estimate the cointegration relationship between trade prices through the following mathematical representation:

$$\Delta p_{i,k}^{PE} = \alpha_1 (p_{i,k-1}^{PE} - p_{i,k-1}^{ChiX}) + \sum_{j=1}^{J} \gamma_{i,j} \Delta p_{i,k-j}^{PE} + \sum_{j=1}^{J} \delta_{i,j} \Delta p_{i,k-j}^{ChiX}$$

$$\Delta p_{i,k}^{ChiX} = \alpha_2 (p_{i,k-1}^{PE} - p_{i,k-1}^{ChiX}) + \sum_{j=1}^{J} \zeta_{i,j} \Delta p_{i,k-j}^{PE} + \sum_{j=1}^{J} \eta_{i,j} \Delta p_{i,k-j}^{ChiX}$$

in which the trade price dynamic is characterized by the adjustment of the gap $p_{i,k}^{PE} - p_{i,k}^{ChiX}$, which is, indeed, an error, because in the long run trading prices, observed in two different platforms, should be both equal to the efficient price ($p_{i,k}^{*}$).

The two error coefficients α_1 and α_2, whose sum is equal to 1, are a quantitative measure of each trading venue's relevance in the price adjustment process. As a consequence, we try to establish which of the two platforms leads the other the basis of the Gonzalo-Granger statistic $\left(\frac{\alpha_2}{\alpha_2 - \alpha_1}\right)$. Indeed, if the Gonzalo-Granger statistic is bigger than 0.5, primary stock exchanges have a leading role in the price discovery process, in the sense that ChiX tends to simply react to price innovations observed on regulated markets. If, vice versa, the Gonzalo Granger statistic is less than 0.5, the adjustment process to the long-run equilibrium price is driven by ChiX.

The just described econometric methodology is weakened by some limitations. First of all, on Chi-X trades tend to be far less frequent respect to trades on primary stock exchanges (in particular for Spanish and Italian shares). Secondly, the application of VECM does not always allow to find the trading platform which has a leading role in the price discovery process. Indeed, when the Gonzalo Granger statistic is exactly equal to 0.5, it does not allow to establish which exchange platform

drives the price adjustment process. Moreover, the VECM can be applied only if the two trade-price time series are cointegrated. Otherwise, it is possible to use the *Granger causality test*, which in turn, however, is not always able to give an answer about the role of different venues in the price discovery process.

The just described statistical methodology has been applied on infra-day (each 5-minutes) trade-price observations starting from the 1st of September 2010 to the 28th of February 2011. Main result is that primary stock exchanges have a leading role in the price discovery process in 46% of the cases, while Chi-X in 32% of the cases (Table 8). In 22% of the cases, it is not possible to establish which of the two exchange platforms has a leading role. The 88% of the shares, for which Chi-X is the leading market, is characterized by a high or medium-high level of fragmentation. The 83% of the shares, for which primary stock exchanges has a leading role in the price discovery process, is, instead, characterized by a low or medium-low level of fragmentation. The empirical analysis illustrated in this section shows that regulated markets tend to lose their role in the price formation process above all when shares are highly fragmented.

Table 8 Price discovery model

Share	Market	Level of fragmentation	Time series cointegrated	Gonzalo Granger	Granger causality test	*Leading* SE	*Leading* Chi-X
Societè Generale	France	Medium low	yes	0.99	.	Yes	no
E on	Germany	Medium Low	yes	0.97	.	Yes	no
Allianz	Germany	Low	yes	0.96	.	Yes	no
Iberdrola	Spain	Low	yes	0.93	.	Yes	no
Banco Santander	Spain	Low	yes	0.93	.	Yes	no
Ing Groep	Holland	Low	yes	0.92	.	Yes	no
Bbv Argentaria	Spain	Low	yes	0.90	.	Yes	no
Arcelormittal	Holland	Medium High	yes	0.80	.	Yes	no
Telefonica	Spain	Low	yes	0.77	.	Yes	no
Basf	Germany	Medium Low	yes	0.71	.	Yes	no
Daimler	Germany	Medium Low	yes	0.67	.	Yes	no
Rwe	Germany	Medium Low	yes	0.66	.	Yes	no
Total	France	Medium high	yes	0.61	.	Yes	no
Bnp Paribas	France	Medium Low	yes	0.61	.	Yes	no
Axa	France	Medium Low	yes	0.60	.	Yes	no
Gdf Suez	France	Medium Low	yes	0.59	.	Yes	no
Generali	Italy	Low	yes	0.58		Yes	no
Ericcson	Sweden	Low	yes	0.55	.	Yes	no
Astrazeneca	United Kingdom	Medium high	yes	0.55	.	Yes	no
Siemens	Germany	Medium Low	yes	0.55	.	Yes	no
Unicredit	Italy	Low	yes	0.55	.	Yes	no
Credit Suisse	Switzerland	High	yes	0.54	.	Yes	no

