# Effects of Lit and Dark Trading Venue Competition on Liquidity: The MiFID Experience[♣]

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# Effects of Lit and Dark Trading Venue Competition on Liquidity: The MiFID Experience


## Abstract

Based on trade and quote data from eight exchanges and a trade reporting facility for a sample of LSE- and Euronext-listed equities, this article compares the consolidated liquidity of competing markets, also called global liquidity, and the local liquidity of the primary exchang, before and after MiFID. It then investigates how liquidity measured by spreads and best-quote depth relate to market fragmentation and internalization after MiFID. Market fragmentation is found to improve global and local liquidity, with spreads decreasing proportionally to market competition. The decline in depth observed in the early post-MiFID period is driven by other factors than market fragmentation. The only harmful effect is that fragmentation may reduce market depth for small stocks. Further, internalization is not found to be detrimental for liquidity.

## 1. Introduction

Security markets are often considered as natural monopolies because of the so-called virtuous circle of liquidity. Traders choose the market with the best liquidity, and the most liquid market is the one with the most participants because it offers the highest probability of order execution and the most competitive prices (Mendelson, 1987). As a result of "liquidity begetting liquidity", the market with the greatest number of traders should attract all other traders, so that the order flow should inevitably consolidate in a single market (Pagano, 1989). Nevertheless, today, equity trading is anything but consolidated.

There are several reasons why the market for a security may fragment: (1) multiple trading mechanisms exist on the primary exchange for the trading of the security; (2) the security is cross-listed and several exchanges compete for its order flow; (3) alternative trading platforms compete with the primary exchange; or (4) a portion of the order flow is internalized by broker-dealers or executed in the OTC market. With the development of sophisticated trading technologies and the enforcement of pro-competition market regulations, order flow fragmentation of type (3) has undeniably increased in all large western stock markets. More than fifty trading venues now exist in the US, with almost 30% of volume traded off primary exchanges in the first quarter of 2008 according to O'Hara and Ye (2011). In Europe, market fragmentation is a relatively more recent phenomenon. Nevertheless, more than ten trading venues have become fairly active in liquid European stocks during the past five years.

There is concern among regulators, issuers, and asset managers, about how this may impact the quality of order execution and market liquidity. Whereas competition between trading venues is most often considered as beneficial to the quality of order execution services offered to investors, there is little empirical evidence about the impact of order flow fragmentation on the consolidated liquidity of competing platforms. O'Hara and Ye (2011) have addressed the topic by analyzing the cross-section of 262 US stocks. Their comparison

of high and low fragmented stocks shows no harmful effect of fragmentation. Degryse, De Jong, and Van Kervel (2010) compare the primary market resiliency of Dutch large equities before and after fragmentation became substantial for those securities. They find that the order book of the primary exchange is more resilient in the fragmented period, in that it reverts quicker to its normal level of liquidity after aggressive orders. Degryse, De Jong, and Van Kervel (2011) evaluate the impact of fragmentation on depth for 52 Dutch stocks from 2006 to 2009. They find that fragmentation between lit order books improves the depth of the consolidated marketplace but reduces that of the primary exchange. They also find a detrimental effect of OTC and dark trading. The present article complements this literature by examining how the consolidated liquidity of competing trading systems, also called global liquidity, and the local liquidity of the primary exchange relate to fragmentation and internalization. The relation is investigated over a relatively large sample of equities listed at the London Stock Exchange and on Euronext, through two distinct empirical approaches that exploit not only the cross sections but also the time series of spreads, depth, and fragmentation measures.

A first approach consisted in comparing liquidity before and after the trading in European stocks fragmented with the implementation of the Markets in Financial Instruments Directive (MiFID)[1] on 1 November 2007. In Europe, the enforcement of MiFID abolished the concentration rule[2] in the countries of the European Economic Area (EEA), and has created a competitive environment for trading systems and services, in which new trading systems allowed by technological innovation may be widely exploited. As a result, MiFID has served as a catalyst for the soaring of competition between marketplaces, and the number of trading

[1] This European Union law provides a comprehensive and harmonized regulatory regime for investment services and activities across the 30 member states of the European Economic Area (EEA), i.e. the 27 member states of the European Union (EU) plus Norway, Iceland, and Liechtenstein.

[2] A provision in the 1993 Investment Services Directive (ISD) permitted (but did not mandate) individual member states to require orders from investors in that member state to be executed only on regulated markets. This provision was applied in France, Italy, and Spain.

venues at the disposal of investors has rapidly increased for European equities. In that, the implementation of MiFID is a unique event of shifting from consolidated markets to fragmented markets within a relatively short period of time, and this specific event makes it ideal for original research on fragmentation. The present study uses this event to provide empirical evidence on how market liquidity relates to order flow fragmentation. What makes the analysis somehow delicate is the simultaneity of the 2008 financial crisis with the immediate post-MiFID period. The observation periods and the methodology were thus carefully chosen so as to avoid the background effect of the 2008 subprime crisis and its related potential biases. In a second approach, I analyzed the two-way temporal relation between fragmentation and liquidity by a two-stage panel methodology over a later post-MiFID and post-crisis period. Results show that (1) spreads and depth have improved with multiple-trading-platforms competition after controlling for endogeneity; (2) fragmentation may nevertheless reduce depth for smaller stocks; (3) OTC and internalized trading has not substantially harmed liquidity; while it may adversely affect quoted spread on the one hand for some groups of stocks, it however favors depth on the other hand.

The remainder of the paper is organized as follows. Section 2 reviews the related literature. Section 3 provides details about the regulatory framework that motivated the study as well as on the organization of the marketplace. Section 4 describes the sample and the data. The fragmentation and liquidity measures used in the empirics are presented in Section 5. Section 6 provides comparative statistics about fragmentation and liquidity before and after MiFID came into force. In Section 7, a two-stage multivariate analysis is conducted to compare the liquidity of the pre-MiFID quasi-consolidated marketplace with that of post-MiFID fragmented markets. Section 8 exposes panel analyses of the relation between fragmentation and liquidity in the post-MiFID fragmented markets. Section 9 concludes.

## 2. Pros and cons of multi-market trading: A review of the literature

Whether order flow fragmentation adversely affects market quality has already been addressed in numerous research articles. The earliest work usually quoted in this body of literature is that of Hamilton (1979) who studied the effects of off-board trading of NYSE-listed stocks on the regional exchanges and in the third market. Hamilton (1979) documents two opposite effects: on the one hand, the dispersion of trading may increase competition and thus improve liquidity (competition effect); on the other hand, it may "prevent full realization of any economies of centralized trading on the exchange" (fragmentation effect).

### *2.1. Benefits of market consolidation and fragmentation effects*

Security market centers are often considered as natural monopolies because the marginal cost of a trade decreases with the quantity of orders executed in the market. First, a great part of the costs born to run a market are fixed expenses, so that a consolidated market enjoys economies of scale. If several markets that use the same technology and market model compete together, the one with the highest volume has the lowest average cost, and thereby enjoys a competitive advantage.

Second, there are network externalities associated with running a market. A market becomes more attractive as the number of traders increases. It is easier to find a counterparty in a market where there are more people willing to trade, so that the consolidation of the order flow creates economies of scale on the provision of liquidity (Mendelson, 1987). Pagano (1989) shows that, when a security trades in two markets with similar structures and types of investors, orders concentrate in the market where traders are foreseen to be more numerous.

Third, under information asymmetry, Chowdry and Nanda (1991) show that adverse selection costs increase with the number of markets listing an asset. Besides, when a new market opens for a stock, it may skim the least informed and consequently more profitable orders, and then harm the liquidity of the primary market (Easley, Kiefer, and O'Hara, 1996;

Bessembinder and Kaufman, 1997). In practice, dealers or market makers are the most able to cream-skim profitable orders, and market fragmentation between competing dealers usually result in larger spreads (for theoretical proofs see the inventory-cost model by Biais (1993) or the information-based model by Madhavan (1995)). Empirically, Bennett and Wei (2006) provide evidence that stocks switching from a fragmented environment (the old Nasdaq structure) to a more consolidated structure (NYSE) experience an improvement in spreads. Using European data, Gajewski and Gresse (2007) show that trading costs are smaller in a centralized order book than in a hybrid market equally fragmented between an order book and competing dealers off the order book.

Fourth, another cost of fragmentation is that priority rules are difficult to maintain across markets. In particular, price priority can be violated when large orders in one market trade through prices in another market (see Foucault and Menkveld, 2008; Riordan, Storkenmaier, and Wagener, 2010).

*2.2. Benefits of multi-market trading and competition effects*

Because of the positive network externality that characterizes markets, trading systems with identical structures have a natural tendency to consolidate, as shown in Pagano (1989). Therefore, fragmentation often arises between trading systems that use different mechanisms and thereby addresses the needs of different categories of investors (Harris, 1993). The ability to serve different clienteles and satisfy diverse trading needs is a benefit of fragmentation (Hendershott and Mendelson, 2000; Gresse, 2006).

Another positive effect stemming from fragmentation is that monopolistic exchanges may behave noncompetitively and accumulate rents at the expenses of final investors while fragmentation between competing markets often promotes innovation and efficiency. As mentioned by Stoll (2003), “The term “fragmentation” has a harmful connotation, but, in fact, fragmentation is just another word for competition.”. In the 90s, SEAQ International, an

order-driven market segment of the LSE, was competing with the continental European exchanges for the trading of blue chips stocks. It succeeded in diverting block trading from the primary exchanges, but progressively disappeared after continental exchanges and, in particular, the Paris Bourse, implemented block trading procedures in the home market. More recently, Euronext reduced tick sizes on 19 February 2007 and, in September 2008, the LSE adopted a maker-taker fee schedule to remain competitive in front of emerging MTFs. In the US, the development of electronic trading on established exchanges was spurred by competitive pressures. In October 2002, in response to the pressure of ECNs, Nasdaq launched SuperMontage, an electronic trading platform gathering quotes from market makers and ECNs. In October 2006, the NYSE started to introduce its Hybrid market to enhance electronic trading (cf. Hendershott and Moulton, 2008).

With competition between market places, spreads often narrow. Battalio (1997) shows that the bid-ask spreads of NYSE-listed securities tightens after a major third market broker-dealer starts operating. Boehmer and Boehmer (2003) document that the NYSE entry in the trading of ETFs listed on the American Stock Exchange improves their liquidity. By examining the entries of multiple markets into transacting three major US ETFs, Nguyen, Van Ness, and Van Ness (2007) show that the competition effect dominates the fragmentation effect. Mayhew (2002) and Fontnouvelle, Fishe, and Harris (2003) finds that multi-market trading has the same consequences for the bid-ask spreads of equity options. With respect to European markets, Lee (2002) reviews several empirical studies conducted on the competition between SEAQ International and various continental European exchanges in the 90s. He concludes that most of the measures of market performance show that such competition was beneficial. Competition from new entrants has similar effects. The findings of Huang (2002) suggest that the proliferation of alternative trading venues, such as ECNs, has promoted order execution quality rather than fragmenting markets. O'Hara and Ye (2011) analyze the cross-

section of a large sample of Nasdaq and NYSE listed equities and show that fragmentation between incumbent exchanges and new trading platforms has reduced transaction costs and increased execution speed. Furthermore, competition between order books may have specific features. Foucault and Menkveld (2008) focus on the recent competition between EuroSETS, the order book run by the LSE for Dutch stocks, and NSC, the order-driven system of Euronext Amsterdam. They show, both theoretically and empirically, that, due to the absence of price priority across markets, consolidated depth (i.e. the sum of all shares available at that price or better in both markets) is larger after EuroSETS entry.

