Fragmentation and price discovery dynamics: The contributions of Multilateral Trading Facilities and Regulated Market☆

Roland Gillet[a,b], Stéphanie Ligot[a,*]

[a]*Sorbonne Management School (PRISM and Labex RéFi), University Paris 1 Panthéon - Sorbonne, Rue de la Sorbonne 17, F-75231 Paris Cedex 05, France*
[b]*Solvay Brussels School, Free University of Brussels, Avenue F.D. Roosevelt 42, B-1050 Brussels, Belgium*

Abstract

Since 2007, the European Markets in Financial Instruments Directive (MiFID) has ended the national rule of order concentration and the directive has increased the fragmentation among the trading venues. This paper examines the price discovery dynamics for cross-listed CAC40 stocks, through the Information Shares metric, over the years 2012 and 2013 for three key places: NYSE Euronext Paris, BATS Europe and Chi-X Europe. We use the high-frequency order flow on individual stocks to study the monthly contribution of the Regulated Market (Euronext Paris) and Multilateral Trading Facilities (BATS and Chi-X Europe) to the price discovery by using the spread midpoint on the best limits at one-second intervals. We observe that the Multilateral trading facilities contribute significantly to the price discovery dynamics. The revision of MiFID should enhance the trade-through protections, and unified trade and price reporting protocols to avoid that fragmentation is detrimental on the market quality after the Brexit.

Keywords: Market microstructure, Security market regulation, Price discovery dynamics
JEL Classification: G12, G14, G18

☆We thank Maureen O'Hara and the participants at the French Finance Association - AFFI (Paris, 2018) for their useful comments and suggestions. Moreover, we thank the participants at the 16th Paris December Finance Meeting organized by EUROFIDAI (European Financial Data Institute) and ESSEC Business School with the participation of AFFI (Paris, 2018), the participants at the 1st Annual Conference of the Joint Research Centre Community of Practice in Financial Research on "The Resilience of the Financial System" (Brussels, European Commission, November 2018) and the participants at the Conference on Quantitative Methods for Financial Regulation organized by the Labex ReFi and the Stony Brook University (New York, 2016). We would like to thank EUROFIDAI for providing the AMF (Autorité des marchés financiers) - EUROFIDAI/BEDOFIH European High Frequency database. More information on the BEDOFIH European High Frequency financial database can be found at the following link: https://www.eurofidai.org/en/bedofih-database. We thank also IODs for providing BATS and Chi-X intra-day data. The analysis, the interpretations and the conclusions of this study are the responsibility of authors and they are not meant to represent the stances of the AMF. This work was achieved through the Laboratory of Excellence on Financial Regulation (Labex ReFi) supported by PRES heSam under the reference ANR-10-LABEX-0095. It benefited from a French government support managed by the National Research Agency (ANR) within the project Investissements d'Avenir Paris Nouveaux Mondes (Investments for the future Paris-New Worlds) under the reference ANR-11-IDEX-0006-02.

*Corresponding author
Email address: stephanie.ligot@univ-paris1.fr (Stéphanie Ligot)

I. INTRODUCTION

The Market in Financial Instruments Directive (MiFID), introduced in 2007, has given rise to alternative methods of equity market trading for the European equity markets. The MiFID aims to further the integration, competitiveness and efficiency of European financial markets by improving the quality of order executions through the promotion of transaction cost reduction[1]. The MiFID has suppressed the rule of national concentration of orders and enabled European-wide competition between Regulated Markets (RM) and the arrival of Multilateral Trading Facilities (MTF), Systematic Internalisers (SI) and dark pools. Moreover, competition in the European equity markets has been organized around the introduction of the "best execution policy" notion, which means achieving the best possible result for retail and professional clients when executing their orders.

Dewenter et al. (2017) examine what drives volume and spread changes when stock exchanges compete. Results show average trading costs on European exchanges decrease almost 9 percent, and turnover increases over 30 percent. Frankfurt, Paris, London, and Milan are winners, while Madrid and Brussels lose volume and the euro conversion prompted competition by increasing transparency in market prices.

The significant market change with the implementation of the MiFID for our study is that the cross-listed stocks may be exchanged on the Regulated Market (RM), which remains the single entry point for the admission for the cote, and on the Multilateral Trading Facilities (MTF), with the aim of organizing a multilateral confrontation between buyers and sellers in the European equity markets[2]. The main evolutions of the European equity markets since 2000 is available in Table A.2 in the Appendix.

[1] This directive does not cover all financial instruments. It concerns only transferable securities, instruments on the money market and funds and impacts the front, middle and back offices.

[2] Article 4 of the MiFID describes MTFs as multilateral systems, operated by an investment firm or market operator, that bring together multiple third-party buying and selling interests in financial instruments (in the system and in accordance with non-discretionary rules) in a way that results in a contract. The term "non-discretionary rules" means that the investment firm that operates an MTF has no discretion as to how interests may interact. Interests are brought together by forming a contract and the execution takes place under the system's rules or by means of the system's protocols or internal operating procedures. An MTF can be operated by a market operator or by an investment firm, whereas the operation of an regulated market is not considered an investment service and is carried out exclusively by market operators that are authorised to do so. The United States equivalent is an alternative trading system.

With the implementation of the MiFID at a European level, the spatial fragmentation of the liquidity has accelerated. When securities are exchanged on several markets, it is important to determine where the price discovery occurs. Our paper aims to study if the price discovery takes place at the Regulated Market level (NYSE Euronext Paris) and/or at the Multilateral Trading Facilities (MTF) level for the CAC40 stocks. The main objective of this paper is to study the evolution of market contributions to the price discovery process for the CAC40 Index stocks after the implementation of the MiFID directive.

The article is based on Hasbrouck's (1995) methodology and suggests an econometric approach founded on the common implicit and unobservable efficient price for all markets. The part of the information associated with a particular market is defined as the proportional contribution of its innovations with regard to the innovations of the common efficient price, through the computation of the Information Share (IS).

Our paper draws on new data sources to provide better metrics for addressing these issues. We use new microstructure data, the BEDOFIH[3] AMF - NYSE Euronext Paris High Frequency Database and the IODS BATS Chi-X intra-day database, to investigate the price discovery dynamics between NYSE Euronext Paris, BATS and Chi-X Europe. These new databases are particularly interesting because as the stock markets are becoming automated, the time at which orders are submitted, modified or cancelled on the marketplace is now very short. One feature of the data is that the precision of time-stamp orders is of a microsecond.

Our analysis yields a number of results and our contributions are twofold. Firstly, we provide new evidence on the nature of fragmentation in the European equity markets between the Regulated Market and the Multilateral Trading Facilities for the CAC40 stocks. This gives us a clear view on the importance of alternative trading venues after the implementation of MiFID.

Secondly, we examine the price discovery dynamics with the measurement of the monthly Information Share (IS) for the CAC40 stocks for the Regulated Market (NYSE Euronext Paris) and the main Multilateral Trading Facilities (BATS and Chi-X Europe). This price discovery metric gives us the evolution of price discovery dynamics across the different trading venues, based on a model using individual stock quotations to determine the impacts of spatial fragmentation on the price discovery dynamics in the case of quote synchronisation. We find a particularly significant price discovery on BATS and Chi-X Europe for the cross-traded CAC40 stocks.

[3]BEDOFIH is the Base Européenne de Données Financières à Haute Fréquence.

We provide confirming evidence that the Multilateral Trading Facilities contribute significantly to the price discovery efficiency in a spatially fragmented environment. An immediate application of our results is to the revision of MiFID that has allowed fragmentation to occur in the European markets since 2007 and the ongoing policy debate on the Brexit. In a highly fragmented context with a significant price discovery activity for the Multilateral Trading Facilities (BATS, Chi-X Europe), it is important to ensure the virtual consolidation of the European equity market to ensure the principle of fairness between investors without neglecting the price discovery efficiency and the market quality. At this level, it would be wise to focus on the measures taken in US equity markets (with the existence of a consolidated tape and the SEC Rules 611 and 605) to better address the impacts of fragmentation on the potential market quality issues.

To counterbalance the fragmentation of liquidity due to the multiplication of the possible exchange places and to ensure the investor protection with an efficient price discovery process, the MiFID II best execution augments the current best execution requirements in 2018 with the request for a quarterly own quality of execution report which has to be published by all execution venues, an annual top 5 execution venue report (applicable for all investment firm executing client orders) and an annual report about the monitoring of the execution quality of all used execution venues (when executing client orders)[4].

Moreover, with the implementation of MiFID II, the rules governing trading should impose an harmonized set of organisational requirements on investment firms and trading venues, and the provisions regulating the non-discriminatory access to central counterparties (CCPs), trading venues and benchmarks should be designed to increase competition. With the Brexit, the risk of an increased fragmentation and regulatory barriers being imposed on the EU and UK trading venues should highlight the need to establish contingency plans.

The paper is organised as follows. In Section II, we present the literature review around the fragmentation and the price discovery dynamics. Section III sets out our databases, our sample period and our methodology to assess the spatial fragmentation and the contributions of NYSE Euronext Paris, BATS and Chi-X Europe to the price discovery dynamics. In Section IV, we present the empirical results for the Information Share (IS) of these three markets in a fragmented environment. Our conclusions and policy implications appear in Section V.