Table 8

Share	Market	Level of fragmentation	Time series cointegrated	Gonzalo Granger	Granger causality test	*Leading* SE	*Leading* Chi-X
Hsbc	United Kingdom	Medium high	yes	0.54	.	Yes	no
Deutsche Bank	Germany	Medium Low	yes	0.54	.	Yes	no
Bp	United Kingdom	Medium high	yes	0.51	.	Not definable	Not definable
Rio Tinto	United Kingdom	Medium high	yes	0.51	.	Not definable	Not definable
Sap	Germany	Medium Low	yes	0.51	.	Not definable	Not definable
France Telecom	France	Medium high	yes	0.51	.	Not definable	Not definable
Barclays	United Kingdom	Medium high	yes	0.51	.	Not definable	Not definable
Intesa	Italy	Low	yes	0.50	.	Not definable	Not definable
Sanofi Aventis	France	Medium Low	no	.	Both causality relations are significant	Not definable	Not definable
British American Tobacco	United Kingdom	High	no	.	Both causality relations are significant	Not definable	Not definable
Eni	Italy	Low	no	.	Neither causality relation is significant	Not definable	Not definable
Royal Dutch Shell	United Kingdom	High	yes	0.48	.	No	yes
Glaxosmithkline	United Kingdom	High	yes	0.47	.	No	yes
Deutsche Telekom	Germany	Medium high	yes	0.47	.	No	yes
Tesco	United Kingdom	High	yes	0.46	.	No	yes
Ubs	Switzerland	Medium high	yes	0.45	.	No	yes
Nokia	Finland	Low	yes	0.45	.	No	yes
Anglo American	United Kigdom	Medium high	yes	0.44	.	No	yes
Novartis	Switzerland	Medium high	yes	0.44	.	No	yes
Bayer	Germany	Medium Low	yes	0.43	.	No	yes
Bg	United Kingdom	High	yes	0.43	.	No	yes
Nestlé	Switzerland	High	yes	0.39	.	No	yes
Diageo	United Kingdom	High	yes	0.39	.	No	yes
Unilever	Holland s	Medium high	yes	0.39	.	No	yes
Bhp Billiton	United Kingodm	High	yes	0.37	.	No	yes
Roche Holding	Switzerland	High	yes	0.36	.	No	yes
Vodafone	United Kingdom	High	yes	0.36	.	No	yes
Abbr	Switzerland	Medium high	yes	0.35	.	No	yes

VECM model has been applied on infra-day (5-minute) trade prices observed during continuous trading sessions (from 09:00 to 17:00). To verify the cointegration relationship the Johansen cointegration test has been applied at a significance level of 5%. The level of fragmentation has been estimated by computing the quartiles of the level of fragmentation index (see Tab. A.1 in the Appendix). In particular a share is characterised by a "high" level of fragmentation if it belongs to the IV° quartile of the fragmentation index distribution. by a "medium-high" level of fragmentation if it belongs to the III° quartile, by a "medium-low" level of fragmentation if it belongs to the II° quartile, "low" level of fragmentation if it belongs to the I° quartile. In the Granger causality test column "." means that the test has not been applied because the two trade-price time series are cointegrated.

4 Conclusions

MiFID has removed the so-called concentration rule, enhancing the development of new trading venues and, as a consequence, increasing the volume of trading outside primary stock exchanges. However, the debate on the effects of this phenomenon on market quality is still open. Indeed, on one side competition among trading venues can lead to more efficient and innovative services. On the other side, the reduction of trading volume on each individual venue reduces the opportunities to take advantage of economies of scale and network externalities.

In Europe, the intensity of the fragmentation process is significantly increased after MiFID adoption. The share of trading on multilateral trading facilities (MTF) was approximately null at the beginning of 2008, while on February 2011 was equal to 18% of total turnover. The success of MTF is due to several factors. First of all, trading commissions required by multilateral trading facilities are significantly lower than traditional stock exchange's ones in particular for investors providing liquidity in the system. Moreover, multilateral trading facilities have adopted advanced technological facilities which reduce the latency, that is the average time between the transmission of an order and its execution. These characteristics of MTFs have attracted sophisticated investors like high frequency traders.