## 3. Regulatory framework, stock universe, and market organization

Since 1 November 2007, MiFID has recognized three types of order execution venues: Regulated Markets (RMs), Multilateral Trading Facilities (MTFs), and Systematic Internalizers (SIs). RMs and MTFs are multilateral trading systems with similar functionalities but they differ in that RMs have to be authorized by a competent authority. Both RMs and MTFs may organize primary listings, but securities with a primary listing on a MTF are not considered as regulated instruments. SIs are investment firms which, "on an organized, frequent and systematic basis," execute client orders outside a regulated market or an MTF, either on their principal accounts or against other clients' orders. Legally, a SI does not have to be designated by a regulated market, and an institution can be a SI for securities listed on different stock exchanges. Creating the legal status of SIs institutionalizes internalization. In counterpart, MiFID treats SIs as mini-exchanges and imposes pre-trade and post-trade transparency requirements on them.[3] In addition, under the post-trade transparency rules introduced by MiFID, all transactions in regulated financial instruments must be reported, even if they are carried out over the counter (OTC). Such disclosures do not

[3] The same pre- and post-trade transparency requirements apply to all venues except dark pools, that is MTFs which trading mechanisms do not generate price discovery and are exempt from pre-trade transparency rules.

have to be made to the regulated primary market; they may be made using proprietary resources or submitted to a MiFID-compliant trade reporting facility (TRF).

Main RMs are run by three exchange groups – Deutsche Boerse, LSE-Borsa Italiana and NYSE-Euronext. They are challenged by a handful of pan-European MTFs that emerged in 2007 and 2008: BATS Europe, the subsidiary of US exchange BATS; Chi-X, owned by broker Instinet at the time of the study and now taken over by BATS; Turquoise, which was launched by a consortium of investment banks and then acquired by the LSE; and Nasdaq OMX Europe, which belonged to the Nasdaq OMX group and then closed on 21 May 2010. Further, PLUS-Markets, a new UK exchange often called PLUS, operates as an RM for small caps and as an MTF for European securities. The legislation on transaction reporting introduced by MiFID also led to the creation of several TRFs that offer MiFID-compliant services. The largest of these by market share is the BOAT platform of Markit, a financial information provider. Table 1 charts the key events in the development of Europe's RMs, MTFs and TRFs.

**Table 1 about here**

MiFID changed the European trading industry in three key ways:[4]

- it abolished the concentration rule which existed on most continental exchanges, such as the European branches of Nyse-Euronext, and forced any regulated trade to be executed on the primary exchange;
- it offered a regulatory framework for internalization;
- it extended post-trade transparency duties to OTC trades in regulated securities and allowed entities other than primary exchanges to report trades, which resulted in a fragmentation of the trade reporting activity.

[4] For details and comparison with RegNMS, the US counterpart of MiFID, refer to Davies (2008) and Petrella (2009).

Those regulatory changes combined with the rise of high frequency trading allowed European stock markets to shift from quasi-consolidated markets to fragmented markets within a relatively short period of time. This changing environment offers a perfect field of investigation on how rapidly market competition can rise after regulatory changes and how liquidity is affected in relation. I use this event to test the impact of market fragmentation on the liquidity of three stock indices: the FTSE 100, the CAC 40, and the SBF 120. The FTSE 100 is comprised of the largest capitalization stocks of the LSE. The CAC 40 is the flagship index of Euronext Paris and comprises the largest stocks of Euronext Paris as well as some large capitalization stocks primarily listed on Euronext Amsterdam and Euronext Brussels. The SBF 120 index comprises the CAC-40 stocks plus the next eighty most liquid stocks listed on Euronext Paris. In the rest of the paper I use the SBF 120 acronym to designate the non-CAC-40 components of this index. Studying FTSE-100 and CAC-40 securities will allow me to compare stocks for which there was a concentration rule before MiFID (CAC 40) with stocks that had no concentration rule prior to MiFID (FTSE 100). Comparing the SBF-120 and the CAC-40 stocks will allow me to examine whether order flow fragmentation affects middle capitalizations stocks differently.

*3.1. Market design of primary exchanges*

FTSE-100, CAC-40, and SBF-120 stocks have their primary listings on four exchanges recognized as RMs: the LSE, Euronext Amsterdam, Euronext Paris, and Euronext Brussels. Those exchanges run electronic order books on which buy and sell orders are continuously matched from the open to the close according to the price/time priority rules. Trading sessions commence and finish with call auctions. Until 14 January 2009, the order books of Euronext, the European branch of Nyse-Euronext, operated with the NSC system. After that date, the UTP system was introduced. On the LSE, the order-driven trading platform used for FTSE-100 securities has been SETS since 1997.

On both the LSE and Euronext, off-order-book trading is permitted but with different rules and practices. At the LSE, an important dealership activity has always existed simultaneous to order book trading since its introduction in 1997 (cf. Gajewski and Gresse, 2007). Broker-dealers execute a significant part of the order flow outside the book and the majority of retail orders are routed to dealers specialized in retail trading, the so-called RSPs. Off order book trading is less developed on Euronext, where the order book market model has prevailed for a long time, and where concentration rules existed before the implementation of MiFID. Only two categories of trades are executed outside the central order book: block and VWAP trades.

*3.2. Other trading venues*

The most active MTFs at the time of the study are Chi-X, BATS Europe, Turquoise, and Nasdaq OMX Europe. They run order-driven matching engines in which anonymous orders are matched continuously in time-price priority. No call auctions are organized either at the open or at the close. Their business model is based on a make/take fee structure that remunerates liquidity-providing orders and charges aggressive orders. In addition, PLUS, a London-based quote-driven electronic platform, offers an execution venue for securities listed elsewhere in London and in continental Europe, in addition of those primarily listed on PLUS.

The list of stocks traded on PLUS covers more than 850 liquid securities including FTSE-100 stocks and other European blue chip stocks. On the PLUS platform, competing market makers display two-way quotes in a minimum size known as the Exchange Market Size, during the Mandatory Quote Period (MQP), i.e. from 8:00 to 16:30 UK time.

## 4. Sample selection and data

My empirical work consists of two parts: a pre/post-MiFID comparison and a post-MiFID time series analysis. Both parts are based on trade and quote data generously provided by IFS for FTSE-100, CAC-40, and SBF-120 stocks.

### *4.1. Sample selection*

In the pre-post MiFID comparison, the pre-MiFID period of October 2007 is confronted to three post-MiFID one-month periods. These periods were determined so as to sidestep the effects of the 2008 subprime crisis which unfortunately overlaps the immediate post-MiFID period. Year 2008 was voluntarily avoided. The three one-month periods were chosen in 2009 in order to correspond to different levels of fragmentation and volatility. Table 2 gives a timetable and details some of the characteristics of the four observation periods. Pre-MiFID period October 2007 comes just after the start-up of Chi-X but precedes the launch of the other MTFs. The three post-MiFID observation periods (January, June and September 2009) come after the launch of all the MTFs that now have visible market share, but correspond to different levels of fragmentation and fundamental volatility measured by the standard deviation of daily returns of the CAC-40 and FTSE-100 indices. Fragmentation progressively increased from January to September 2009. Volatility was extreme in January, owing to the financial crisis. Volatility had somewhat decreased by June 2009 but still exceeded the baseline level of October 2007. October 2007 and September 2009, while characterized by very different levels of fragmentation, were almost comparable in terms of volatility.

**Table 2 about here**

The post-MiFID time series analysis covers 63 trading days from 1 September to 30 November 2009. Stocks which were not continually part of their index from 2007 to 2009 were dropped from the sample. Financial stocks were excluded as very specific factors drove their liquidity and volatility during the observation periods. This selection procedure resulted in a pre/post-MiFID-comparison sample of 140 stocks of which 51 pertained to the FTSE 100, 32 to the CAC 40, and 57 to the SBF 120 specifically, and in a post-MiFID time-series-analysis sample of 152 stocks distributed between 64 FTSE-100 components, 32 CAC-40 components, and 56 SBF-120-specific components.

*4.2. Daily data, high frequency data, and data filtering*

Daily closing prices, adjustment factors for corporate actions, and market values were collected from Datastream. Prices of UK stocks are expressed in pence sterling. Some metrics used in the study require expressing all prices and volumes in euro. For that purpose, the daily foreign exchange rates of the GBP against EUR were downloaded from the Oanda website (www.oanda.com).

The high-frequency data used in this study were kindly provided by Intelligent Financial Systems (IFS). IFS data were generated from the original data flows of Euronext, the LSE, Deutsche Boerse, Chi-X, Turquoise, Nasdaq OMX Europe, BATS Europe, PLUS, and BOAT. The database includes transaction and best-limit data time-stamped to the second.[5]

For each stock, the data contain the trade prices and best limit quotes of all trading venues where the stock is priced in the same currency as that of the primary listing. Order flow in other currencies is not considered. All timestamps in the database are in UK time and hours will be expressed in UK time throughout the article.

[5] Data from dark pools such as POSIT, Liquidnet, or Chi-X Delta, are not covered, but the total market share of dark MTFs in trading volumes did not exceed a few percent at the time of the study, so that not holding their data should not bias the results.

Best limit data received from IFS provide, at each second of the trading session from 8:00 to 16:30, the best bid price, the best ask price, and quantities associated, for every trading venue where a quote is displayed. The quotes originate from PLUS, Chi-X, BATS Europe, Turquoise, Nasdaq OMX Europe, the Euronext order books, the SETS order book of the LSE, and the Xetra order book of Deutsche Boerse. Bid and ask prices with times that could fall inside the opening auction periods or after the end of the continuous session of the primary exchange, are eliminated. As a result of this rule, I have deleted from the dataset bid and ask quotes with times before 08:01 and after 16:30.

Trade data cover the same markets as quote data plus BOAT-reported trades. For each trade, the data provide the execution time, the price, the size in number of shares, as well as best bid and ask prices and displayed quantities prevailing on every sampled RM or MTF at the time of the trade. Euronext and LSE data encompass opening and closing auction transactions as well as all continuous trades except block and VWAP trades for Euronext. LSE data include an indicator that can be used to identify trades executed on the SETS order book, off-book trades executed by LSE members, and trades reported to the LSE European Trade Reporting Service but not executed on the LSE regulated market. The third category of trades (LSE-reported trades) are of the same type as trades reported by BOAT and should be considered as OTC or internalized trades.

For all trading venues, overnight transactions, that is transactions executed before 07:00 and after 17:00, have been eliminated from the dataset. LSE-reported trades have a 2-figure trade-type code. Any LSE trade for which this code indicates that the trade results from an option exercise, a stock swap, or the cancellation of a previous trade, is deleted.

I have then identified batch auction trades. For the LSE, SETS call auction trades are flagged with a special trade code. On Euronext, fixing trades have to be identified with trading times. At the open, trades whose execution time is the first trade time observed at or

after the official start time of the open auction period are considered as open auction trades. At the close, trades executed at the first trade time immediately superior or equal to the official start time of the close auction but no later than the end time of the close auction period are identified as close auction trades. Once auction trades have been determined, other trades are classified into three groups: continuous trades executed between the open and the close auctions, pre-open trades, and post-close trades.

## 5. Fragmentation and liquidity measures

The order flow in a given security distributes between trading volumes executed on MTFs and RMs, further referred to as the lit order flow, and trading volumes executed by SIs or in the OTC market, further referred to as the internalized order flow. I there present the metrics used to measure both sources of fragmentation and then describe the way traditional measures of liquidity are adapted to measure liquidity in a multi-market environment.