[4]Gillet et al. (2017) have proposed a review of the challenges and implications of the MiFID and its revision on the efficiency of financial markets. The main changes induced by MiFID II are listed in Table A.1 in the Appendix.

II. LITERATURE REVIEW

The fragmentation of trading, corresponding to the dispersal of the trading of a security in multiple markets, has emerged in the European markets with the introduction of the MiFID in 2007[5]. According to Schwartz (2010), fragmentation may be a threat to an accurate price discovery, which is defined by Schreiber and Schwartz (1986), Hasbrouck (1995), Booth et al. (1999), Baillie et al. (2002), Lehmann (2002), O'Hara (2003), Yan and Zivot (2010), Caporale and Girardi (2013) and Foucault et al. (2013) as the impounding of new information into the price of a security. This definition of the price discovery process is completed by the market search for a new equilibrium price. The price that should be discovered is defined as the value that best reflects a broad array of buy and sell desires, namely, an equilibrium value (see Schreiber and Schwartz (1986)). However, this definition of the equilibrium is not easy and it is a central question for the market participants for multiple trading in equities. An accurate price discovery has many attributes for a public good and it should be prioritised as a regulatory objective to ensure the market quality. O´Hara and Ye (2011) define market quality as a market's ability to meet its dual goals of liquidity and price discovery.

The price discovery function of a market includes all information which affects the fundamental value of assets, also known as the efficient price. The variations in the efficient price are the result of the price discovery process and reflects the capacity of a market to collect and proceed with the information. Indeed, its ability to be a leader in terms of price discovery, which means having a quotation who is the first to incorporate the new information, is important. Clapham and Zimmermann (2016) underline that the literature review on price discovery in the European market system has revealed that there are rather few studies that analyze price discovery in a fragmented European market environment compared to literature based on US data. Consequently, we study the impacts of spatial fragmentation on the price discovery dynamics in the post-MiFID environment with the introduction of Multilateral Trading Platforms (MTF).

[5]The theoretical and empirical work argued in favour of market consolidation or market fragmentation are shared and discussed by Stigler (1964), Bloch and Schwartz (1978), Cohen et al. (1982), Cohen (1985), Mendelson (1987), Pagano (1989), Chowdhry and Nanda (1991), Lawrence (1993), Biais (1993), Harris (1993), Madhavan (1995), Madhavan (2000), Bennett and Wei (2006), Gajewski and Gresse (2007), Foucault and Menkveld (2008), De Jong and Rindi (2009), O´Hara and Ye (2011), Foucault et al. (2013), Aitken et al. (2017), Gresse (2017), Gomber et al. (2017).

The tested hypothesis in our paper on the revelation of the information is the following:

- **H 1.** Prices quoted on Multilateral Trading Facilities (MTFs) contribute in a preponderant way to the discovery efficient price.
- **H 2.** Prices quoted on Multilateral Trading Facilities (MTFs) contribute that in a lesser extent to the discovery of the efficient price.

Domowitz et al. (1998) suggest that the impacts of cross-listing is complex and depends on the degree of transparency of quotations. The way in which information on a price is available and is observable in both markets is primordial. Later studies focusing on multiple trading in equities and price discovery dynamics include Garbade and Silber (1979), McInish et al. (1995), Röell (1992), Pallmann (1992) , Grünbichler et al. (1994), Kleidon and Werner (1993), Huang (2002), Eun and Sabherwal (2003), Barclay and Hendershott (2003), Barclay et al. (2003), Pascual et al. (2006), Riordan et al. (2011), Riordan and Storkenmaier (2012), Riordan et al. (2013), Brogaard et al. (2014) and Clapham and Zimmermann (2016).

On the US markets, Garbade and Silber (1979) have analysed the trading patterns of the NYSE and regional exchanges from the point of view of price discovery, concluding that the NYSE is the dominant market and the regional markets are satellites[6]. According to Garbade and Silber (1979), the true equilibrium price is an uncertain parameter that could be defined as the price that would bring a contemporaneous Walrasian auction in which all investors participated into equilibrium. This concept of equilibrium implies financial models based on frictionless markets and complete information in a perfect competitive environment. A key point in the studies of Garbade and Silber (1979) and Garbade and Silber (1982) is the assumption that the prices in the diverse markets share a common implicit efficient price. Hasbrouck (1991) assumes that a single observed security price impounds an implicit efficient price, and attributes the sources of variation in this efficient price to trades and orders (see Hasbrouck (1993) for more explanations).

[6]The introduction of the consolidated tape in 1975 in the US has allowed the information content reflected in regional prices to be reported to the dominant market, the NYSE. This innovation has facilitated the timely disclosure of information to NYSE participants. However, it has not allowed the full integration of the NYSE and regional markets because it was always possible to differentiate (statistically) a transaction executed on a regional market or on the NYSE. Such a consolidated tape should be introduced with MiFID II for the European equity market.

Our paper relies on the methodology developed by Hasbrouck (1995) because this methodology returns to the Garbade and Silber approach in the presumption of a common implicit efficient price shared by the diverse markets. Hasbrouck (1995) is a multiple market extension in which the implicit efficient price is common to all markets and the sources of variation in this efficient price are attributed to different markets. The common implicit efficient price supports the economic intuition that, subject to transaction cost bounds, the securities traded in different markets are linked by arbitrage or short-term equilibrium considerations. In this framework, price discovery refers to innovations in the efficient price. A market's contribution to price discovery is its Information Share (IS), defined as the proportion of the efficient price innovation variance that can be attributed to that market.

The econometric approach that constrains multiple price series to share a common component relies on cointegration. It refers to the feature that while two price series may be non-stationary, they do not diverge from each other without bound. Cointegration allows the representation of several non-stationary price processes that have the same long-term trend with an error correction system in the short-term process. Hasbrouck (1995) has used the Stock and Watson (1988) common stochastic trend decomposition to decompose transaction prices into noise and a random walk, which is interpreted as the efficient price.

The Component Share (CS), defined by Gonzalo and Granger (1995) as the decomposition of the Permanent-Transitory variance, is an alternative to the IS approach. It was introduced into the microstructure by McInish et al. (1995) and Booth et al. (1999). Both methodologies use cointegration to constrain multiple market prices to share a common efficient price, and both approaches use a reduced form of the VECM for estimation purposes. For Gonzalo and Granger (1995), the model developed is based on an ECM with a common factor that is a linear combination of prices. What is not explained by the common factor, only has a transitory price impact. The drawback to this approach, however, is that the permanent component needs not to be a random walk and may therefore be forecast.

As noted by Hasbrouck (2002), this point does not respect the condition that the efficient price should be a martingale, in the sense that a common random walk corresponds to the fundamental value of the assets. McInish et al. (2002) have underlined that common factor components and information sharing provide competing approaches to estimating price discovery parameters in cointegrated markets.

The paper reveals that Gonzalo and Granger's (1995) procedure for estimating and testing common factor components recovers the true information structure in a wide range of financial market microstructure models. Yan and Zivot (2010) have analysed the structural determinants of the IS and the CS between multiple markets that trade closely related securities. As other alternative price discovery measures, De Jong and Schotman (2009) have proposed a structural time series model for intraday price dynamics in fragmented financial markets, based on the unobserved components approach. Grammig and Peter (2013) have demonstrated how the tail dependence of price changes, which may emerge as a result of differences in market design, can be exploited to estimate unique IS. Putnins (2013) has developed the information leadership share, which uses both the IS and the CS to identify the first price series to impound new information. Hagströmer and Menkveld (2016) have modelled an empirical methodology to draw the information percolation network map.

Given that the US equity market data are currently timestamped to nanosecond precision, Hasbrouck (2017) has followed the heterogeneous autoregressive (HAR) approach used for realised volatility forecasting by Corsi (2009) to achieve high resolution in a natural time model. The random-walk volatilities, presumably long-term properties of the securities, are essentially unchanged in the passage to higher resolutions. Short-term effects, however, are much more clearly distinguished.

III. METHODOLOGY, DATA AND SAMPLE SELECTION

Our paper studies the market's contribution for the Regulated Market(NYSE Euronext Paris) and the Multilateral Trading Facilities (BATS and Chi-X Europe) to the price discovery dynamics for 28 CAC40 stocks after the implementation of MiFID. To compute the Information Shares (IS), we use the Eurofidai BEDOFIH database on NYSE Euronext Paris, which consists of high-frequency intraday data on the order flow for individual stocks and the IODs database for the Intraday data on BATS and Chi-X.

III.1. ***Measuring the Information Share (IS)***

When the fragmentation process accelerates, it is important to determine where the price information and discovery took place. We have used Hasbrouck (1995)'s econometric method to assess the contribution of the Euronext Paris, the BATS and the Chi-X to the innovations in the common implicit efficient price for 28 CAC40 stocks in December 2012, February 2013 and April 2013.