However, the impact of MiFID has been less significant respect to what has been observed on the US market after Regulation National Market System adoption. This fact cannot be explained only on the basis of the differences between US and European market microstructures and is mainly due to discrepancies in the ways in which Reg- NMS and MiFID regulate data consolidation and best execution.

After examining the evolution of fragmentation in Europe, our research work empirically analyses the impact of fragmentation on liquidity, on market information efficiency and on the price discovery process. Main results are that fragmentation does not have negative effects on liquidity, but it seems to reduce price information efficiency. Moreover, in some cases it leads regulated markets to lose their leadership in the price discovery process.

These empirical evidences can be explained on the basis of some recent evolutions of market microstructure and some regulatory issues.

In particular, the increase of liquidity could be due to the diffusion of high frequency trading which can have given rise to a trade creation phenomenon. The reduction of efficiency for highly fragmented stocks, instead, could be connected to imperfections in the consolidation process of pre-post trade information, in terms of costs and completeness of data. Moreover, high frequency trading could be driven by sophisticated strategies which tend to be correlated more with intra-day price dynamic than with fundamental values analysis. Lastly, the fact that stock exchanges tend to lose the leadership in the price discovery process for highly fragmented shares shed a new light on MTFs, which cannot be considered "passive" platforms that replicate trading price changes observed on stock exchanges.

The MiFID amendments proposed by the European Commission deals with many of the policy issues discussed in the paper. For example, the reduction in price information efficiency could be mitigated through the establishment of a mandatory consolidated tape and the adoption of measures for improving quality, format, cost and ability to consolidate market data. Moreover, a greater level playing field between regulated markets and MTFs seems appropriate, as these alternative trading venues have acquired a considerable role in the financial markets and thus both competition issues and market surveillance ones need to be properly addressed. Lastly, the introduction of new safeguards for high frequency trading activities seems advisable.

References

Angel J.J., Harris L.E. e Spatt C.S., *Equity trading in the 21st century*, Marshall School of Business, working paper, 2010.

Afme, *The nature and scale of OTC Equity trading in Europe*, Discussion Paper, 2011.

Amihud, Y., *Illiquidity and stock returns: cross section and time-series effects*, Journal of Financial Markets, 5, 2002.

Battalio, R.H., *Third market broker-dealer competition or cream skimmers?*, Journal of Finance, 52, 1992.

Bennett, P. e Wei L., *Market structure, fragmentation, and market quality,* Journal of Financial Markets, 9, 2006.

Bertrand, M., Duflo, E. e Mullainathan, S., *How much should we trust in differences in differences estimates?*, mimeo, 2003.

Biais, B., *Price formation and equilibrium liquidity in fragmented and centralized markets*, Journal of Finance, 48, 1993.

CESR, *CESR Technical Advice to the European Commission in the Context of the MiFID Review and Responses to the European Commission Request for Additional Information, first set of CESR contributions,* Parigi, 2010a.

CESR, *CESR Technical Advice to the European Commission in the Context of the MiFID Review and Responses to the European Commission Request for Additional Information, second set of CESR contributions,* Parigi, 2010b.

Chesini G. e De Crescenzio V., *I servizi di trading e post-trading nell'Unione Europea: recenti evidenze empiriche*, Bancaria, 10, 2010.

Chowdry, B. e Nanda, V., *Multimarket trading and market liquidity,* Review of Financial Studies, 4, 1991.

Cohen, K.J., Maier, S.F., Schwartz, R.A. e Whitcomb, D.K., *An analysis of the economic justification for consolidation in a secondary security market*, Journal of Banking and Finance, 6, 1982.

Cohen, K.J., Conroy, R.M. e Maier, S.F., *Order flow and quality of the market.* In Amihud, Y., Ho, T., Schwartz, R. (Eds.), *Market Making and the changing structure of the securities industry*, Lexington Books, 1985.

European Commission, *Competition in EU securities trading and post trading*, Bruxelles, 2006a.

European Commission, *Economic impact study on clearing and settlement,* Bruxelles, 2006b.

European Commission, *Public consultation, Review of the Markets in Financial Instrument Directive*, Bruxelles, 2010.

Davies, R.J., *MiFID and a changing competitive landscape*, Babson College, mimeo, 2008.