### *5.1. Measuring order flow fragmentation*

Fragmentation is measured by using the reciprocal of a Herfindhal index based on RMs and MTFs market shares in the lit order flow. This fragmentation index[6] is calculated as one divided by the sum of the squared market shares of all RMs and MTFs covered by the database. With perfect concentration, the order flow concentrates in a single market which market share is 100%, so that the fragmentation index equals one. As soon as a new entrant attracts a share of the order flow, the index increases over one. Assuming that $N$ competing markets have perfectly equal market shares in volumes, the fragmentation index is equal to $\frac{1}{N\left(1/N^2\right)} = N$ and increases with $N$. Over the four monthly periods used for the pre/post-

[6] Fidessa, a company that provides trading systems, market data and connectivity solutions, uses this index to publish statistics on market fragmentation.

MiFID comparison, the level of fragmentation for a given stock index was calculated as the cross-sample capitalization-weighted mean of individual stocks' fragmentation indices.

In the post-MiFID observation periods, the weight of internalization was estimated by using BOAT trade report data and LSE trade-reporting-service data. The traded quantities reported by those reporting services were aggregated to calculate the share of internalized volumes in total trading volumes. As most broker-dealer-owned dark pools report their trades to Markit-BOAT, this internalization share covers various types of non-lit-market trades such as trades executed by SIs as principal, dark pool trades, and other OTC trades. For the statistics of September 2009, a fragmentation index of the total order flow including internalized trades was calculated by adding the market share of internalization at the denominator of the index.

### *5.2. Liquidity measures*

Liquidity is measured for two categories of traders: local traders who can only connect to the primary exchange, and cross-market traders who are connected to all trading venues or use smart order routers (SORs) that enable them to distribute their orders across several marketplaces. Three metrics of liquidity are considered: quoted spreads, effective spreads, and depth displayed at best quotes. These metrics are determined locally in each primary market in the perspective of local traders and across markets by optimizing the prices of all competing markets.

#### *5.2.1. Global and local quoted spreads*

In the data provided by IFS, the quoted spreads of each market are observable at every second. The spread observed on the primary market will be referred to as the local spread. Each second, the highest bid price and the lowest ask price across all competing markets are determined. The difference between these two prices divided by their mid value is the quoted spread resulting from matching quotes on all markets. It will be referred to as the global (or

consolidated) quoted spread in the remainder of the study, as contrasted with the local quoted spread. In the pre/post-MiFID comparison, global and local quoted spreads are averaged for each stock and each month. Monthly average quoted spreads are then computed for each stock index by weighting the averages of the individual stocks by market capitalization.[7] In the post-MiFID time-series analysis, local and global quoted spreads are averaged per stock and per day.

*5.2.2. Global and local effective spreads*

The effective spread is a proxy for the implicit cost of a given transaction. It corresponds to the difference between the transaction price and the mid quote prevailing at the time of the transaction, measured as a percentage of this median price. It is doubled to make it comparable with the quoted spread. The mid quote used as the baseline is a cross-market consolidated mid quote, i.e. the mid-point of the best bid and ask prices, all markets combined.

Effective spreads are averaged in the same way as quoted spreads, except that they are weighted by transaction size. The transaction universe used to calculate these averages is reduced to trades executed on-book in the continuous session. OTC, internalized and off-book transactions are excluded. Local effective spreads are obtained by averaging the effective spreads of the transactions executed on a given primary exchange, while global effective spreads are obtained by averaging the spreads of the trades from all markets.

*5.2.3. Global and local depth at best limits*

Best-limit depth is the sum of the quantities associated with the best bid and ask prices. It can be understood as the quantity of shares that can be instantaneously traded with no impact on quoted prices. To ensure that depth is comparable between stocks regardless of price level, it is expressed in terms of capital, specifically in thousands of euros, by multiplying quantities

[7] Market capitalization for weighting purposes is the average of the stock's market capitalization at 1 October 2007 and at 30 September 2009.

by the mid price. Local depth is computed in the traditional way by considering the bid and offer quantities of the primary exchange. Global depth (also denominated consolidated depth) is determined by aggregating the quantities demanded at the best bid limit on all markets quoting the best bid price and the quantities offered at the best ask limit on all markets quoting the best ask price. Average depths are then calculated using the same procedure as for average quoted spreads.

## 6. Shifting from monopolistic-market trading to multi-market trading and contemporaneous changes in liquidity

Part A of Table 3 reports the market shares of the primary market, other regulated markets, MTFs and internalization in FTSE-100, CAC-40 and other SBF-120 stocks respectively in September 2009. Part B presents the same statistics for continuous trading only, excluding opening and closing auctions on the primary market. The primary market is found to have a majority share of order-flow execution in all the samples. If we calculate a fragmentation index by summing the squares of the market shares of each trading venue and the square of the internalization share, and then taking the inverse of that sum, fragmentation is comparable for FTSE-100 stocks (index of 2.7) and CAC-40 stocks (index of 2.65). Comparing the CAC 40 and the SBF 120 reveals that order flow is much less fragmented in mid caps than in large caps, with Euronext capturing over 70% of volumes for the former, compared with 55% for the latter.

**Table 3 about here**

As to the competitive position of MTFs, three players stand out: Chi-X, Turquoise, and BATS Europe. Chi-X is the clear frontrunner with over 10% of volumes in the three samples. BATS Europe and Turquoise are on a par in terms of market share (3-4% for the CAC 40, 4-5% for the FTSE 100). BATS Europe leads Turquoise in UK stocks, but Turquoise has the edge in French stocks.

There is virtually no direct order flow competition between the regulated markets. Euronext loses a few trades to the LSE and Deutsche Boerse, but no more than 1-2% of volume, and Euronext and Deutsche Boerse have no market share in LSE stocks.

Internalization and OTC account for around 20% of total volumes on the CAC 40 and FTSE 100. The share is slightly lower than 20% for UK large caps and significantly higher (approximately 24%) for French large caps.[8]

*6.1. Shifting from monopolistic-market trading to multi-market trading*

To estimate the change in fragmentation between October 2007 and September 2009, volumes executed OTC are excluded from the analysis for the sake of comparability, since these volumes were not reported in October 2007 (pre-MiFID) and only fragmentation between multilateral platforms is comparable across all the observation periods.

Table 4 lists the monthly market shares of all the markets and provides a fragmentation index in the last column, which reveals that fragmentation was substantial in June and September 2009 (around 1.9 for the CAC 40 and FTSE 100 and between 1.4 and 1.5 for the non-CAC-40 SBF 120) and was at an intermediate level in January 2009. In the two samples of large caps, the primary market's share of non-internalized volumes fell from over 95% in October 2007 to around 70% in the final period. Among French mid caps, the primary market's share remained above 80% in September 2009. The share of volumes executed on MTFs stabilized at over 25% for CAC-40 constituents and reached about 30% for FTSE-100 constituents, but did not exceed 18% for the smaller stocks of the SBF 120.

**Table 4 about here**

[8] The accuracy of these figures is a matter of discussion in several respects. First, the share of internalization is very unstable over time. Second, BOAT and LSE's reporting service do not account for all OTC and internalized volumes. However, it may be claimed that BOAT is the market leader in post-trade reporting and that the estimate may be considered to be in the right order of magnitude. Third, it is well acknowledged that internalized volumes may be subject to double or triple reporting, and may sometimes overlap lit volume statistics. An article by Jacquillat and Gresse (1998) dedicated to the competition between the electronic order book of the Paris Stock Exchange and the SEAQI dealer market, showed that dealer-reported volumes could be inflated by a factor 2 or 3.

In Table 4, the LSE market share is separated into volumes executed on the SETS order book and off-book transactions executed by LSE members. This breakdown shows that the structure of the large-cap order flow on LSE changed radically between 2007 and 2009, reflecting competition from MTFs and increased automation of securities trading. In October 2007, over 40% of trading volumes were executed by LSE members off the order book, but by September 2009, just 13.6% of the LSE 69% market share was traded off-book. According to these figures, the SETS system has not really lost market share, but the off-book order flow seems to have diminished as the competition from other trading venues has gained ground.

*6.2. Changes in liquidity: Univariate tests*

Global spreads and the local spreads of primary markets, reported in Table 5, narrowed between October 2007 and September 2009 for the three samples. The biggest decline was on the FTSE 100, for which the average global quoted spread fell from 9.21 to 5.43 bps and the average local quoted spread fell from 9.21 to 7.07 bps. Spreads narrowed far less dramatically for the mid caps of the SBF 120. Effective spreads contracted by less than quoted spreads but nonetheless narrowed significantly, except in the case of SBF-120 mid caps. The decline in spreads is especially noteworthy given that the average volatility of individual stocks was higher in September 2009 than in October 2007 despite returning to levels on a par with those of the pre-MiFID period.

**Table 5 about here**

Spreads declined steadily over the three months observed in 2009, despite high volatility in January and June 2009. Spreads did widen for Euronext stocks in January 2009, but this was weak compared with the surge in the volatility of the CAC 40 index and individual stocks over the period.

Depth did not display such a favorable change over the same period. Between October 2007 and September 2009, as shown in Table 6, average consolidated depth was divided by 3.7 for FTSE-100 stocks, by 2.2 for CAC-40 stocks and 1.7 for the SBF 120. Local depth showed a similar change between the two periods. Although substantial, the reduction in depth is far smaller than the decline in average transaction size. Whereas depth was divided by 3.7 on average for FTSE-100 stocks, average transaction size was divided by 5. Average size was divided by 2.6 for CAC-40 stocks and by 2 for the other stocks of the SBF 120.

**Table 6 about here**

These figures also have to be set in the context of the sharp decline in trading volumes between October 2007 and September 2009 (cf. Table 4): -59% for FTSE-100 stocks, -28% for CAC-40 stocks and -32% for the other stocks of the SBF 120.

Moreover, the statistics in the table reveal dispersion in instant depth across the competing systems. If we sum the local depths of the primary market and the three most active MTFs, the total goes down only for FTSE-100 stocks. It is relatively stable for the CAC 40, and actually increases among SBF-120 constituents that are not in the CAC 40.

## 7. Comparing the pre-MiFID monopolistic-market liquidity with the post-MiFID multi-market liquidity: A two-stage regression analysis

In order to check to what extent the decrease in spreads and depth observed between October 2007 and September 2009 is actually assignable to MiFID coming into force and order flow fragmentation, I conducted two multivariate analyses: (1) panel regressions of liquidity measures onto period dummies serving as proxies for the level of fragmentation; (2) a two-stage regression analysis over the three post-MiFID monthly periods testing the relation between liquidity metrics and fragmentation variables.

*7.1. Assessing the general trend from October 2007 to September 2009: One-stage panel regressions*

In a first approach, I ran one-fixed-effect panel regressions of monthly average measures of spreads and depth according to the following model:

$$L_{im} = a_i + a_1\sigma_{im} + a_2 \ln V_{im} + a_3 1/P_{im} + a_4 B_{Jan09} + a_5 B_{Jun09} + a_6 B_{Sep09} + \varepsilon_{it}, \quad (1)$$

where $L_{im}$ is alternatively the average global quoted spread ($GQS_{im}$), the average global effective spread ($GES_{im}$), the average global depth ($GD_{im}$), the average local quoted spread ($LQS_{im}$), the average local effective spread ($GES_{im}$), and the average local depth ($LD_{im}$), for stock *i* over month *m*; $\sigma_{im}$ is the standard deviation of logarithmic daily closing returns for stock *i* over month *m*; $\ln V_{im}$ is the logarithm of the total trading volume in euros for stock *i* over month *m*; $1/P_{im}$ is the inverse of the average primary market's closing price of stock *i* during month *m*. $B_{Jan09}$, $B_{Jun09}$, and $B_{Sep09}$ are binary variables equal to one in January 2009, June 2009, and September 2009 respectively, and set to zero otherwise. Those panel regressions were run with a fixed effect per stock ($a_i$) with data covering the four month of October 2007, January 2009, June 2009, and September 2009.