We focus on the Lit market, defined as the Limit Orders Books (LOB) for these three markets[7]. In multi-market trading and price discovery analyses, the LOB information is usually summarised by the quote midpoint. To estimate the consensual value of shares, we have computed the midpoint of the best bid and ask limit prices posted every second[8]. Consequently, we use the logarithm of the quote midpoint for each second of each market and each security. As no consolidated tape exists for the European equity markets (contrary to U.S. markets), it is not easy to synchronise the midpoint at the second level day per day for the three markets. The concept behind Hasbrouck's (1995) methodology is that a common efficient price supports the economic intuition that, subject to the transaction costs limits, cross-exchanged securities are bounded by arbitrage or by a short-term equilibrium. The contribution of a market to the price discovery is its Information Share (IS), which is defined as the proportion of the variance of the efficient price innovations attributable to this market.

Our article is based on the methodology developed by Hasbrouck (1995), Hasbrouck (2002), Hasbrouck (2002) and Hasbrouck (2003). This methodology is based on the fact that the quotes for a same security posted on the primary market and on alternative platforms are represented by a price vector, where:

$$p_t = [p_{1t} \;\; p_{2t} ... \;\; p_{nt}]' \tag{1}$$

In our model, each price represents the midpoint of the best limits associated with each market at the second level. A vector correction model of order K can be written as:

$$\Delta p_t = A_1 \Delta p_{t-1} + ... + A_K \Delta p_{t-k} + \gamma(z_{t-1} - \mu_z) + \mu_t \tag{2}$$

Where the A_i are square matrices of order n. The covariance matrix of the disturbances is :

$$Cov(\mu_t) = E\mu_t\mu_t' = \Omega \tag{3}$$

[7]Parlour (1998) provides the price dynamics in limit order markets. Noel (2011) has underlined that stored limit orders are shown as stacked along the price axis, with bid/buy (offer/sell) limit orders shown as negative (positive) stacks. The closer each stack is to the other side of the market establishes price priority, while closer to the price axis establishes time priority. New orders can be placed at any price in the LOB. However, only the unfilled portion of a limit order is stored in the LOB. Stored orders can only be removed from the LOB through either deletion/cancellation or trade matching with incoming orders.

[8]Many empirical microstructure studies of quote behavior use the quote midpoint as a summary measure (see Stoll (2000), Hasbrouck (1991) and Lee et al. (1993)).

The $\gamma(z_{t-1} - \mu_z)$ term contains the error correction coefficients. There are n-1 cointegrating vectors:

$$z_t = \begin{pmatrix} p_{1t} - p_{2t} \\ p_{1t} - p_{3t} \\ p_{1t} - p_{n-1,t} \end{pmatrix} = Fp_t, where \;\; F = [l - I_{n-1}] \tag{4}$$

For I_{n-1} the identity matrix of order n-1 and l a vector of ones; μ_z is the mean vector for the deviations; the elements of γ are the error correction coefficients. In the SAS programs, all parameters are estimated jointly using non-linear least squares. The vector moving average (VMA) representation of the model is :

$$\Delta p_t = B_0\mu_t + B_1\mu_{t-1} + B_2\mu_{t-2} + ..., where \;\; B_0 = I \tag{5}$$

The B coefficients may be calculated by forecasting the system subsequent to a unit perturbation. For example, suppose that $\Delta p_t = 0$ and $z_t = \mu_z$ for t=-1,-2,...

At time t=0, we suppose that there is a shock of $\mu_0 = [1 \;\; 0 \;\; ... \;\; 0]'$, where:

$$\Delta p_0 = \begin{pmatrix} 1 \\ 0 \\ ... \\ 0 \end{pmatrix} \tag{6}$$

$$\begin{aligned} z_0 &= \mu_z + F\Delta p_0 \\ \Delta p_1 &= A_1\Delta p_0 + \gamma z_0 \\ z_1 &= z_0 + F\Delta p_1 \\ \Delta p_2 &= A_1\Delta p_1 + A_2\Delta p_0 + \gamma z_1 \end{aligned} \tag{7}$$

The first column of B_0 is Δp_0; the first column of B_1 is Δp_1, and so forth. To obtain the second column of $B_0, B_1, etc.$, we forecast the system subsequent to an initial shock of $\mu_0 = [0 \; 1 \; 0 ... \; 0]$ and so forth. In this setting, we are interested in the cumulative price changes:

$$C_k = \sum_{i=0}^{k} B_k \tag{8}$$

These are the cumulative impulse response functions. The first columns of the C_k describe the prices subsequent to a shock in the first price. Of particular importance in the present setting is:

$$C_k = \lim_{k \to \infty} C_k \tag{9}$$

When the B's are written as the lag polynomial B(L), C is equivalent to B(1). The rows of C are all identical. Let c be any row of C, then the variance of the common random-walk component of the prices is:

$$\sigma_w^2 = c \Omega c' \tag{10}$$

Where c is a line of C, if Ω is diagonal, the covariance matrix Ω of innovations can be represented as :

$$\Omega = \begin{bmatrix} \sigma_1^2 & 0 & 0 \\ 0 & \sigma_2^2 & 0 \\ 0 & 0 & \sigma_n^2 \end{bmatrix} \tag{11}$$

The Information Share (IS) of the ith market is defined as :

$$IS_i = \frac{c_i^2 \sigma_i^2}{\sigma_w^2} \tag{12}$$

If Ω is not diagonal, then IS_i is not uniquely defined. Instead, we determine lower and upper bounds of IS_i by considering the Cholesky factorisations of all of the rotations (permutations) of the disturbances.

The model give in equation (1) is transformed by moving the lagged price level on the r.h.s, to obtain:

$$p_t = p_{t-1} + A_1 \Delta p_{t-1} + ... + A_K \Delta p_{t-k} + \gamma(z_{t-1} - \mu_z) + \mu_t \tag{13}$$

The impulse response functions are computed by setting :

$$p_{-1} = p_{-2} = ... = \begin{pmatrix} 0 \\ -\mu_z \end{pmatrix} \tag{14}$$

That is, the system is at rest. At time t=0, the system is shocked with a unit impulse to one of the prices. A unit shock to the jth price corresponds to setting :

$$p_0^j = e_j - \begin{pmatrix} 0 \\ \mu_z \end{pmatrix} \tag{15}$$

Where e_j is a vector of zeros with a 1 in the jth place. The system is then stepped forward from this point, with $\mu_1 = \mu_2 = ... = 0$, to obtain $p_1^j, p_2^j, ...$ Each of the p_t^j is an nx1 vector that specifies the prices at time t implied by the initial shock at time 0. We normalise these as:

$$p_t^{*j} = p_t^j + \begin{pmatrix} 0 \\ \mu_z \end{pmatrix} \tag{16}$$

The impulse response functions are then given as:

$$C_k = [p_k^{*1}\ p_k^{*2} ... p_k^{*n}] \tag{17}$$

If t indexes seconds then even a brief lag length will result in a high number of coefficients. The total number of coefficients is n^2K. To reduce the number of coefficients, Hasbrouck (1995) constrains a set of coefficients to be constant and constrains a set of coefficients to lie on a polynomial function of the lag. Polynomial distributed lags are implemented. The number of parameters by binding the a_i to lie on polynomials (in i). That is:

$$a_i = c_0 + c_1 i + c_2 i^2 + ... + c_d i^d \tag{18}$$

Where d is the maximum degree (2 or 3) of the polynomial. The full set of K is broken up into into smaller ranges, where the polynomial is fitted within each range. The ranges short at the near lags, and let the ranges become larger at the distant lags. Regarding the constant coefficients and the moving average, we constrain the a_i to be constant over pre-specified ranges (each 5 seconds). The ranges are shorter for the near lags. Consider the initial terms of the univariate autoregressive model:

$$\begin{aligned} \Delta p_t &= a_1(\Delta p_{t-1} + ... + \Delta p_{t-5}) + a_6(\Delta p_{t-6} + ... + \Delta p_{t-10}) + ... \\ &= 5a_1 movavg5(\Delta p_{t-1} + 5a_6 movavg5(\Delta p_{t-6}) + ... \end{aligned} \tag{19}$$

Where the moving average of order k is:

$$movavgk(x_t) = (x_t + x_{t-1} + ... + x_{t-k})/k \tag{20}$$

The constrained auto-regression therefore has an equivalent representation, the first two terms of which are:

$$\Delta p_t = a_1^* movavg5(\Delta p_{t-1}) + a_6^* movavg10(\Delta p_{t-1}) + ... \tag{21}$$

The VECM price discovery model is generally valid only within a trading session, as we would not normally expect overnight prices to follow the same dynamics. We have therefore estimated the model and all statistics for each day separately. The upper and lower bounds of the IS per day are computed in a set:

$$IS^k for k = 1, ..., D \tag{22}$$

Where D is the number of days in the sample. The mean estimator of IS averaged across days and the usual standard error of this mean can be estimated.