Davies, R.J. e Kim, S.S., *Using matched samples to test for differences in trade execution costs,* Journal of Financial Markets, 2008.

De Fontnouvelle, P., Fishe, R.P.H. e Harris, J.H., *The behavior of bid-ask spreads and volume in options markets during the competition for listings in 1999*, Journal of Finance, 58, 2003.

Easley D., Kiefer N.M. e O'Hara, M., *Cream skimming or profit sharing? The curious role of purchased order flow*, Journal of Finance, 51, 1996.

Engle, R.F. e Granger, C.W.J., *Co-integration and error correction: representation, estimationand testing*, Econometrica, 55, 1987.

FESE, *FESE position on dark pools and broker crossing networks*, Bruxelles, 2010.

Foucalt, T. e Menkveld A., *Competition for order flow and smart order routing systems,* Journal of Finance, 63, 2008

Gomber, P., Gsell, M. e Lutat, M., *The quality of European equity markets after MiFID*, in Lazzari, V. (Ed.), Trends in the European Securities Industry; EGEA, Milano, 2011.

Gresse C., *Effects of the competition between multiple trading platforms on market liquidity: evidence from the MiFID experience*, mimeo, 2011.

Grillet-Aubert L., *Equity trading: a review of the economic literature for the use of market regulators*, AMF, mimeo, 2010.

Grob S., *The fragmentation of the European equity markets*, in Lazzari, V. (Ed.), Trends in the European Securities Industry; EGEA, Milano, 2011.

Harris L., *Minimum price variations, discrete bid-ask spreads and quotation sizes*, Review of Financial Studies, 7, 1994.

Hasbrouck, J., *One security, many markets: determining the contributions to price discovery*, Journal of Finance, 4, 1995.

Hasbrouck, J., *Trading costs and returns for US equities: estimating effective costs from daily data*, Stern School of Business New York University, mimeo, 2006.

Heckman, J., *Sample selection biases as a specification error,* Econometrica, 47, 1979.

Hou, K. e Moskowitz, T.J., *Market frictions, price delay, and the cross-section of expected returns*, Review of Financial Studies, 18, 2005.

Idier J., Jardet C., Le Fol G., *How liquid are markets: an application to stock markets*, Bankers, Market & Investors, 103, 2009.

Lanoo K., *MIFID and Reg NMS, A test-case for 'substituted compliance'?*, ECMI Policy Brief, 2007.

Lee, R., *Capital markets that benefit investors – A survey of the evidence on fragmentation, internalisation and market transparency*, Oxford Finance Group, 2002.

London Economics, *Quantification of the macro-economic impact of integration of EU financial markets,* Final report to the European Commission – Directorate general for the internal market, 2002.

Madhavan, A., *Consolidation, fragmentation and the disclosure of trading information*, Review of Financial Studies, 8, 1995.

Mayhew, A., *Competition, market structure and bid-ask spreads in stock option markets*, Journal of Finance, 57, 2002.

Mendelson, H., *Consolidation, fragmentation, and market performance,* Journal of Financial and Quantitative Analysis, 22, 1987.

Meyer, B., *Natural and quasi-natural experiments in economics*, Journal of Business and Economic Statistics, 12, 1995.

Nera Economic Consulting, *The direct costs of clearing and settlement: an EU-US comparison*, Corporation of London City research series, 1, 2004.

O'Hara, M. e Yee M., *Is market fragmentation harming market quality?*, Journal of Financial Economics, 100, 2011.

Oxera Consulting, *Monitoring prices, cost and volumes of trading and post trading activities*, Report for European Commission Dg Internal Market and Services, 2009.

Pagano, M., *Trading volume and asset liquidity*, Quarterly Journal of Economics, 104, 1989

Pagano M. e Roell A., *Dually-traded italian equities: London vs Milan,* CEPR Discussion Paper, 1991.

Pan, E.J., *A European solution to the regulation of cross-border markets*, Cardozo Legal paper, 2007.

Petrella G., *Il mercato azionario e il divieto di vendite allo scoperto*, Associazione per lo sviluppo degli studi di banca e borsa, mimeo, 2009.

Petrella G., *MiFID, Reg NMS and competiton across trading venues in Europe and the USA*, Journal of Financial Regulation and Compliance, 18, 2010.

Porter, D.C., Thatcher J.G., *Fragmentation, competition and limit orders: new evidence from interday spreads*, Quarterly Review of Economics and Finance, 38, 1998.