The estimates of the regressions of consolidated liquidity measures for the pooled sample and by stock index are reported in Panel A of Table 7. They indicate that global spreads decreased in the post-MiFID period with an increasing statistical and economic significance from January 2009 to September 2009. This spread improvement is most significant for FTSE-100 components and is nearly insignificant for SBF-120 mid-cap stocks. Global depth decreased significantly but with very different patterns: (1) the decrease in depth is highly significant for the three stock indices with no exception for SBF-120 securities; (2) the statistical significance of this decrease was already as high in January 2009 as in later periods; (3) the economic significance of this depth reduction declined from January to September

2009. This leads me to conclude that changes in spreads and changes in depth are not caused by the same factors. Spread reductions seem to relate to the level of market competition as this market competition was weaker for the SBF-120 mid caps at all periods and continually increased from January to September 2009 for all indices. At the opposite, most of the fall in depth happened before January 2009 for all indices and its statistical significance is not weaker for French mid caps, suggesting that the reduction in depth most probably has other determinants than the reduction in spreads.

**Table 7 about here**

Panel B of Table 7 reports the results for the regressions of local liquidity. These regressions produce the same findings with the difference that the coefficients of the monthly dummies have a slightly lower significance.

*7.2. The two-stage regression approach*

In a second approach I tested the relation between the level of fragmentation and liquidity measures with a two-stage regression model that accounted for the co-determination between fragmentation and liquidity. The observation periods were restricted to the three post-MiFID months. As widely discussed by O'Hara and Ye (2011), "An immediate challenge to testing for fragmentation effects on market quality are endogeneity issues". When testing the impact of market fragmentation on liquidity, endogeneity may arise at several levels: (1) at the firm level, if for example, the trading in large stocks is more fragmented, finding greater liquidity for more fragmented stocks could simply be the outcome of large stocks being more liquid; (2) at the order level, the choice of routing an order to a given venue or of splitting it between platforms is endogenous to the relative level of liquidity at each trading venue; (3) at the market level, liquidity and fragmentation may be co-determined, with not only fragmentation impacting liquidity but also liquidity determining fragmentation. For instance, insufficient liquidity in the primary market may induce traders to go to other markets. Conversely, if

newly-established trading systems behave as satellite markets and therefore need a critical mass of orders to attract order flow, higher liquidity may be required to increase fragmentation. In brief, if the level of fragmentation is partly endogenous to liquidity, the residual terms of regressions of liquidity measures onto fragmentation measures may correlate with the independent-considered fragmentation variable. In order to remedy this potential bias, I chose to implement a two-stage regression model in which the fragmentation index is first regressed on instrumental variables and the predicted values of fragmentation obtained from this first-stage regression serve as the regressor in the second-stage regression.

At the first stage, the fragmentation index of the lit order flow for a given stock *i* in a given month *m*, $FI_{im}$,[9] is modeled in the following way:

$$FI_{im} = b_0 + b_1 \ln MV_i + b_2 UV_{im} + b_3 UTS_{im} + b_4 MN_{im} + b_5 MC_{im} + \gamma_{im}, \qquad (2)$$

where $MV_i$ denotes stock *i*'s market value measured as the median between the begin-of-month market capitalization and the end-of-month market capitalization in euros, and plays the role of a fixed effect per security; $UV_{im}$ denotes the component of the logarithmic monthly traded volume which is not correlated to $\ln MV_i$; $UTS_{im}$ denotes the component of the logarithmic average trade size which is not correlated to $\ln MV_i$;[10] $MN_{im}$ is the average number of trading platforms on which traders could find quotes for stock *i* during month *m*; and $MC_{im}$ measures the intensity of the competition between those platforms as the average number of markets quoting the best bid and ask prices divided by the average number of markets quoting stock *i*.

$\ln MV_i$ and $UV_{im}$ controls for the fact that the order flow of larger and more traded stocks may fragment more. $UTS_{im}$, $MN_{im}$, and $MC_{im}$ represent exogenous determinants of

[9] This fragmentation index is the reciprocal of an Herfindhal index based on RMs' and MTFs' market shares as defined in Sub-section 5.1.

[10] $UV_{im}$ and $UTS_{im}$ are the residuals of preliminary OLS regressions of the average daily volume in logarithm and the average euro trade size in logarithm on $\ln MV_i$. This procedure was designed to avoid colinearity in regression (2).

fragmentation related to changes in the trading environment such as the rise of high frequency (HF) trading or the effective entry in business of new electronic order books. Regarding $UTS_{im}$, order size has often been considered as a determinant of routing strategies, leading several researchers (Madhavan and Cheng, 1997; Bessembinder, 2003; O'Hara and Ye, 2011; Degryse, De Jong, and van Kervel, 2011) to use trade size as a first-stage regression instrument in order to address the order-level endogeneity issue. Further, fragmentation is highly determined by HF trading as suggested by Menkveld (2011) because HF traders are the most eager for the low latency offered by alternative trading systems and the most likely to slice and dice orders across markets or to supply liquidity at several venues. Because of the slicing and dicing argument, HF trading negatively affects trade size so that average trade size, even if far from being a perfect proxy, can be used as a first-stage instrument partially reflecting the level of HF trading.[11] $MN_{im}$ and $MC_{im}$ accounts for exogenous determinants of changes in fragmentation such as the entry of new markets ($MN_{im}$) or their ability to be competitive in quotes relative to incumbent markets ($MC_{im}$). First-stage regressions are OLS-estimated for each index separately.

At the second stage, the values of $FI_{im}$ predicted by regressions (2) and denoted $\hat{FI}_{im}$, as well as $ITN_{im}$, the share of internalization defined at Sub-section 5.1, served as regressors for liquidity measures:

$$\begin{cases} GQS_{im} \text{ or } LQS_{im} = c_0 + c_1 CV_{im} + c_2 \hat{FI}_{im} + c_3 ITN_{im} + \eta_{im}^{QS} \\ GES_{im} \text{ or } LES_{im} = d_0 + d_1 CV_{im} + d_2 \hat{FI}_{im} + d_3 ITN_{im} + \eta_{im}^{ES} \\ GD_{im} \text{ or } LD_{im} = e_0 + e_1 CV_{im} + e_2 \hat{FI}_{im} + e_3 ITN_{im} + \eta_{im}^{D}. \end{cases} \quad (3)$$

$CV_{im}$ is a vector of control variables comprising $\sigma_{im}$, $\ln MV_i$, $UV_{im}$, and $1/P_{im}$, i.e. return volatility, market size, trading volumes, and price level. $c_1$, $d_1$, and $e_1$ are 3-dimension

[11] More accurate proxies for HF trading volumes are based on the amount of message traffic (cf. Hendershott, Jones, and Menkveld, 2010; Hasbrouck and Saar, 2010). Calculating such proxies requires order submission and cancellation data that I do not hold.

coefficient vectors. Regressions (3) were estimated as seemingly unrelated regressions (SUR) which assumed non-zero correlations between error terms $\eta_{im}^{QS}$, $\eta_{im}^{ES}$, and $\eta_{im}^{D}$. They were run for global liquidity measures on the one hand, and for local liquidity measures on the other hand. Results are reported in Table 8.

**Table 8 about here**

All in all, liquidity has improved with fragmentation. Global and local spreads are all negatively related to fragmentation with greater significance for FTSE-100 securities. The only exception is the absence of statistical significance for the negative coefficient of SBF-120 local quoted spreads. The economic impact is relatively low but greater for FTSE-100 stocks than for CAC-40 stocks. Global and local depths are also positively impacted by fragmentation for all indices except the group of SBF-120 mid caps for which depth is not significantly affected.

The effect of internalization is more mitigated and insignificant in most cases. According to pooled-sample regressions, global and local spreads narrowed with the share of internalization, whereas global and local depths were adversely affected by internalization. However, those findings fail to be significant in by-index regressions, except for the global depth of SBF-120 securities which was negatively affected at the 10% level.

## 8. A time series analysis of the relation between order flow fragmentation and liquidity

While Sections 6 and 7 compare market liquidity in two different trading environment and regulatory regimes, this section focuses on how liquidity relates to fragmentation in a multi-market trading structure in which fragmentation has reached a substantial level. To test this relation, I conducted several panel analyses on the basis of daily fragmentation and liquidity measures over 63 trading days spreading from 1 September 2009 to 30 November 2009. The sample consisted of 152 stocks distributing between 64 FTSE-100 constituents, 32 CAC-40

constituents, and 56 SBF-120 specific constituents, selected according to the sampling procedure described at Section 4.

*8.1. One-stage panel regressions*

I started this time-series analysis by running, as a first approach, simple two-fixed-effects panel regressions of liquidity measures onto fragmentation and internalization with the following design:

$$L_{it} = \gamma_i + \gamma_t + \gamma_1 \sigma_{it} + \gamma_2 \ln V_{it} + \gamma_3 1/P_{it} + \gamma_4 L_{it-1} + \gamma_5 FI_{it} + \gamma_6 ITN_{it} + u_{it} . \quad (4)$$

Dependent variable $L_{it}$ is alternatively the global or local average quoted spread, average effective spread, and average best-limit depth of stock *i* on day *t*. $FI_{it}$ and $ITN_{it}$ are respectively the Herfindhal fragmentation index and the share of internalized volumes for stock *i* on day *t*. $\sigma_{it}$ denotes the mid-quote range of stock *i* on day *t*. $V_{it}$ is the daily euro trading volume. $P_{it}$ is the primary market's closing price of stock *i* on day *t*. Panel regressions (4) were estimated with two fixed effects.[12] $\gamma_i$ and $\gamma_t$ denotes those cross-sections and time series fixed effects respectively. Autocorrelation was addressed by including the first lag of the dependent variable. $u_{it}$ is a residual term.

The pooled-sample results, displayed at Panel A of Table 9, indicate a significant positive impact of fragmentation on global liquidity regarding quoted spreads and best-limit depth. The relation is insignificant for effective and local quoted spreads. Further, local depth appears to have deteriorated. By-index regressions, whose estimates are reported in the left half of Table 10, show that this detrimental effect on local depth is attributable to Euronext stocks (CAC 40 and SBF 120). This adverse effect has a high statistical significance but a low economic magnitude. Fragmentation most positively affected the liquidity of LSE-listed equities, for which it has improved liquidity without harming any dimension of local liquidity.

[12] The hypothesis of time-series and cross-sections random effects was rejected on the basis of a Hausman test.

More strikingly, findings for SBF-120 mid caps are in stark contrast: no measure of liquidity was significantly correlated with fragmentation for those stocks; on the contrary, their quoted spreads increased and their local depth was reduced with fragmentation.

**Table 9 about here**

**Table 10 about here**

As for internalization, no harmful effect was identified either over the pooled sample or over any index subsample. It was even found to positively affect the depth of LSE equities and the quoted spreads of Euronext equities both at the primary-exchange and global levels.