III.2. ***Limits around the Information Share (IS)***

The methodology of the Information Share (IS) metric has some advantages and disadvantages compared to other price discovery measures. De Jong (2002) has demonstrated that the Information Share (IS) and the common factor component weight (CS) are closely related, but the Information Share (IS) is the only measure to take into account the variability of the innovations in each market's price. Baillie et al. (2002) have noted that the Gonzalo and Granger model focuses on the components of the common factor and the error correction process, while the Hasbrouckś model considers each market's contribution to the variance of the innovations to the common factor.

According to Baillie et al. (2002), the two models provide similar results only if the residuals are uncorrelated between markets. When prices are contemporaneously determined, these contributions generally cannot be unambiguously determined. The solution is to set bounds on these proportions by imposing orthogonalisations on the cross-market innovation covariance matrix in Hasbrouck's (1995) methodology. These bounds may be tightened by estimating the specifications in a short time interval in order to reduce time-aggregation-induced correlation.

A short time interval has some inconveniences, however. First, it is necessary to propagate prices past the time of their initial posting. Second, a VECM specified for short intervals may have an excessively large number of parameters. This can be reduced, however, by using polynomial distributed lags. With a one-second interval, the number of parameters is roughly Mn^2, where M

is the maximum lag employed and n is the number of price series, since each equation in the VAR includes all variables through all lags. To manage these dimensions, polynomial distributed lags have been employed, with a constraint on coefficients to lie on segments that presented linear lags over lags at 1-5, 6-10, 11-30, and 31-60 seconds.

Moreover, Yan and Zivot (2010) have highlighted that the CS, in conjunction with the IS, can help sort out the confounding effects of two types of shocks (new information versus liquidity shocks). The IS only accounts for the immediate (one-period) response of market prices to the news innovation, which implies that the IS estimates based on high sampling frequencies may be distorted by transitory frictions and may miss important price discovery dynamics. Hasbrouck (2017) has followed the heterogeneous autoregressive (HAR) approach used by Corsi (2009) for realised volatility forecasting to achieve a high resolution in a natural time model.

Finally, while Hasbrouck's (1995) methodology addresses issues that concern the price discovery in a spatially fragmented environment, Yu et al. (2010) have theoretically addressed the price discovery in a spatially consolidated but temporally fragmented environment, where the adaptive valuation behaviour of investors with divergent expectations leads to the endogenous determination of share values given information concerning the state of the world. Being protracted, the process of discovering equilibrium values involves price discovery noise and an accentuation of volatility, especially at market openings and after news events. In our paper, we do not look at endogenous issues in the trading process.

In our paper, we focus on the immediate (one-period) response of market prices to the news innovation at one-second intervals, as well as Hasbrouck (1995). We choose to study the Information Share (IS) because it is based on the assumption that there exists an implicit common efficient price, shared by the different trading venues. Moreover, this metric is useful in a fragmented trading environment to know which is the first trading venue to incorporate the new information.

III.3. ***Data and sample selection***

Our analysis focuses on the French equity market. The CAC40 Index is a benchmark French stock market index. The index represents a capitalisation-weighted measure of a sample of 40 equities that are selected from the top 100 highest market capitalisations on the Euronext Paris, computed in euros every 15 seconds during Euronext regulated trading hours. NYSE Euronext Paris is the Regulated Market, where trading has taken place in a computerised limit order environment on the UTP since 2009. The list of the 28 individual stocks studied is available in the

Appendix (Table A.3). As stock markets are becoming automated, the time at which orders are submitted, modified or cancelled on the marketplace is now very short. One feature of the data is that the precision of order timestamps is of a microsecond, referred to as ultra-high-frequency data by Engle (2000).

We need to choose a common post-period, where the data are available to compare the Information Share (IS) metric between the Regulated Market, NYSE Euronext Paris, and the Multilateral Trading Platforms (MTFs). Since January 2012, Eurofidai has led the Base Européenne de Données Financières à Haute Fréquence (BEDOFIH) project, which aims to create a European intra-day financial database. One feature of the data is that the precision of timestamp orders is of a microsecond. Engle and Russell (2004) have emphasised that such data contain tens of thousands of transactions or posted quotes in a single day, time stamped to the nearest second. The analysis of these data is complicated by irregular temporal spacing, diurnal patterns, price discreteness and complex, often very long-lived dependence. Ait Sahalia and Jacod (2014) have covered the mathematical foundations of stochastic processes, described the primary characteristics of high-frequency financial data, and presented the asymptotic concepts that their analysis relies on.

We compute the Information Share (IS) metric based on the spread midpoint from the Limit Order Book of NYSE Euronext Paris from the BEDOFIH AMF - NYSE Euronext Paris High Frequency database and from the Limit Order Books of BATS and Chi-X Europe from the IODs BATS Chi-X intra-day database. The aim is to compare the Information Share (IS) metric for the CAC40 stocks between the Regulated Market and the Multilateral Trading Platforms in December 2012, February 2013 and April 2013 to study the contribution of these different trading venues to the price discovery dynamics and to the discovery of the common implicit efficient price. We choose the 28 CAC40 stocks, where it is possible to synchronise data on the three trading venues.

These three months correspond to a highly fragmented environment. BATS Chi-X Europe is a London-based, order-driven pan-European equity exchange that has been a subsidiary of BATS Global Markets since 2011 introduced by MiFID. Initially two separate entities, Chi-X Europe was the first pan-European multilateral trading facility (MTF) for equity markets to be launched in 2007 after the implementation of MiFID and BATS Europe was launched in 2008.

The Multilateral Trading Facilities (MTFs) are low latency, low cost alternative to exchange traded equities and exchange-traded funds (ETFs) that are listed on primary exchanges such as the London Stock Exchange, Frankfurt Stock Exchange, Euronext and OMX. The continuous trading for BATS and Chi-X Europe begins at 08:00 AM and closes at 04:30 PM, indicated in UK time.

Data on the BATS Chi-X Europe are based on the TCP PITCH protocol to receive real-time full depth of book quotations and execution information direct from the BATS Chi-X. The TCP PITCH protocol used by the BATS on its European trading platforms (the BXE and the CXE) is very similar to the PITCH protocol used in the U.S. markets, but with the addition of new long-form message types that can accommodate larger order sizes, wider symbols and finer grained prices. For bandwidth efficiency, long-form messages are only sent if required. The PITCH cannot be used to enter orders based on the FIX specification. All visible orders and executions are reflected via the PITCH feed. Each PITCH message reflects the addition, deletion, or execution of an order in the system. All orders and executions are anonymous, and do not contain the identity of the participant.

NYSE Euronext Paris is the Regulated Market within the meaning of the Markets in Financial Instruments Directive (MiFID) for the CAC40 stocks that are selected. NYSE Euronext operates Euronext Securities Markets in Amsterdam, Brussels, Lisbon, London and Paris via its five Euronext Market Undertakings. Trading takes place in a computerised limit order environment. The market mechanism was known initially as the CAC (Cotation Assitée en Continu) in the 80's as an adaptation of the CATS system from the Toronto Stock Exchange. Afterwards the NSC (Nouveau Système de Cotation or Supercac) was implemented in the 90's to be replaced by the Universal Trading Platform (UTP) in 2009 when Euronext merged with the NYSE. The trading hours for NYSE Euronext Paris are presented in Fig. 1.

Fig. 1
Trading time on NYSE Euronext Paris (indicated in France time). To facilitate price discovery, NYSE Euronext Paris has always relied on a transparent pre-opening phase and on a call auction to open continuous markets.

The pre-opening phase on Euronext Paris starts at 7:15 am	
Opening price	09:00 AM
Session	09:00 AM to 05:30 PM
Pre-market closure	05:30 PM to 05:35 PM
Fixing at market closure	05:35 PM
Trading At Last (TAL)	05:35 PM to 05:40 PM
Double Call Auction	11:30 AM to 12:00 AM
Double Call Auction	04:30 PM to 05:00 PM
Simple Call Auction	03:00 PM and 03:00 PM to 03:30 PM

On NYSE Euronext Paris, the continuous trading takes place from 09:00 AM to 05:30 PM. The market opens at 09:00 AM with a batch auction and trading takes place on a continuous basis until 05:30 PM for continuously traded securities. The Trading At Last (TAL) Phase is from 05:35 PM to 05:40 PM. The double auction of traded securities on Brussels, Lisbon, Paris and Amsterdam is from 11:30 AM to 04:30 PM and the Trade Confirmation System (TCS) reporting tool for off-order book trades from 07:15 AM to 07:00 PM. For auction-traded securities, the orders are managed through an order book that operates continuously from 07:00 AM to 06:00 PM, but are matched just twice daily. Member firms are allowed to act as market makers for certain medium-sized stocks and in the case of block trades to enhance liquidity. The descriptive statistics for our sample are provided in the Table 1[9].

Table 1
Descriptive statistics
Our sample concerns 28 individual CAC40 stocks on NYSE Euronext Paris, BATS and Chi-X Europe. The description regards the average number of monthly observations per trading venue, the median, the mean, the minimum and maximum price and the standard deviation for the prices with the step method and for the returns in December 2012, February 2013 and April 2013.