SEC, *Regulation of Exchanges*, *Concept release,* 1998.

SEC, *Concept Release on Equity Market Structure*, 2010.

SIRRI E., *Speech by SEC staff: Electric money: trading in the 21st century*, SEC, 2007.

Appendix

Table A Shares included in the Stoxx Europe 50 index ordered for level of fragmentation

Name	Stock exchange	Index of fragmentation	Median of daily capitalisation (bln euro)	Median of daily traded volume (mln euro)
IV° quartile (high level of fragmentation)				
Diageo	LSE	2.59	28.72	54.47
Bg group	LSE	2.45	42.19	87.61
Royal Dutch Shell A	Euronext Amsterdam	2.45	71.99	137.89
Nestlè	Six Swiss	2.44	117.21	232.77
British American Tobacco	LSE	2.44	43.96	76.80
Glaxosmithkline	LSE	2.30	71.50	120.38
Roche Holding	Six Swiss	2.29	78.11	183.03
Credit Suisse	Six Swiss	2.29	41.17	215.66
Vodafone	LSE	2.28	81.12	176.30
Novartis	Six Swiss	2.22	95.78	188.33
Bhp Billiton	LSE	2.19	45.53	204.81
Tesco	LSE	2.18	37.03	77.71
III° quartile				
Bp	LSE	2.17	120.22	205.12
Astrazeneca	LSE	2.15	46.63	115.98
Rio Tinto	LSE	2.11	52.92	229.69
Anglo American	LSE	2.08	35.78	144.24
Ubs	Six Swiss	2.07	39.15	181.38
Barclays	LSE	2.06	41.39	199.66
Hsbc hdg.	LSE	2.02	133.04	264.07
Unilever	Euronext Amsterdam	2.01	32.42	110.52
Abbr	Six Swiss	2.01	31.09	108.50
France Telecom	Euronext Paris	1.95	45.87	137.84
Total	Euronext Paris	1.89	97.80	257.48
Arcelormittal	Euronext Amsterdam	1.85	41.33	256.04
Deutsche Telekom	Deutsche Borse	1.85	41.21	156.14

Table A

Name	Stock exchange	Index of fragmentation	Median of daily capitalisation (bln euro)	Median of daily traded volume (mln euro)
II° quartile				
Sap	Deutsche Borse	1.84	40.67	134.94
Sanofi-Aventis	Euronext Paris	1.82	67.50	158.23
E on	Deutsche Borse	1.81	53.94	196.11
Siemens	Deutsche Borse	1.81	59.01	222.30
Basf	Deutsche Borse	1.77	36.98	153.44
Gdf Suez	Euronext Paris	1.77	63.67	113.63
Bayer	Deutsche Borse	1.76	39.91	156.45
Rwe	Deutsche Borse	1.75	32.76	121.30
Axa	Euronext Paris	1.75	35.54	118.84
Daimler	Deutsche Borse	1.74	35.91	182.64
Deutsche Bank	Deutsche Borse	1.73	30.61	274.48
Bnp Paribas	Euronext Paris	1.72	62.26	198.09
Societè Generale	Euronext Paris	1.72	32.27	155.44
I° quartile (low level of fragmentation)				
Nokia	Borsa di Helsinki	1.71	35.26	172.56
Allianz	Deutsche Borse	1.70	37.43	195.57
Ing Groep	Euronext Amsterdam	1.63	24.15	165.88
Ericcson	Borsa di Stoccolma	1.60	21.02	96.40
Intesa Sanpaolo	Borsa Italiana	1.50	33.40	180.25
Eni	Borsa Italiana	1.39	68.57	279.21
Generali	Borsa Italiana	1.38	26.33	100.29
Unicredit	Borsa Italiana	1.28	39.23	547.86
Banco Santander	Borsa di Madrid	1.01	84.14	524.90
Bbv.Argentaria	Borsa di Madrid	1.01	42.19	291.32
Iberdrola	Borsa di Madrid	1.01	32.87	161.05
Telefonica	Borsa di Madrid	1.01	81.78	424.23

Computations on Thomson Financial Datastream and Fidessa Fragmentation Group data. Quartiles are referred to fragmentation index's distribution. The sample is composed of the constituent shares of Stoxx Europe 50 index at the 31th May 2010. Fragmentation index is computed as the inverse of the Herfindhal concentration index on the basis of the exchange volumes observed between 31/05/2009 till 31/05/2010.