*8.2. Two-stage panel regressions*

As discussed in Section 7, the estimates of the previous panel regressions may be subject to endogeneity. Here again, I addressed this issue by implementing a two-stage methodology which consisted in substituting to variables $FI_{it}$ and $ITN_{it}$, in panel regressions (4), their predictions $\hat{FI}_{it}$ and $\hat{ITN}_{it}$ as estimated in the following first-stage regressions:

$$FI_{it} = \alpha_0 + \alpha_1 \ln MV_i + \alpha_2 \ln V_{it} + \alpha_3 TS1_{it} + \alpha_4 MC_{it} + \alpha_5 FI_{it-1} + u_{it}; \quad (5)$$

$$ITN_{it} = \beta_0 + \beta_1 \ln MV_i + \beta_2 \ln V_{it} + \beta_3 TS2_{it} + \beta_4 MC_{it} + \beta_5 ITN_{it-1} + v_{it}. \quad (6)$$

$V_{it}$ denotes volume as previously defined. $MV_i$ equals the market capitalization of stock $i$ on the first day of the observation period. $MC_{it}$ is the level of competition between markets, measured by the average number of markets quoting the best bid and ask prices divided by the average number of markets with quotes. This variable is computed in the same way as in Subsection 7.2 but on a daily basis. $TS1_{it}$ and $TS2_{it}$ are daily average euro trade sizes in logarithm. The *TS2* measure involves all trades executed during the continuous session either in electronic markets or by internalization while *TS1* does not include internalized trades. $v_{it}$, and $w_{it}$ are residual terms. Regressions (5) and (6) were OLS-estimated by stock index and included one lag of the dependent variable to correct auto-correlation.

**Table 11 about here**

The reasons for using market value, volume, trade size, and multi-market competition level as first-stage instrumental variables are the same as those exposed in Subsection 7.2. Instrument *MN*, that is the average number of markets quoting prices for a stock, was abandoned because its variance was insufficient to provide explanatory power on a daily frequency after September 2009. Table 11 provides the Pearson correlations between fragmentation measures and several market characteristics including the selected instruments. It shows that for FTSE-100 and SBF-120 stocks, the variables that correlate most with fragmentation measures are trade size and multi-market competition level. For those indices, the fragmentation index of the lit order flow has a higher correlation with a trade size measure that does not include internalized trades ($TS1_{it}$) while, unsurprisingly, the internalization rate is more correlated with the $TS2_{it}$ measure. This justifies the use of $TS1_{it}$ as an instrument for $FI_{it}$ and the use of $TS2_{it}$ as an instrument for $ITN_{it}$. In the case of CAC-40 stocks, $ITN_{it}$ correlates more with $TS1_{it}$ than with $TS2_{it}$ and the correlation rate with $MC_{it}$ is relatively low; yet for consistency, I preferred to use the same model for all indices.

Second-stage panel estimates are displayed in Panel B of Table 9 for the pooled sample and in the right half of Table 10 for subsamples by index. They show greater benefits from fragmentation than those assessed by the one-stage method. All global and local liquidity measures are positively impacted with greater statistical and economic significance than predicted by the one-stage procedure. The only adverse effect is a reduction in the global and local depths of SBF-120 mid caps.

The two-step procedure confirmed the positive impact of internalization on depth with a much greater economic magnitude. Whereas this effect was only significant for the FTSE-100 sample with the one-step test, it has also become highly significant for the mid-cap sample with the two-step test. Nonetheless, the two-stage approach revealed that

internalization could be harmful for quoted spreads: the coefficients of the internalization variable are significantly positive in the regressions of global and local spreads for the pooled, the FTSE-100, and the French mid-cap samples, with greater values in the case of local spreads.

*8.3. GMM dynamic panel regressions*

As a robustness check, panel regressions (4) were estimated by using the dynamic panel estimator method by Arellano and Bond (1991) with ln$MV_i$, ln$Vit$, ln$TS2_{it}$, $MC_{it}$, lagged fragmentation $FI_{it-1}$, and a SBF-120 dummy as instrumental variables.[13] This methodology was run for the pooled sample but could not converge by index. Results are reported at Panel C of Table 9. They indicate that fragmentation and internalization positively impact all measures of liquidity, both globally across markets and locally in the primary market. All coefficients are significant at the 1% level except that of the fragmentation index in the regression of local quoted spreads.

## 9. Conclusion

The coming into force of MiFID in 2007 has fomented competition, complexity, and change in the trading industry across Europe. This study draws on high frequency data from the most active markets for FTSE-100, CAC-40, and SBF-120 stocks to show that the trading in European large equities was substantially fragmented by the end of 2009. Primary exchanges, however, were still dominant players in terms of volume and price competitiveness. Three MTFs had built significant market shares: Chi-X in all categories of equities, BATS Europe more specifically in large UK securities, and Turquoise more specifically in Euronext large equities. Between October 2007 and September 2009, spreads decreased while depth and trade size declined dramatically. The decline in trade size was

[13] All instruments were specified as exogenous except ln$MV_i$ and the SBF-120 dummy which were specified as correlated.

greater than that in depth. The pre/post-MiFID multivariate comparison shows that spreads narrowed gradually as the fragmentation of lit order flow increased, with the spread reduction being more significant after June 2009. It was less significant for mid caps than for large caps, consistent with the lower fragmentation of the mid-caps order flow. Among large caps, the decrease in spreads was more significant for LSE-listed stocks which were subject to fiercer competition from Chi-X. The depth reduction identified with univariate tests followed a different pattern. It was more significant in January 2009 than later, meaning that it could have been driven by other explaining factors than fragmentation. In particular, the decrease in average depth and average trade size can be as much a consequence of algorithmic trading[14] as a consequence of fragmentation. Further, when focusing on 2009 data with a multivariate two-stage approach, depth is even found to be positively related to fragmentation.

The post-MiFID time-series analysis confirms that market fragmentation should be viewed as value-creating competition that benefits global liquidity or, in the worst-case scenario, does not affect it. In most cases, it positively impacts the local liquidity of the primary market as well. After an equilibrium level of order flow fragmentation is reached, marginal gains in liquidity become relatively low in terms of economic magnitude, even if their statistical significance is high. One exception to those benefits is that fragmentation may harm the market depth of small stocks. This finding is consistent with those of Degryse et al. (2011) for Euronext Dutch stocks.

Results on internalization are more mitigated. Contrary to Degryse et al. (2011), I found that internalization could positively impact depth, but that it could be harmful for quoted spreads. Those effects, however, are not significant for all indices and are not robust to the methodology employed.

[14] Cf. Hendershott, Jones, and Menkveld (2008).

There are inevitably some caveats. First, the measure of depth used in this study, which is the most widely used indicator, is a static measure of instantly available quantities. It does not take account of the frequency with which these quantities are renewed. Yet with the proliferation of trading facilities and the rise of algorithmic trading, the frequency of order submission has increased exponentially and orders are much more broken up. In an ideal world, we would measure depth dynamically, but the data do not allow this. Second, other dimensions of liquidity such as speed of order execution, fill rate of orders, hidden depth or depth available at farther limits inside the order book could not be tested.

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**Table 1. The development of the main European RMs, MTFs and TRFs**

| Date | Event |
|---|---|
| 22 September 2000 | Amsterdam, Brussels and Paris exchanges merge, Euronext created |
| 30 January 2002 | Euronext group absorbs Lisbon exchange |
| September 2006 | Nine investment banks create BOAT, a MiFID-compliant TRF |
| 30 March 2007 | Chi-X MTF begins trading in 5 Dutch stocks and 5 German stocks |
| 4 April 2007 | NYSE and Euronext merge, following announcement on 1 June 2006 |
| 12 April 2007 | Chi-X extends trading to all DAX 30 constituents |
| 13 April 2007 | Chi-X extends trading to all AEX 25 constituents |
| 29 June 2007 | Chi-X begins trading in 11 FTSE-100 stocks |
| 13 July 2007 | Chi-X extends trading to all FTSE-100 stocks |
| 28 September 2007 | Chi-X begins trading in 19 CAC-40 stocks |
| 8 et 22 October 2007 | Chi-X extends trading to all other CAC-40 stocks |
| 4 July 2008 | Chi-X begins trading in Belgian stocks |
| 21 August 2008 | Chi-X extends trading to mid caps |
| 2008 to today | Progressive expansion in universe of stocks traded on Chi-X |
| 1st October 2007 | LSE acquires Borsa Italiana |
| 22 January 2008 | Financial information provider Markit acquires BOAT TRF |
| 22 September 2008 | Pan-European platform Turquoise launched |
| 1er October 2008 | Pan-European platform Nasdaq OMX Europe launched |
| 31 October 2008 | BATS Europe launched as MTF for LSE, Euronext and Deutsche Boerse stocks |
| 9 March 2009 | NYSE-Euronext launches MTF NYSE Arca Europe |
| 21 December 2009 | Announcement that LSE is taking 60% stake in Turquoise, later reduced to 51% |
| 2 November 2009 | Deutsche Boerse launches Xetra International Market platform |

**Table 2. Characteristics of observation periods**

| Observation period | Regulatory framework | MTFs operating | Volatility | Fragmentation | # of trading days |
|---|---|---|---|---|---|
| **October 2007** | Pre-MiFID | Chi-X for FTSE 100, starting up for CAC-40 securities, PLUS | Baseline | None or weak | 23 |
| **January 2009** | Post-MiFID | Chi-X, Turquoise, Nasdaq OMX Europe, BATS Europe, PLUS | Extreme, owing to financial crisis | Significant | 21 |
| **June 2009** | Post-MiFID | Chi-X, Turquoise, Nasdaq OMX Europe, BATS Europe, PLUS | Lower but still high and above Oct. 2007 level | Significant | 21 |
| **September 2009** | Post-MiFID | Chi-X, Turquoise, Nasdaq OMX Europe, BATS Europe, PLUS | Comparable to October 2007, slightly higher | Significant | 21 |

**Table 3. Relative market shares and trading volumes in September 2009**

| | Trading volumes, EUR 000 | Euronext | LSE | Deutsche Boerse | Chi-X | BATS Europe | Turquoise | Nasdaq OMX Europe | PLUS | BOAT | LSE Reporting service |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Part A.** ***Auctions and continuous trading*** | | | | | | | | | | | |
| **FTSE 100** | 97,610,438 | 0.00% | 55.65% | 0.00% | 13.93% | 5.05% | 4.43% | 0.96% | 0.68% | 18.66% | 0.64% |
| **CAC 40** | 99,760,432 | 55.08% | 0.55% | 0.94% | 11.63% | 2.96% | 3.96% | 0.91% | 0.00% | 21.11% | 2.86% |
| **SBF 120** | 13,959,377 | 70.53% | 0.34% | 0.20% | 10.18% | 1.11% | 2.75% | 0.40% | 0.00% | 14.37% | 0.11% |
| **Part B.** ***Continuous trading only*** | | | | | | | | | | | |
| **FTSE 100** | 84,694,596 | 0.00% | 53.35% | 0.00% | 16.05% | 5.82% | 5.10% | 1.10% | 0.78% | 17.29% | 0.50% |
| **CAC 40** | 83,918,213 | 51.51% | 0.57% | 1.03% | 13.82% | 3.52% | 4.71% | 1.08% | 0.00% | 20.81% | 2.94% |
| **SBF 120** | 12,131,266 | 70.18% | 0.37% | 0.22% | 11.71% | 1.28% | 3.17% | 0.46% | 0.01% | 12.46% | 0.13% |

*Note*: This table shows the relative market shares of trading venues in September 2009 for each sample of stocks. The second column shows total trading volumes in thousands of euros. All trading volumes, regulated and OTC, are included in the statistics. OTC trades and trades executed by SIs included in the statistics are those reported by BOAT or LSE. Part A of the table reports market shares when primary market auction transactions are included. Part B reduces the sample to transactions executed in continuous trading.