	Observations	**Median**	**Minimum**	**Maximum**	**Mean**	**Standard deviation**
price_NYSE Euronext Paris	355394	47.46	23.74	322.58	47.45	1.42
price_BATS Europe	355393	47.46	36.53	54.47	47.44	0.68
price_Chi_X Europe	355395	47.46	4.72	1742.08	47.45	3.62
y_NYSE Euronext Paris	355393	0.00	-1.63	1.63	0.00	0.01
y_BATS Europe	355392	0.00	-0.35	0.35	0.00	0.00
y_Chi_X Europe	355394	0.00	-4.12	4.12	0.00	0.02
price_NYSE Euronext Paris	413505	49.24	14.02	1710.49	49.26	5.26
price_BATS Europe	413504	49.24	35.33	114.62	49.24	1.34
price_Chi_X Europe	413505	49.24	7.59	1878.68	49.25	3.95
y_NYSE Euronext Paris	413504	0.00	-2.13	2.13	0.00	0.01
y_BATS Europe	413503	0.00	-0.55	0.54	0.00	0.00
y_Chi_X Europe	413504	0.00	-3.69	3.68	0.00	0.01
price_NYSE Euronext Paris	471972	50.32	31.86	1153.94	50.42	2.98
price_BATS Europe	471969	50.28	38.00	58.85	50.37	1.37
price_Chi_X Europe	471973	50.30	16.92	4165.91	50.45	7.66
y_NYSE Euronext Paris	471971	0.00	-1.44	1.44	0.00	0.01
y_BATS Europe	471968	0.00	-0.40	0.39	0.00	0.00
y_Chi_X Europe	471972	0.00	-2.76	2.76	0.00	0.01

[9]We replace the missing values with the most recent observation in order to deal with the missing values on Chi-X and BATS for some CAC40 stocks. This procedure corresponds to the step method with the SAS program. This methodology is also used by Hasbrouck (1995) to compute the Information Shares (IS).

In this paper, we use the add order messages that represent a newly accepted visible order on the BATS Chi-X book. If an order is repriced within the BATS matching engine, a cancel order message is immediately followed by an add order message with the same order ID as the original order. For data on NYSE Euronext Paris, we have used the date of the entry of the order, that is, the date on which the order entered the central order book.

The comparison of market databases between London and Paris is not easy because the communication protocols are quite different and the time references as well. Moreover, each market has it own trading rules book. We have used the limit orders added to the order book on the three markets (Euronext Paris, BATS and Chi-X) at one-second level, based on the computed spread mid-point of the best bid and ask limit prices posted every second for December 2012, February 2013 and April 2013. In the three markets, the synchronisation occurs at one-second levels by adjusting the time of the NYSE Euronext Paris to that of London from 08:30:00 to 16:30:00. The time series analysis has only been applied to the continuous trading session. Hasbrouck (1995) has highlighted that the spread midpoint is a summary measure of the consensual value.

If the price innovations are correlated across markets, then Ω will not be diagonal. To minimize the correlation and to bound the effects of the correlation, Hasbrouck (1995) shortens the interval of observation to minimize the correlation. Hasbrouck (1995) underlines that most of the contemporaneous correlation is due to time aggregation because the market prices usually change sequentially, where a new price is posted in one market and then the other markets respond and if the observation interval is so long that the sequencing cannot be determined, the initial change and the response will appear to be contemporaneous. The specifications in this paper are estimated with one-second sampling intervals. However, this will not eliminate all the contemporaneous correlation because two markets may still report simultaneous price changes. Consequently, the triangularization of the covariance matrix is used to establish upper and lower bounds, when no unique values may be found for the Information Shares (IS).

IV. RESULTS

IV.1. Spatial fragmentation in the Post-MiFID context

With the introduction of the MiFID in 2007 and the suppression of the rule of national orders concentration for execution, a fragmentation trend has emerged in the post-MiFID environment.

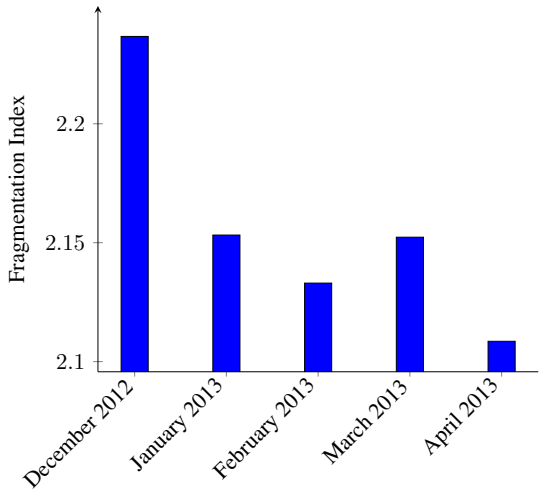
An increasing volume of trading in Euronext Paris-listed equities has moved from Euronext Paris to the Multilateral Trading Facilities, such as BATS, Chi-X and Turquoise. These venues reflect diverse market structures and regulatory constraints. In Fig. 2, we compute the Fidessa Fragmentation Index (FFI) for the three months of our study, there is a significant evolution of the FFI for the 28 CAC40 firms in the post-MiFID period. This measure of the spatial fragmentation assesses the concentration of orders within a trading venue based on the Herfindahl Index (HI). The FFI is defined as the inverse of the sum of the squares of the market shares of each individual trading venue. As such, it can range from 1 to Vn moving from all trading residing in only one venue to an even amount of trading across Vn venues, where Vn is the number of venues trading the stock. Thus, the FFI will range from one for a single execution venue to Vn, where Vn is the total number of venues trading the stock and the FFI corresponds to this metric to assess the level of spatial fragmentation :

$$FFI = \frac{1}{HerfindahlIndex} = \frac{1}{\sum_{i=1}^{N}(MarketShare_i)^2} \tag{23}$$

The rationale behind taking the inverse of this value is that we are measuring a move away from the status quo of a single stock exchange with the monopolistic hold on liquidity (in this case, the FFI is one) to a fragmented marketplace with a number of new trading venues taking the market share (in this case, the FFI is more than one). The major benefit of FFI in relation to other such measures is that it gives more weight to venues with the largest market share. The FFI was developed to give a complete picture of how trading in a given stock is broken down across the lit venues with the orders on-book, the dark pools with the orders that are not visible pre-trade, the systematic internalisers and the bilateral off-book trades with the trades executed over the counter and reported to one of the reporting venues. The market share of each venue is calculated as the percentage of the total consideration traded by that venue over the total consideration traded by all the venues in the supported indices. However, for Europe, the USA, Canada and Japan, only the order book trades, termed the Lit trades, are included in the FFI calculations.

Before the implementation of the MiFID, the FFI was one on the Lit market. In Fig. 2, we observe that the FFI was on average above two for our sample in 2012-2013, which means that trading no longer belonged to the regulated market, NYSE Euronext Paris on the Lit market. This result confirms the existence of spatial fragmentation after the implementation of MiFID. Two trading venues are necessary on average to rebuild the liquidity for the CAC40 stocks.

Fig. 2
Evolution of the Fidessa Fragmentation Index (FFI) for the CAC40 Firms in the post-MiFID environment.



In Table 2, we observe that BATS Chi-X CXE, BATS Chi-X BXE and Turquoise are the three main MTFs for the Lit Market in terms of market shares, after NYSE Euronext Paris. BATS Chi-X BXE and BATS Chi-X CXE are two different Lit Order Books (LOBs); the first one is BATS and the second one Chi-X Europe. We observe clearly in Table 2 that BATS Chi-X CXE, BATS Chi-X BXE and Turquoise are the three main MTFs for the Lit Market in terms of market shares for our sample, after NYSE Euronext Paris.

Table 2
Evolution of Market Shares for the Lit market (Percentage) for the CAC40 Firms in the post-MiFID environment.

Market Share (Lit)	**December 2012**	**February 2013**	**April 2013**
NYSE Euronext Paris	***34.06%***	***38.09%***	***36.26%***
Bats Chi-X CXE	***10.42%***	***11.93%***	***11.76%***
Turquoise	3.33%	5.07%	5.01%
Bats Chi-X BXE	***2.17%***	***2.41%***	***1.97%***
Equiduct	0.88%	0.92%	0.73%
Others	0.79%	0.65%	0.20%
Total	***50.86%***	***59.06%***	***55.58%***

Instinet established Chi-X Europe in 2007. When it was launched, Chi-X Europe was the first MTF introduced in Europe as an alternative trading venue in anticipation of the implementation of the MiFID. The BATS Europe was established in 2008 by U.S. exchange operator BATS Global

Markets. By 2010, BATS Europe was the second-largest MTF, behind Chi-X Europe. In 2011, BATS Global Markets bought Chi-X Europe, which has been authorised by the Financial Services Authority (FCA) to operate an MTF for the trading of pan-European securities, as defined under the MiFID. The BATS Chi-X Europe is a London-based, order-driven pan-European equity exchange that has been a subsidiary of BATS Global Markets since 2011. It was initially two separate entities (the BATS and the Chi-X).