**Table 4. Distribution of trading volumes between RMs and MTFs - October 2007 to September 2009**

| Sample | Period | Trading volumes EUR 000 | Euronext | LSE | Deutsche Boerse | Chi-X | BATS Europe | Turquoise | Nasdaq OMX Eur. | PLUS | Fragmentation index |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **FTSE 100** | **Oct. 2007** | 191,653,000 | 0.00% | 99.99% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% | 1.00 |
| | **Jan. 2009** | 76,368,643 | 0.00% | 75.94% | 0.00% | 14.72% | 1.72% | 5.82% | 0.29% | 1.52% | 1.66 |
| | **June 2009** | 90,706,502 | 0.00% | 71.59% | 0.00% | 17.14% | 4.36% | 4.58% | 0.71% | 1.62% | 1.83 |
| | **Sep. 2009** | 78,769,760 | 0.00% | 68.96% | 0.00% | 17.26% | 6.26% | 5.49% | 1.19% | 0.84% | 1.95 |
| **CAC 40** | **Oct. 2007** | 105,322,607 | 96.45% | 2.92% | 0.63% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 1.07 |
| | **Jan. 2009** | 66,111,453 | 76.41% | 1.63% | 0.61% | 13.07% | 1.28% | 6.93% | 0.08% | 0.01% | 1.65 |
| | **June 2009** | 67,564,708 | 70.35% | 1.18% | 1.30% | 16.42% | 6.18% | 3.74% | 0.84% | 0.00% | 1.90 |
| | **Sep. 2009** | 75,847,834 | 72.44% | 0.72% | 1.24% | 15.29% | 3.89% | 5.21% | 1.19% | 0.01% | 1.81 |
| **SBF120** | **Oct. 2007** | 17,582,701 | 99.99% | 0.00% | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 1.00 |
| | **Jan. 2009** | 8,569,064 | 92.87% | 1.15% | 0.01% | 5.11% | 0.31% | 0.51% | 0.03% | 0.01% | 1.16 |
| | **June 2009** | 9,625,224 | 80.61% | 0.95% | 0.02% | 13.87% | 2.11% | 2.26% | 0.19% | 0.00% | 1.49 |
| | **Sep. 2009** | 11,937,753 | 82.47% | 0.40% | 0.23% | 11.90% | 1.30% | 3.22% | 0.47% | 0.01% | 1.44 |

*Note*: This table shows the relative market shares of trading venues for each sample of stocks in each of the observation periods. The statistics are based on a reduced transaction universe comprising RMs and MTFs. Transactions executed during opening and closing auctions on the primary market are included. OTC trades and internalization are excluded. The third column shows total trading volumes in thousands of euros. The last column gives a fragmentation index calculated by taking the inverse of the sum of the squares of market shares.

**Table 5. Comparison of quoted spreads and effective spreads from October 2007 to September 2009**

| Sample | Period | Index volatility | Average stock return volatility | Global | Primary market | Chi-X | BATS Europe | Turquoise | Nasdaq OMX Eur. |
|---|---|---|---|---|---|---|---|---|---|
| **Part A. Quoted spreads** | | | | | | | | | |
| **FTSE 100** | **Oct. 2007** | 0.91% | 1.66% | 0.0921% | 0.0921% | | | | |
| | **Jan. 2009** | 1.90% | 9.99% | 0.0898% | 0.1129%** | 0.1275% | 0.1688% | 0.4060% | 0.2803% |
| | **June 2009** | 1.16% | 6.03% | 0.0638%*** | 0.0864% | 0.0862% | 0.1024% | 0.1614% | 0.1295% |
| | **Sep. 2009** | 0.77% | 3.81% | 0.0543%*** | 0.0707%*** | 0.0695% | 0.0801% | 0.0949% | 0.1100% |
| **CAC 40** | **Oct. 2007** | 0.70% | 1.37% | 0.0604% | 0.0617% | | | | |
| | **Jan. 2009** | 2.42% | 9.74% | 0.0644% | 0.0943%*** | 0.1121% | 0.1871% | 0.1107% | 0.3566% |
| | **June 2009** | 1.43% | 4.41% | 0.0502%** | 0.0735%** | 0.0714% | 0.0850% | 0.1728% | 0.1191% |
| | **Sep. 2009** | 0.90% | 3.58% | 0.0446%*** | 0.0595% | 0.0606% | 0.0933% | 0.0833% | 0.0989% |
| **SBF120** | **Oct. 2007** | --- | 1.63% | 0.1452% | 0.1454% | | | | |
| | **Jan. 2009** | --- | 12.12% | 0.2502%*** | 0.2644%*** | 0.3064% | 0.2848% | 0.0053% | 0.2975% |
| | **June 2009** | --- | 4.99% | 0.1615% | 0.1945%*** | 0.2650% | 0.3375% | 0.4252% | 0.3924% |
| | **Sep. 2009** | --- | 4.85% | 0.1198%** | 0.1399% | 0.2722% | 0.3017% | 0.2553% | 0.2882% |
| **Part B. Effective spreads** | | | | | | | | | |
| **FTSE 100** | **Oct. 2007** | 0.91% | 1.66% | 0.0744% | 0.0744% | | | | |
| | **Jan. 2009** | 1.90% | 9.99% | 0.0721% | 0.0716% | 0.0780% | 0.0739% | 0.0642% | 0.0833% |
| | **June 2009** | 1.16% | 6.03% | 0.0669%* | 0.0756% | 0.0547% | 0.0508% | 0.0518% | 0.0574% |
| | **Sep. 2009** | 0.77% | 3.81% | 0.0591%*** | 0.0680% | 0.0496% | 0.0428% | 0.0464% | 0.0433% |
| **CAC 40** | **Oct. 2007** | 0.70% | 1.37% | 0.0493% | 0.0493% | | | | |
| | **Jan. 2009** | 2.42% | 9.74% | 0.0614%*** | 0.0612%** | 0.0637% | 0.0592% | 0.0597% | 0.0730% |
| | **June 2009** | 1.43% | 4.41% | 0.0506% | 0.0511% | 0.0509% | 0.0468% | 0.0460% | 0.0630% |
| | **Sep. 2009** | 0.90% | 3.58% | 0.0414%** | 0.0408%** | 0.0442% | 0.0413% | 0.0425% | 0.0461% |
| **SBF 120** | **Oct. 2007** | --- | 1.63% | 0.1130% | 0.1129% | | | | |
| | **Jan. 2009** | --- | 12.12% | 0.2010%*** | 0.2010%*** | 0.0778% | 0.1055% | 0.0161% | 0.1122% |
| | **June 2009** | --- | 4.99% | 0.1408%* | 0.1394%* | 0.1443% | 0.1585% | 0.1334% | 0.2323% |
| | **Sep. 2009** | --- | 4.85% | 0.1129% | 0.1117% | 0.1147% | 0.1309% | 0.1091% | 0.1674% |

*Note*: Part A of this table reports average global quoted spreads and average local quoted spreads for the primary market and the four leading MTFs, by month and by sample. Part B reports average global effective spreads and average local effective spreads for the primary market and the four leading MTFs, by month and by sample. Effective spread statistics are based on a reduced universe comprising transactions exchanged in on-book continuous trading. The third column shows the volatility of daily returns on the index during the month. The fourth column is the capitalization-weighted average volatility of daily returns for the stocks in the sample. ***,**,* means that the difference between the average in consideration and that of October 2007 is statistically different from zero at the 1%, 5%, or 10% level respectively.

**Table 6. Comparison of depths at best limits and trade sizes from October 2007 to September 2009**

| Sample | Period | Depth | | | | | | Average trade size |
|---|---|---|---|---|---|---|---|---|
| | | Global | Primary market | Chi-X | BATS Europe | Turquoise | Nasdaq OMX Europe | |
| **FTSE 100** | **Oct. 2007** | 531.017 | 531.017 | | | | | 91.227 |
| | **Jan. 2009** | 118.782*** | 113.545*** | 106.008 | 78.746 | 88.798 | 16.484 | 18.037 |
| | **June 2009** | 137.711*** | 159.549*** | 131.612 | 83.381 | 36.401 | 51.881 | 19.924 |
| | **Sep. 2009** | 142.950*** | 134.107*** | 116.373 | 68.551 | 38.685 | 68.272 | 18.444 |
| **CAC 40** | **Oct. 2007** | 132.637 | 137.146 | | | | | 44.557 |
| | **Jan. 2009** | 43.280*** | 41.015*** | 34.062 | 32.386 | 33.798 | 33.172 | 16.151 |
| | **June 2009** | 44.582*** | 43.194*** | 29.296 | 25.813 | 23.224 | 23.562 | 14.830 |
| | **Sep. 2009** | 59.401*** | 54.846*** | 38.263 | 27.556 | 28.664 | 18.279 | 17.208 |
| **SBF120** | **Oct. 2007** | 35.028 | 35.222 | | | | | 16.077 |
| | **Jan. 2009** | 16.937*** | 16.919*** | 8.329 | 7.079 | 0.339 | 6.285 | 7.858 |
| | **June 2009** | 17.955*** | 18.216*** | 14.489 | 12.610 | 13.110 | 13.069 | 6.988 |
| | **Sep. 2009** | 21.113*** | 21.594*** | 14.378 | 13.153 | 13.459 | 11.432 | 7.842 |

*Note*: This table reports average global depth and average local depth for the primary market and the four main MTFs, by month and by sample, expressed in thousands of euros. Quantities taken into account are disclosed quantities at best limits. The last column is the average trade size in thousand euros. ***,**,* means that the difference between the average in consideration and that of October 2007 is statistically different from zero at the 1%, 5%, or 10% level respectively.

## Table 7. One-stage panel regressions of monthly liquidity measures

| | Pooled sample | FTSE 100 | CAC 40 | SBF 120 | Pooled sample | FTSE 100 | CAC 40 | SBF 120 | Pooled sample | FTSE 100 | CAC 40 | SBF 120 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Panel A – Global liquidity** | **Global quoted spread ($GQS_{im}$)** | | | | **Global effective spread ($GES_{im}$)** | | | | **Global best-limit depth ($GD_{im}$)** | | | |
| Jan. 2009 dummy ($B_{01/09}$) | -0.00002 | -0.00063*** | -0.00008** | 0.00052** | 0.00009 | -0.00041*** | 0.00001 | 0.00051*** | -0.69604*** | -0.79258*** | -0.85670*** | -0.41534*** |
| | (-0.24) | (-7.38) | (-2.06) | (2.46) | (1.11) | (-6.24) | (0.26) | (2.75) | (-14.35) | (-8.05) | (-9.58) | (-6.68) |
| Jun. 2009 dummy ($B_{06/09}$) | -0.00050*** | -0.00095*** | -0.00023*** | -0.00022 | -0.00013* | -0.00049*** | -0.00008** | 0.00013 | -0.61521*** | -0.60153*** | -0.84921*** | -0.42931*** |
| | (-5.83) | (-12.62) | (-7.87) | (-1.38) | (-1.78) | (8.45) | (-2.42) | (0.91) | (-14.60) | (-6.90) | (-11.89) | (-9.25) |
| Sep. 2009 dummy ($B_{09/09}$) | -0.00067*** | -0.00105*** | -0.00023*** | -0.00048*** | -0.00025*** | -0.00053*** | -0.00012*** | -0.00005 | -0.50359*** | -0.54449*** | -0.61695*** | -0.31897*** |
| | (-8.58) | (14.15) | (-9.20) | (-3.56) | (-3.80) | (-9.33) | (-4.28) | (-0.42) | (-13.22) | (-6.33) | (-9.94) | (-7.95) |
| Adjusted $R^2$ | 0.8353 | 0.8772 | 0.8890 | 0.8503 | 0.8362 | 0.8291 | 0.8580 | 0.8466 | 0.9306 | 0.8911 | 0.9017 | 0.8573 |
| **Panel B – Local liquidity** | **Local quoted spread ($LQS_{im}$)** | | | | **Local effective spread ($LES_{im}$)** | | | | **Local best-limit depth ($LD_{im}$)** | | | |
| Jan. 2009 dummy ($B_{01/09}$) | 0.00015 | -0.00040*** | 0.00019*** | 0.00058*** | 0.00008 | -0.00041*** | 0.00002 | 0.00051*** | -0.73178*** | -0.78983*** | -0.92423 | -0.40662*** |
| | (1.59) | (-4.75) | (5.05) | (2.74) | (0.99) | (-6.19) | (0.52) | (2.75) | (-16.10) | (-9.54) | (-12.16) | (-6.38) |
| Jun. 2009 dummy ($B_{06/09}$) | -0.00023*** | -0.00071*** | -0.00001 | 0.00010 | -0.00011 | -0.00041*** | -0.00007** | 0.00012 | -0.61427*** | -0.53461*** | -0.89054 | -0.43049 |
| | (-2.76) | (-9.51) | (-0.33) | (0.62) | (-1.48) | (-6.95) | (-2.61) | (0.88) | (-15.56) | (-7.30) | (-14.67) | (-9.05)*** |
| Sep. 2009 dummy ($B_{09/09}$) | -0.00047*** | -0.00083*** | -0.00010*** | -0.00029*** | -0.00023*** | -0.00044*** | -0.00014*** | -0.00005 | -0.48063*** | -0.44075*** | -0.67329 | -0.29059*** |
| | (-6.30) | (-11.24) | (-3.92) | (-2.11) | (-3.44) | (-7.54) | (-6.22) | (-0.43) | (-13.47) | (-6.10) | (-12.75) | (-7.07) |
| Adjusted $R^2$ | 0.8449 | 0.8860 | 0.9329 | 0.8489 | 0.8333 | 0.8056 | 0.8977 | 0.8442 | 0.9381 | 0.9155 | 0.9284 | 0.8541 |
| Number of cross sections | 140 | 51 | 32 | 57 | 140 | 51 | 32 | 57 | 140 | 51 | 32 | 57 |
| Time Series Length | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |

*Note*: This table reports the estimates of the panel regressions of global (Panel A) and local (Panel B) liquidity measures, run with a fixed effect per stock, on monthly dummies standing for January, June, and September 2009. The observation period includes those three post-MiFID months plus the pre-MiFID month of October 2007. Variables used in the regressions are monthly observations per stock for 140 non-financial equities (51 FTSE-100 components, 32 CAC-40 components, and 57 SBF-120-specific components). The set of control variables includes volatility measured by the standard deviation of closing returns, volume measured by the logarithm of the total euro trading volume; and price level measured by the reciprocal of the average primary market's closing price. ***,**,* indicates statistical significance at the 1%, 5%, or 10% level respectively. *t*-statistics are provided in brackets.

## Table 8. 2nd-stage seemingly unrelated regressions of monthly liquidity measures

| Dependent variable | Independent variable | Pooled sample | FTSE 100 | CAC 40 | SBF 120 |
|---|---|---|---|---|---|
| **Panel A – Global liquidity** | | | | | |
| Global quoted spread ($GQS_{im}$) | Predicted fragmentation ($\hat{FI}_{im}$) | -0.00160*** | -0.00099*** | -0.00030*** | -0.00122*** |
| | | (-9.47) | (-5.24) | (-2.79) | (-2.72) |
| | Internalized trading ($ITN_{im}$) | -0.00068** | 0.00019 | -0.00001 | -0.00046 |
| | | (-2.03) | (0.43) | (-0.06) | (-0.87) |
| Global effective spread ($GES_{im}$) | Predicted fragmentation ($\hat{FI}_{im}$) | -0.00132*** | -0.00044*** | -0.00022* | -0.00073** |
| | | (-8.95) | (-3.24) | (-1.95) | (-2.06) |
| | Internalized trading ($ITN_{im}$) | -0.00091*** | -0.00006 | 0.00000 | -0.00044 |
| | | (-3.10) | (-0.19) | (0.03) | (-1.05) |
| Global best-limit depth ($GD_{im}$) | Predicted fragmentation ($\hat{FI}_{im}$) | 0.96246*** | 1.07940*** | 0.86811*** | -0.00392 |
| | | (10.85) | (6.43) | (4.45) | (-0.04) |
| | Internalized trading ($ITN_{im}$) | -0.50645*** | 0.37374 | -0.19660 | -0.20483* |
| | | (-2.86) | (0.95) | (-0.81) | (-1.85) |
| System weighted $R^2$ | | 0.6914 | 0.6437 | 0.7597 | 0.6945 |
| **Panel B – Local liquidity** | | | | | |
| Local quoted spread ($LQS_{im}$) | Predicted fragmentation ($\hat{FI}_{im}$) | -0.00144*** | -0.00107*** | -0.00059*** | -0.00074 |
| | | (-8.65) | (-5.62) | (-4.34) | (-1.60) |
| | Internalized trading ($ITN_{im}$) | -0.00062* | -0.00012 | 0.00012 | -0.00032 |
| | | (-1.85) | (-0.26) | (0.72) | (-0.58) |
| Local effective spread ($LES_{im}$) | Predicted fragmentation ($\hat{FI}_{im}$) | -0.00124*** | -0.00033** | -0.00022** | -0.00076** |
| | | (-8.35) | (-2.40) | (-2.24) | (-2.13) |
| | Internalized trading ($ITN_{im}$) | -0.00094*** | -0.00016 | 0.00005 | -0.00042 |
| | | (-3.16) | (-0.51) | (0.40) | (-0.98) |
| Local best-limit depth ($LD_{im}$) | Predicted fragmentation ($\hat{FI}_{im}$) | 0.94595*** | 0.85803*** | 0.73961*** | -0.00596 |
| | | (10.84) | (5.83) | (4.70) | (-0.06) |
| | Internalized trading ($ITN_{im}$) | -0.59916*** | -0.09950 | -0.22770 | -0.19035 |
| | | (-3.45) | (-0.29) | (-1.16) | (-1.62) |
| System weighted $R^2$ | | 0.6722 | 0.6388 | 0.7753 | 0.6803 |
| Number of observations | | 420 | 153 | 96 | 171 |

*Note*: This table displays the estimates of second-stage seemingly unrelated regressions of global (Panel A) and local (Panel B) liquidity measures on fragmentation and internalization. Variables used in the regressions are monthly observations per stock for 140 non-financial equities (51 FTSE-100 components, 32 CAC-40 components, and 57 SBF-120-specific components) over the three post-MiFID months of January, June, and September 2009. Internalization is measured by the share of trading volume reported by Markit-BOAT and the LSE reporting service. The fragmentation variable is the value of the monthly fragmentation index per stock as predicted by a first-stage regression in which instrumental variables are the average trade size, the average number of markets quoting the stock, and the average percentage of markets quoting the best bid and ask prices and in which market value and volume serve as controls. Second-stage regressions control for volatility, market value, volume, and price level. ***,**,* indicates statistical significance at the 1%, 5%, or 10% level respectively. *t*-statistics are provided in brackets.

**Table 9. Pooled-sample panel regressions of daily liquidity measures**

| | Global quoted spread ( $GQS_{it}$ ) | Global effective spread ( $GES_{it}$ ) | Global best-limit depth ( $GD_{it}$ ) | Local quoted spread ( $LQS_{it}$ ) | Local effective spread ( $LES_{it}$ ) | Local best-limit depth ( $LD_{it}$ ) |
|---|---|---|---|---|---|---|
| **Panel A – Fixed-effect panel regression** | | | | | | |
| Fragmentation index ( $FI_{it}$ ) | -0.00004*** (0.0018) | -0.00014 (0.1988) | 0.03649*** (<.0001) | 0.00002 (0.4954) | -0.00014 (0.2179) | -0.02478*** (0.0017) |
| Internalization share ( $ITN_{it}$ ) | -0.00002 (0.5729) | -0.00031 (0.3126) | 0.08695*** (<.0001) | -0.00010 (0.1683) | -0.00032 (0.3046) | 0.04705** (0.0273) |
| $R^2$ | 0.8662 | 0.1997 | 0.9308 | 0.6129 | 0.1974 | 0.9302 |
| **Panel B – 2nd stage panel regressions with fixed effects** | | | | | | |
| Fragmentation index ( $\hat{FI}_{it}$ ) | -0.00019*** (<.0001) | -0.00075*** (0.0008) | 0.10661*** (<.0001) | -0.00026*** (<.0001) | -0.00076*** (0.0009) | -0.00343 (0.8267) |
| Internalization share ( $\hat{ITN}_{it}$ ) | 0.00034*** (<.0001) | 0.00041 (0.5066) | 0.66626*** (<.0001) | 0.00061*** (<.0001) | 0.00038 (0.5431) | 0.55843*** (<.0001) |
| $R^2$ | 0.8684 | 0.2006 | 0.9323 | 0.6152 | 0.1980 | 0.9315 |
| **Panel C – GMM dynamic panel regressions** | | | | | | |
| Fragmentation index ( $FI_{it}$ ) | -0.00008*** (0.0070) | -0.00159*** (<.0001) | 0.23891*** (<.0001) | -0.00006 (0.1423) | -0.00167*** (<.0001) | 0.20251*** (<.0001) |
| Internalization share ( $ITN_{it}$ ) | -0.00130*** (<.0001) | -0.00928*** (<.0001) | 2.52926*** (<.0001) | -0.00188*** (<.0001) | -0.00950*** (<.0001) | 1.86933*** (<.0001) |

*Note*: This table reports the estimates of panel regressions of daily liquidity measures on fragmentation measures run with three different methods, on a sample of 152 stocks made of 64 FTSE-100 constituents, 32 CAC-40 constituents, and 56 SBF-120 constituents, over 63 trading days from 1 September to 30 November 2009. The dependent variable was alternatively the average global quoted spread, the average global effective spread, the average global depth, the average local quoted spread, the average local effective spread, and the average local depth. The independent fragmentation measures were the fragmentation index and the internalization share. All regressions controlled for price range, volume, and price level. Panel A displays the estimates of two-way fixed-effects panel regression directly run on fragmentation measures. Panel B displays the estimates of second-stage two-fixed-effects panel regressions in which the fragmentation and the internalization variables were replaced by their values as predicted in first-stage regressions. Panel C displays the estimates of GMM dynamic panel regressions in which market value, volume, trade size, multi-market competition level, lagged fragmentation and a SBF-120 dummy serve as instruments. ***,**,* indicates statistical significance at the 1%, 5%, or 10% level respectively. *P*-values are provided in brackets.