According to FCA (2010), Chi-X Europe meets the same level of regulatory standards as traditional exchanges and receives the same level of supervision, even though MTFs sit under a slightly different legal regulatory regime. However, the Multilateral Trading Facilities (MTFs) are low-latency, low-cost alternative to exchange-traded equities and exchange-traded funds that are listed on primary exchanges such as the LSE, the Frankfurt Stock Exchange, the Euronext and the OMX. It used to be an MTF but in May 2013, the BATS Chi-X Europe also received the Recognised Investment Exchange (RIE) status from the Financial Services Conduct Authority (FCA) and was from then on authorised to operate an RM for primary listings alongside its existing business.

*IV.2. **Information Shares (IS): Determining the contributions of Regulated Market and Multilateral Trading Facilities to the price discovery dynamics***

We select the CAC40 stocks because the competition for order flow between exchanges is mainly in large capitalisation stocks (see Hasbrouck (1995)). This study is based on the spread midpoint based on the best limits at one-second intervals. According to Hasbrouck (1995), transaction prices may suffer autocorrelation problems induced by infrequent trading. With relatively infrequent trades, there is a risk of obsolescence of the last prices and a lack of information, although the quotes may be updated in the absence of trades. The exchange that is first aware of the transaction should reflect it in the quotes. In basing the computation of the Information Shares (IS) solely on quotes, the hypothesis is that the cross-market transaction effects are negligible.

The Information Shares (IS) have been estimated only during daily continuous trading sessions across a day; they do not include the overnight returns. The upper and lower bounds of the IS of the three markets have been computed for each stock. We have observed that the lower and upper bounds at the level of one second differ for the maximum and minimum Information Shares (IS). According to Hasbrouck (1995), these bounds differ only to the extent that there is a contemporaneous correlation observation between the quote movements of the different markets with a one-second frequency of observation.

The cointegration model described in the last section was estimated for all 28 stocks in the sample. The contribution of each market to the price discovery dynamics have been computed through the Information Share (IS) in Table 3. The details on a stock by stock basis are available in Tables A.4, A.5 and A.6 in the Appendix for the period: December 2012, February 2013 and April 2013. The contributions are significantly different from one stock to another and change significantly from one month to another. Table 3 gives us a summary of the Information Shares (IS) across the months for our 28 CAC40 stocks.

Table 3
Evolution of monthly average Information Shares (IS) (percent) of each market (NYSE Euronext Paris, BATS and Chi-X Europe) for the 28 CAC40 stocks based on the step methodology. The maximum and the minimum Information Shares (IS) correspond to the upper and lower bounds, when no unique values may be found for the Information Shares (IS). The mean is computed for each month.

		Maximum			**Minimum**		
	Information Share	**Chi-X**	**BATS**	**Euronext Paris**	**Chi-X**	**BATS**	**Euronext Paris**
December 2012	Maximum IS	0.830	0.924	0.413	0.694	0.896	0.327
	Mean IS	**0.335**	**0.632**	**0.137**	**0.251**	**0.542**	**0.106**
	Minimum IS	0.045	0.178	0.006	0.026	0.065	0.004
February 2013	Maximum IS	0.720	0.942	0.437	0.544	0.916	0.356
	Mean IS	**0.282**	**0.682**	**0.137**	**0.197**	**0.595**	**0.111**
	Minimum IS	0.028	0.286	0.008	0.016	0.145	0.006
April 2013	Maximum IS	0.796	0.905	0.570	0.685	0.873	0.527
	Mean IS	**0.307**	**0.568**	**0.211**	**0.238**	**0.498**	**0.181**
	Minimum IS	0.002	0.144	0.000	0.001	0.077	0.000
Three-months average	Maximum IS	0.782	0.924	0.473	0.641	0.895	0.403
	Mean IS	**0.308**	**0.628**	**0.162**	**0.229**	**0.545**	**0.133**
	Minimum IS	0.025	0.203	0.005	0.015	0.096	0.003

We observe that BATS has the highest average Information Share (IS) in comparison to NYSE Euronext Paris and Chi-X Europe. On BATS, the Information Share (IS) averages between 54.5 percent and 62.8 percent for the 28 CAC40 stocks on the three-months period. For Chi-X Europe, it averages between a maximum of 30.8 percent and a minimum of 22.9 percent, while for the Euronext Paris, it is between 16.2 percent and 13.3 percent. Across the months, the results of the contributions to price discovery are, on average, quite similar.

Comparing each market's share, we have observed that NYSE Euronext Paris has the biggest market share, with 36 percent of Lit market, which represents an average of 55 percent of total trading for the three months studied. BATS and Chi-X Europe collect, on average, 2.1 percent and 11 percent of market shares, respectively.

This result confirms our first hypothesis and prior research. Riordan et al. (2011) indicate that the Multilateral Trading Facilities (MTFs) contribute substantially to price discovery and that they might even be the price leading venue predominantly translating information into market prices. This outcome surprises since Multilateral Trading Facilities (MTFs) have lower market shares than traditional exchanges. Furthermore, Clapham and Zimmermann (2016) underline that this finding contradicts the conclusions based on the analyses of internationally cross-listed stocks, which reveal that price discovery predominantly occurs on the home markets, which are also more liquid in terms of market share.

However, Hasbrouck (1995) has underlined that it is relatively expensive for a market to provide a price discovery mechanism. While balancing the supply and demand is costly to provide, it is relatively cheap to provide order matching or crossing functions once a price has been determined and publicised. By observing other markets, the Multilateral Trading Facilities (MTFs) may determine their prices by appropriating the informational value of the price determined in the primary regulated market, such as NYSE Euronext Paris.

In the presence of spatial fragmentation, the risk is that some trading places will receive more buy orders and others will receive more sell orders. If sufficient order flow is removed from the regulated and transparent market, the regulated market may no longer be able to ensure the price discovery efficiency because the prices and equilibrium quantities would not have been discovered by the market as a whole. Moreover, the free riding issue is one risk with spatial fragmentation. A free-riding problem exists when the Multiple Trading Facilities (MTFs) can trade the same securities, the satellite markets can also offer fast execution at low commissions by taking advantage of price discovery provided by the main regulated market center. The risk around the market shares may be that the cost of producing the price information may not be recovered with its sale, all the more in the case of a significant cancellation of orders. The table A.7 in the Appendix gives an indication of cancellations for one day on NYSE Euronext Paris.

The question of market quality is important and which regulation should promote this outcome at a European level is challenging. O´Hara and Ye (2011) defines market quality as a market's ability to meet its dual goals of liquidity and price discovery and they underline that while US

equity markets are spatially fragmented, they are virtually consolidated due to the development of sophisticated order routing combined with the existence of a consolidated tape and the trade-through rule in the US equity markets that have resulted in a single virtual market with many points of entry. Consequently, this allows the positive benefits of greater competition and specialization to prevail without the negative effects that accompany the loss of consolidation.

In US markets, the NYSE and the regional exchanges are electronically linked in that all quotes and trades are disseminated by the Consolidated Tape Association, which is a central transmission authority. In addition, the Intermarket Trading System (ITS) provides a direct communication for orders and messages between the market makers at different exchanges, and trade-throughs[10] are prohibited. With such a structure, the different exchanges compete for the incoming order flow by posting aggressive quotes. Hasbrouck (1995) has highlighted that alternative market makers execute orders at the best prevailing intermarket quote (generally the NYSE quote) on the US equity market. This consequently leaves a disproportionate concentration of informative trading occurring at the NYSE.

The regulations to protect against trade-throughs were first passed in the 1970s for the US equity markets and were later improved upon in Rule 611 of Regulation NMS that passed in 2007. The Reg NMS has the following objectives: the economically efficient execution of securities transactions, the fair competition among broker-dealers, among exchange markets, and between exchange markets and non-exchange markets; the price transparency; the best execution of investor orders; and an opportunity, consistent with economic efficiency and best execution, for investor orders to meet without the participation of a dealer.

SEC (2015) provides a Memorandum on the Rule 611 of Regulation NMS. The rule 611 promotes inter-market price protection by restricting trade-throughs to minimize the potentially adverse effects of fragmentation, which is still defined as the execution of trades on one venue at prices that are inferior to publicly displayed quotations on another venue.

O´Hara and Ye (2011) underline that in Europe, the development of multilateral trading facilities (MTFs) is accelerating the movement of trades away from established exchanges. However, the lack of a consolidated tape collecting price feeds from all execution venues greatly inhibits the ability to establish market-wide trade-through protection.

[10]It corresponds to the execution of orders at prices inferior to a quote advertised anywhere on the ITS.

O´Hara and Ye (2011) point that without such protection, it is hard to see how a single virtual market can emerge. In the European equity markets, the risk of trade-through remains important (see the study of Foucault and Menkveld (2008)). The current revision of MiFID, through MiFID II and MiFIR should provide the trade-through protections, and unified trade and price reporting protocols to avoid that fragmentation is detrimental on the market quality in terms of liquidity and price discovery efficiency. This requirement should be reinforced with the Brexit to ensure the equivalence and the absence of regulatory arbitrage for a same security exchanged on the Multilateral Trading Facilities (MTFs) in London and on the Regulated Market, NYSE Euronext Paris.