**Table 10. Panel regressions of daily liquidity measures by stock index**

| | One-stage panel regressions | | | 2nd-stage panel regressions | | |
|---|---|---|---|---|---|---|
| | Fragmentation ($FI_{it}$) | Internalization ($ITN_{it}$) | $R^2$ | Fragmentation ($\hat{FI}_{it}$) | Internalization ($\hat{ITN}_{it}$) | $R^2$ |
| **Panel A – FTSE-100 stocks** | | | | | | |
| Global quoted spread($GQS_{it}$) | -0.00005*** (<.0001) | -0.00001 (0.8401) | 0.7739 | -0.00015*** (<.0001) | 0.00012** (0.0163) | 0.7776 |
| Global effective spread ($GES_{it}$) | -0.00007*** (<.0001) | 0.00004 (0.2823) | 0.6563 | -0.00014*** (<.0001) | 0.00014** (0.0401) | 0.6579 |
| Global best-limit depth ($GD_{it}$) | 0.03251*** (0.0036) | 0.07816** (0.0309) | 0.9195 | 0.10231*** (<.0001) | 0.68358*** (<.0001) | 0.9214 |
| Local quoted spread ($LQS_{it}$) | -0.00004 (0.4265) | -0.00037** (0.0471) | 0.1158 | -0.00049*** (<.0001) | 0.00064** (0.0419) | 0.1226 |
| Local effective spread ($LES_{it}$) | -0.00004*** (0.0075) | 0.00005 (0.2998) | 0.6379 | -0.00013*** (<.0001) | 0.00013 (0.1166) | 0.6399 |
| Local best-limit depth ($LD_{it}$) | 0.00405 (0.6943) | 0.06344* (0.0577) | 0.8925 | 0.03674* (0.0952) | 0.59583*** (<.0001) | 0.8952 |
| **Panel B – CAC-40 stocks** | | | | | | |
| Global quoted spread ($GQS_{it}$) | -0.00005*** (<.0001) | -0.00006*** (0.0004) | 0.8368 | -0.00030*** (<.0001) | 0.00000 (0.9013) | 0.8652 |
| Global effective spread ($GES_{it}$) | 0.00003 (0.9001) | -0.00061 (0.1944) | 0.4573 | -0.00288*** (<.0001) | 0.00089 (0.4639) | 0.4617 |
| Global best-limit depth ($GD_{it}$) | 0.04763*** (0.0078) | 0.03305 (0.3340) | 0.8662 | 0.11680** (0.0249) | 0.10420 (0.2386) | 0.8656 |
| Local quoted spread ($LQS_{it}$) | -0.00002** (0.0270) | -0.00011*** (<.0001) | 0.8172 | -0.00041*** (<.0001) | -0.00005 (0.2459) | 0.8532 |
| Local effective spread ($LES_{it}$) | -0.00003 (0.9171) | -0.00059 (0.2430) | 0.4415 | -0.00298*** (0.0001) | 0.00071 (0.5831) | 0.4457 |
| Local best-limit depth ($LD_{it}$) | -0.04848*** (0.0041) | 0.02355 (0.4656) | 0.8622 | 0.11824** (0.0167) | 0.13085 (0.1181) | 0.8619 |
| **Panel C – SBF-120 stocks** | | | | | | |
| Global quoted spread ($GQS_{it}$) | 0.00011*** (0.0031) | -0.00016* (0.0546) | 0.7979 | -0.00052*** (<.0001) | 0.00041* (0.0621) | 0.8033 |
| Global effective spread ($GES_{it}$) | 0.00049 (0.1535) | 0.00014 (0.8581) | 0.1881 | 0.00109 (0.1237) | 0.00347* (0.0970) | 0.1886 |
| Global best-limit depth ($GD_{it}$) | -0.00729 (0.6620) | -0.01274 (0.7255) | 0.7295 | -0.16491*** (<.0001) | 0.33596*** (0.0008) | 0.7339 |
| Local quoted spread ($LQS_{it}$) | 0.00020*** (<.0001) | -0.00020** (0.0201) | 0.7897 | -0.00057*** (<.0001) | 0.00050** (0.0310) | 0.7945 |
| Local effective spread ($LES_{it}$) | 0.00055 (0.1159) | 0.00012 (0.8799) | 0.1906 | 0.00117 (0.1055) | 0.00340 (0.1122) | 0.1910 |
| Local best-limit depth ($LD_{it}$) | -0.08417*** (<.0001) | -0.04888 (0.2049) | 0.7397 | -0.24686*** (<.0001) | 0.44443*** (<.0001) | 0.7443 |

*Note*: This table reports the estimates of panel regressions of daily liquidity measures on fragmentation measures for three samples of stocks – 64 FTSE-100 stocks (Panel A), 32 CAC-40 stocks (Panel B), and 56 SBF-120 stocks (Panel C) – over 63 trading days from 1 September to 30 November 2009. The dependent variable was alternatively the average global quoted spread, the average global effective spread, the average global depth, the average local quoted spread, the average local effective spread, and the average local depth. The independent fragmentation measures were the fragmentation index and the internalization share. All regressions controlled for price range, volume, and price level. The left part of the table ("One-stage panel regressions") displays the estimates of two-way fixed-effects panel regression directly run on fragmentation measures. The right part of the table ("2nd stage panel regressions") displays the estimates of second-stage two-fixed-effects panel regressions in which the fragmentation and the internalization variables were replaced by their values as predicted in first-stage regressions. ***,**,* indicates statistical significance at the 1%, 5%, or 10% level respectively. *P*-values are provided in brackets.

**Table 11. Descriptive statistics and correlations**

| | Fragmentation index ($FI_{it}$) | Internalization share ($ITN_{it}$) | Price range ($\sigma_{it}$) | Volume in logarithm ($\ln V_{it}$) | Market value in logarithm ($\ln MV_i$) | Price level ($1/P_{it}$) | Average trade size ($\ln TS2_{it}$) | Av. non-internalized-trade size ($\ln TS1_{it}$) | Multi-market competition level ($MC_{it}$) |
|---|---|---|---|---|---|---|---|---|---|
| **Panel A – FTSE-100 stocks** | | | | | | | | | |
| **Mean** | 2.3186 | 16.10% | 2.68% | 10.6649 | 8.7767 | 0.1743 | 2.5835 | 2.4486 | 57.10% |
| **Standard deviation** | 0.3836 | 12.21% | 1.46% | 0.9582 | 1.0463 | 0.1604 | 0.4887 | 0.4711 | 12.29% |
| **No. observations** | | | 4,032 | | | | | | |
| **Pearson correlations** | | | | | | | | | |
| Fragmentation index | 1.0000 | | | | | | | | |
| Internalization share | 0.0394*** | 1.0000 | | | | | | | |
| Price range | -0.1628*** | -0.0983*** | 1.0000 | | | | | | |
| Volume in logarithm | -0.0315** | -0.0511** | 0.1180*** | 1.0000 | | | | | |
| Market value in logarithm | 0.1312*** | -0.0918*** | -0.0998*** | 0.8381*** | 1.0000 | | | | |
| Price level | -0.0085 | 0.1244*** | -0.0710*** | -0.2897*** | -0.3393*** | 1.0000 | | | |
| Average trade size | -0.1171*** | 0.2680*** | -0.0836*** | 0.7979*** | 0.7263*** | -0.3040*** | 1.0000 | | |
| Av. non-internalized-trade size | -0.1304*** | -0.0130 | -0.0690*** | 0.8402*** | 0.7764*** | -0.3539*** | 0.9541*** | 1.0000 | |
| Multi-market competition level | 0.2583*** | 0.1151*** | -0.2654*** | 0.1733*** | 0.2904*** | -0.0603*** | 0.4239*** | 0.4231*** | 1.0000 |
| **Panel B – CAC-40 stocks** | | | | | | | | | |
| **Mean** | 1.9401 | 16.38% | 2.59% | 11.6626 | 9.6021 | 0.0424 | 3.0348 | 2.8744 | 32.13% |
| **Standard deviation** | 0.3976 | 12.42% | 1.26% | 1.1074 | 0.8664 | 0.0645 | 0.9432 | 0.9563 | 5.57% |
| **No. observations** | | | 2,016 | | | | | | |
| **Pearson correlations** | | | | | | | | | |
| Fragmentation index | 1.0000 | | | | | | | | |
| Internalization share | 0.3407*** | 1.0000 | | | | | | | |
| Price range | -0.1687*** | -0.1204*** | 1.0000 | | | | | | |
| Volume in logarithm | -0.5291*** | -0.1248*** | 0.0493** | 1.0000 | | | | | |
| Market value in logarithm | 0.2023*** | 0.2916*** | -0.3202*** | 0.4436*** | 1.0000 | | | | |
| Price level | -0.1727*** | -0.0679*** | 0.2721*** | 0.0067 | -0.2503*** | 1.0000 | | | |
| Average trade size | -0.6231*** | -0.0646*** | -0.0380* | 0.9079*** | 0.2701*** | -0.0206 | 1.0000 | | |
| Av. non-internalized-trade size | -0.6704*** | -0.2750*** | -0.0166*** | 0.9062*** | 0.2049*** | -0.0100 | 0.9741*** | 1.0000 | |
| Multi-market competition level | 0.0581*** | 0.0590*** | -0.0887*** | 0.1873*** | 0.1664*** | -0.0162 | 0.1760*** | 0.1626*** | 1.0000 |

**Table 11. cont'd**

| | Fragmentation index ($FI_{it}$) | Internalization share ($ITN_{it}$) | Price range ($\sigma_{it}$) | Volume in logarithm ($\ln V_{it}$) | Market value in logarithm ($\ln MV_i$) | Price level ($1/P_{it}$) | Average trade size ($\ln TS2_{it}$) | Av. non-internalized-trade size ($\ln TS1_{it}$) | Multi-market competition level ($MC_{it}$) |
|---|---|---|---|---|---|---|---|---|---|
| **Panel C – SBF-120 stocks** | | | | | | | | | |
| **Mean** | 1.4844 | 9.34% | 2.91% | 8.7960 | 7.4259 | 0.0586 | 1.9367 | 1.8576 | 31.19% |
| **Standard deviation** | 0.3261 | 11.32% | 1.80% | 1.1496 | 0.8912 | 0.0684 | 0.5817 | 0.5604 | 15.12% |
| **No. observations** | | | 3,528 | | | | | | |
| **Pearson correlations** | | | | | | | | | |
| Fragmentation index | 1.0000 | | | | | | | | |
| Internalization share | 0.2756*** | 1.0000 | | | | | | | |
| Price range | -0.1216*** | -0.0830*** | 1.0000 | | | | | | |
| Volume in logarithm | 0.1616*** | 0.1775*** | 0.2565*** | 1.0000 | | | | | |
| Market value in logarithm | 0.4716*** | 0.3097*** | -0.2226*** | 0.5171*** | 1.0000 | | | | |
| Price level | -0.0648*** | -0.0349** | 0.2601*** | -0.0226 | -0.3176*** | 1.0000 | | | |
| Average trade size | -0.0839*** | 0.2868*** | 0.0484*** | 0.7747*** | 0.3853*** | -0.1747*** | 1.0000 | | |
| Av. non-internalized-trade size | -0.1369*** | 0.0301* | 0.0673*** | 0.7798*** | 0.3460*** | -0.1731*** | 0.9588*** | 1.0000 | |
| Multi-market competition level | -0.2569*** | -0.1617*** | 0.0494*** | -0.3211*** | -0.4152*** | 0.0975*** | -0.1652*** | -0.1424*** | 1.0000 |

*Note*: This table provides the matrix of Pearson correlations between the fragmentation index of the lit order flow ($FI_{it}$), the internalization share ($ITN_{it}$), the daily price range ($\sigma_{it}$), the market value in logarithm ($\ln MV_i$), the daily euro traded volume in logarithm ($\ln V_{it}$), price level ($1/P_{it}$), the logarithm of the average size in euro of all continuous trades ($\ln TS2_{it}$), the logarithm of the average size in euro of continuous trades internalized trades excluded ($\ln TS1_{it}$), and the level of competition between markets ($MC_{it}$). Means and standard deviations of those variables are also reported. Panel A displays the statistics established for FTSE-100 stocks, Panel B those for CAC-40 stocks, and Panel C those for SBF-120 stocks. The observation period covers 63 trading days from 1 September to 30 November 2009. ***,**,* indicate that correlation coefficients statistically differs from zero at the 1%, 5%, or 10% level respectively.