It is important to structure the communication protocols and technological connections between the different market participants through regulations at the European level. At the European level, the consolidated tape should be introduced in 2018 with MiFID II, it was planned with MiFID but it was not implemented. Moreover, with MiFID II, the trading venues must make pre- and post-trade information available to the public separately and on a reasonable commercial basis and ensure non-discriminatory access to it. Information must be made available free of charge 15 minutes after publication. The offering of data, including the level of disaggregation required, will be specified in the RTS. Trading venues must also make their publication arrangements available to investment firms fulfilling their transparency obligations, on a reasonable commercial and non-discriminatory basis.

In the absence of consolidated tape, the synchronisation between markets at the trade and quote level is not easy. Comparing markets when data are missing or there have been no transactions is consequently complex. Moreover, the time resolution in a context of increasing High Frequency Trading (HFTs) is important. A precise definition regarding the role of high frequency traders, market makers and the order-cancellation ratio accepted by the regulators is important to ensure the market's quality at the European level.

V. Conclusion and policy implications

Since 2007, the MiFID has changed the European equity markets, with an increased fragmentation. Its main objectives were to increase investor protection and open the competition among exchange places. These concepts introduced the best execution principle for investors. Even while this directive has fixed rules regarding the pre- and post-transparency, it constitutes a list of principles that each market participant has to interpret and apply.

In the current framework, the best execution principle is complex to assess in practice. First, because it relies on several criteria such as price, costs, speed, likelihood of execution and settlement, size, the nature of the transaction or any other consideration relevant to the execution of the order. In the U.S. equity market, the only criteria is the price improvement according to the Reg NMS, which makes the best execution quality easier to assess through supervision at the US national securities market level by the SEC. According to the SEC requirement, brokers must guarantee the best available ask or bid price when they buy or sell for customers on the US equity market, which corresponds to the National Best Bid and Offer (NBBO)[11]. In Europe, the MiFID has opened competition between exchange places with the introduction of MTFs such as BATS, Chi-X and Turquoise, without the creation of a consolidated tape, contrary to the US equity markets.

Buy-side traders are consequently suffering from a decline in the quality of market data that drives their investment decisions. Without the data on previous trades in a stock, it is almost impossible for institutional investors to determine whether they have paid the best price for a stock, both prior to making an investment decision and after a trade has been completed. The creation of a consolidated tape for equities is one of the most important market structure changes for the buy side under the MiFID II. This should be implemented in 2018.

Within this framework of no consolidated tape, our paper has studied the contributions of Euronext, BATS and Chi-X to the price discovery of the CAC40 stocks by synchronising the best limit midpoints for each market at the second level. The aim is to determine the contributions of the Regulated Market NYSE Euronext Paris and of the Multilateral Trading Platforms, BATS and Chi-X Europe, based on Hasbrouck's (1995) methodology. The principle of this econometric analysis of a single security trading in multiple markets is that the price differences between markets do not diverge without bound. The common factor is the implicit efficient price of the security, which is statistically defined as the random-walk component of the prices from the diverse markets.

[11] According to Hasbrouck (2010), at a given point in time the best bid (offer) is the maximum (minimum) bid (offer), taken over the set of current bids posted by all venues until one of the bids posted by any of the venues changes; then the maximum is recomputed. Incorrect sequencing within a reporting exchange's records is much more serious than incorrect sequencing between exchanges.

According to Hasbrouck (1995), the innovation variance in this random walk is a measure of the information intensity of the efficient price process, where the Information Share (IS) of a market is defined as the proportion of this innovation variance that can be attributed to that market. Our analysis was achieved for 28 CAC40 stocks, high-volume stocks that have significant trading activity away from the Euronext. The results suggest that price discovery appears to be concentrated at BATS: the average Information Share is between 54.5 percent and 62.8 percent, on average, for the 28 stocks for the three months studied. For most of the CAC40 stocks, this is larger than the market share of BATS.

From a perspective of price discovery efficiency, as the Multilateral Trading Facilities BATS Chi-X contributes significantly to the price discovery, it is important to maintain it. Nevertheless, in the current context of Brexit, the question of performance, viability and stability of the different markets are the most important for the future. From the point of view of financial regulation, the risk is that different countries will adopt different rules regarding the duty of the best execution of orders, the consolidation of market data, the distribution of information concerning the execution quality of orders and the legal and institutional organisation of the protection of investors. The revision of the MiFID directive under the MiFID II and the MiFIR will come into effect in 2018.

The UK may decide to keep the MiFID II regime to access the EU market based on equivalence through the third-country provisions of the MiFID II and the MiFIR. An equivalence decision has to be resolved by the European Commission; however, the MiFIR only provides third-country firms a passport for professional clients and ECPs, not businesses with retail clients. This still depends on the law of individual Member States, unless it is carried out through reverse solicitation but it is not so easy to ensure it on the long run.

Moreover, an inappropriate market organisation at the European level may increase the market manipulations and decrease the market quality. The main risk concerns losing convergence and coherence between the financial regulations in the various economic zones. This could introduce competitive distortions and open the way for regulatory arbitrage. At this level, the question of how markets will be organised to ensure market quality through regulation in order to avoid arbitrage and to insure the viability and stability of the financial markets at an international level is important for the future. The supervision principle with the MiFID and MiFID II is that the ESMA should supervise the regulated market in accordance with the European harmonised rules. Moreover, the Alternative platforms should comply with the rules governing the Regulated Markets in order to avoid regulatory arbitrage for the same securities.

The MiFID II should provide the trade-through protections, and unified trade and price reporting protocols to avoid that fragmentation is detrimental on the market quality in terms of liquidity and price discovery efficiency. Consolidation at the spatial and temporal levels and the definition of harmonised rulebooks should be priorities in the revision of the MiFID, without harming the fragmentation that encourages competition and price discovery efficiency between the different market participants[12].

[12]As mentioned by AMF (2015), on 4 December 2015, the Enforcement Committee handed down a penalty of 5 million euros to Virtu Financial Europe for market manipulation and ignoring Euronext market rules. It also handed down a penalty in the same amount to Euronext Paris for failing to meet its obligation to operate with neutrality and impartiality, in accordance with market integrity. The company's strategy consisted of identifying the best bid or offer price for a security on a platform, usually Euronext, and then placing four passive orders at a slightly different price on four other platforms; as soon as one of the orders was executed, giving rise to a gain equal to the difference in price, it would then cancel the remaining three orders. These operations were carried out within a few milliseconds and the algorithm used by Madison Tyler Europe constantly placed and cancelled orders in the various order books in line with the best bid or offer prices. The two non respected articles of the AMF General Regulation were: Article 631-2 because of the time lag before other participants were notified of those orders, a significant proportion of which no longer existed and Article 631-1 due to a dominant position giving rise to unfair trading conditions for other participants. Moreover, the Article 8105/1 of the Euronext Market Rules was not respected, which forbid market members from 'engaging in practices which may cause degradation of the service or give rise to a disorderly market'. No penalties regarding the ratio of the number of orders placed to the number of trades executed in a given security on a given day, at that time set by Euronext at 100 to 1.

VI. Bibliography

[1] Yacine Ait Sahalia and Jean Jacod. *High-Frequency financial econometrics*. Princeton University Press, 2014.

[2] Michael Aitken, Haoming Chen, and Sean Foley. The impact of fragmentation, exchange fees and liquidity provision on market quality. *Journal of Empirical Finance*, 41:140–160, 2017.

[3] AMF. Enforcement committee. http://www.amf-france.org, 2015. [Online; accessed 07-April-2018].

[4] Richard T Baillie, G Geoffrey Booth, Yiuman Tse, and Tatyana Zabotina. Price discovery and common factor models. *Journal of financial markets*, 5(3):309–321, 2002.

[5] Michael J Barclay and Terrence Hendershott. Price discovery and trading after hours. *The Review of Financial Studies*, 16(4):1041–1073, 2003.

[6] Michael J Barclay, Terrence Hendershott, and D Timothy McCormick. Competition among trading venues: Information and trading on electronic communications networks. *The Journal of Finance*, 58(6):2637–2665, 2003.

[7] Paul Bennett and Li Wei. Market structure, fragmentation, and market quality. *Journal of Financial Markets*, 9(1):49–78, 2006.

[8] Bruno Biais. Price formation and equilibrium liquidity in fragmented and centralized markets. *The Journal of Finance*, 48(1):157–185, 1993.

[9] Ernest Bloch and Robert A Schwartz. The great debate over NYSE rule 390. *The Journal of Portfolio Management*, 5(1):5–8, 1978.

[10] Bloomberg. MiFID II solutions guide. https://spotlight.bloomberg.com, 2017. [Online; accessed 29-August-2017].

[11] G Geoffrey Booth, Raymond W So, and Yiuman Tse. Price discovery in the german equity index derivatives markets. *Journal of Futures Markets*, 19(6):619–643, 1999.

[12] Jonathan Brogaard, Terrence Hendershott, and Ryan Riordan. High-Frequency trading and price discovery. *Review of Financial Studies*, 27(8):2267–2306, 2014.

[13] Guglielmo Maria Caporale and Alessandro Girardi. Price discovery and trade fragmentation in a multi-market environment: Evidence from the MTS system. *Journal of Banking & Finance*, 37(2):227–240, 2013.

[14] Bhagwan Chowdhry and Vikram Nanda. Multimarket trading and market liquidity. *The Review of Financial Studies*, 4(3):483–511, 1991.

[15] Benjamin Clapham and Kai Zimmermann. Price discovery and convergence in fragmented securities markets. *International Journal of Managerial Finance*, 12(4):381–407, 2016.

[16] Kalman Cohen. Order flow and the quality of the market. *Market Making and the Changing Structure of the Securities Industry*, 1985.

[17] Kalman J Cohen, Steven F Maier, Robert A Schwartz, and David K Whitcomb. An analysis of the economic justification for consolidation in a secondary security market. *Journal of Banking & Finance*, 6(1):117–136, 1982.

[18] Fulvio Corsi. A simple approximate long memory model of realized volatility. *Journal of Financial Econometrics*, 7(2):174–196, 2009.

[19] Frank De Jong. Measures of contributions to price discovery: a comparison. *Journal of Financial markets*, 5(3):323–327, 2002.

[20] Frank De Jong and Barbara Rindi. *The microstructure of financial markets*. Cambridge University Press, 2009.

[21] Frank De Jong and Peter C Schotman. Price discovery in fragmented markets. *Journal of Financial Econometrics*, 8(1):1–28, 2009.

[22] Kathryn L Dewenter, Xi Han, and Jennifer L Koski. Who wins when exchanges compete? Evidence from competition after euro conversion. *Review of Finance*, 2017.

[23] Ian Domowitz, Jack Glen, and Ananth Madhavan. International cross-listing and order flow migration: Evidence from an emerging market. *The Journal of Finance*, 53(6):2001–2027, 1998.

[24] Robert F Engle. The econometrics of ultra-High-Frequency data. *Econometrica*, 68(1):1–22, 2000.

[25] Robert F Engle and Jeffrey R Russell. Analysis of High-Frequency financial data. *Handbook of Financial Econometrics, Yacine Ait Sahalia (ed), forthcoming*, 2004.

[26] Cheol S Eun and Sanjiv Sabherwal. Cross-border listings and price discovery: Evidence from us-listed canadian stocks. *The Journal of Finance*, 58(2):549–575, 2003.

[27] FCA. The market regulatory agenda. http://www.fsa.gov.uk/pubs/other/markets.pdf, 2010. [Online; accessed 07-April-2018].

[28] Thierry Foucault and Albert J Menkveld. Competition for order flow and smart order routing systems. *The Journal of Finance*, 63(1):119–158, 2008.

[29] Thierry Foucault, Marco Pagano, and Ailsa Röell. *Market liquidity: Theory, evidence, and policy*. Oxford University Press, 2013.

[30] Jean-Francois Gajewski and Carole Gresse. Centralised order books versus hybrid order books: A paired comparison of trading costs on NSC (Euronext Paris) and SETS (london stock exchange). *Journal of Banking & Finance*, 31(9):2906–2924, 2007.

[31] Kenneth D Garbade and William L Silber. Dominant and satellite markets: A study of dually-traded securities. *The Review of Economics and Statistics*, pages 455–460, 1979.

[32] Kenneth D Garbade and William L Silber. Best execution in securities markets: An application of signaling and agency theory. *The Journal of Finance*, 37(2):493–504, 1982.

[33] Roland Gillet, Stéphanie Ligot, and Hassan Omidi Firouzi. The challenges and implications of MiFiD and its revision on the efficiency of Financial Markets. In *Financial Regulation in the EU*, chapter 8, page 393. Springer, 2017.

[34] Peter Gomber, Satchit Sagade, Erik Theissen, Moritz Christian Weber, and Christian Westheide. Competition between equity markets: A review of the consolidation versus fragmentation debate. *Journal of economic surveys*, 31(3):792–814, 2017.

[35] Jesus Gonzalo and Clive Granger. Estimation of common long-memory components in cointegrated systems. *Journal of Business & Economic Statistics*, 13(1):27–35, 1995.

[36] Joachim Grammig and Franziska J Peter. Tell tale tails: A new approach to estimating unique market information shares. *Journal of Financial and Quantitative Analysis*, 48(2):459–488, 2013.

[37] Carole Gresse. Effects of lit and dark market fragmentation on liquidity. *Journal of Financial Markets*, 35:1–20, 2017.

[38] Andreas Grünbichler, Francis A Longstaff, and Eduardo S Schwartz. Electronic screen trading and the transmission of information: An empirical examination. *Journal of financial Intermediation*, 3(2):166–187, 1994.

[39] Björn Hagströmer and Albert J Menkveld. A network map of information percolation. 2016.

[40] Lawrence E Harris. Consolidation, fragmentation, segmentation, and regulation. In *Journal of Finance*, volume 48, pages 1092–1093, 1993.

[41] Joel Hasbrouck. Measuring the information content of stock trades. *The Journal of Finance*, 46(1):179–207, 1991.

[42] Joel Hasbrouck. Assessing the quality of a security market: A new approach to transaction-cost measurement. *Review of Financial Studies*, 6(1):191–212, 1993.

[43] Joel Hasbrouck. One security, many markets: Determining the contributions to price discovery. *The Journal of Finance*, 50(4):1175–1199, 1995.

[44] Joel Hasbrouck. Price discovery analysis in SAS version 1.0. 2002.

[45] Joel Hasbrouck. Stalking the efficient price in market microstructure specifications: an overview. *Journal of Financial Markets*, 5(3):329–339, 2002.

[46] Joel Hasbrouck. Intraday price formation in us equity index markets. *The Journal of Finance*, 58(6):2375–2400, 2003.

[47] Joel Hasbrouck. The best bid and offer: A short note on programs and practices. 2010.

[48] Joel Hasbrouck. High-Frequency trading. 2017.

[49] Roger D Huang. The quality of ECN and NASDAQ market maker quotes. *The Journal of Finance*, 57(3):1285–1319, 2002.

[50] Allan W Kleidon and Ingrid M Werner. Round-the-clock trading: Evidence from UK cross-listed securities. Technical report, National Bureau of Economic Research, 1993.

[51] Harris Lawrence. Consolidation, fragmentation, segmentation and regulation. *Financial Markets, Institutions and Instruments*, 2(5), 1993.

[52] Charles MC Lee, Belinda Mucklow, and Mark J Ready. Spreads, depths, and the impact of earnings information: An intraday analysis. *Review of Financial Studies*, 6(2):345–374, 1993.

[53] Bruce N Lehmann. Some desiderata for the measurement of price discovery across markets. *Journal of Financial Markets*, 5(3):259–276, 2002.

[54] Ananth Madhavan. Consolidation, fragmentation, and the disclosure of trading information. *Review of Financial Studies*, 8(3):579–603, 1995.

[55] Ananth Madhavan. Market microstructure: A survey. *Journal of Financial markets*, 3(3): 205–258, 2000.

[56] Thomas H McInish, Gary L Shoesmith, Robert A Wood, et al. Cointegration, error correction, and price discovery on informationally linked security markets. *Journal of financial and quantitative analysis*, 30(4):563–579, 1995.

[57] Thomas H McInish, Robert A Wood, et al. Common factor components versus information shares: a reply. *Journal of Financial Markets*, 5(3):341–348, 2002.

[58] Haim Mendelson. Consolidation, fragmentation, and market performance. *Journal of Financial and Quantitative Analysis*, 22(2):189–207, 1987.

[59] Dorian M Noel. The application of SAS® hash object to ultra-High-Frequency financial data: A case study in Limit Order Book reconstruction. 2011.

[60] Maureen O'Hara. Presidential address: Liquidity and price discovery. *The Journal of Finance*, 58(4):1335–1354, 2003.

[61] Maureen O´Hara and Mao Ye. Is market fragmentation harming market quality? *Journal of Financial Economics*, 100(3):459–474, 2011.

[62] Marco Pagano. Trading volume and asset liquidity. *The Quarterly Journal of Economics*, 104(2):255–274, 1989.

[63] N Pallmann. Market structure and the speed of incorporating new information into security prices: Evidence from germany. Technical report, Working Paper, New York University, 1992.

[64] Christine A Parlour. Price dynamics in limit order markets. *The Review of Financial Studies*, 11(4):789–816, 1998.

[65] Roberto Pascual, Bartolomé Pascual-Fuster, and Francisco Climent. Cross-listing, price discovery and the informativeness of the trading process. *Journal of Financial Markets*, 9(2): 144–161, 2006.

[66] Talis J Putnins. What do price discovery metrics really measure? *Journal of Empirical Finance*, 23:68–83, 2013.

[67] Ryan Riordan and Andreas Storkenmaier. Latency, liquidity and price discovery. *Journal of Financial Markets*, 15(4):416–437, 2012.

[68] Ryan Riordan, Andreas Storkenmaier, and Martin Wagener. Do multilateral trading facilities contribute to market quality? 2011.

[69] Ryan Riordan, Andreas Storkenmaier, Martin Wagener, and S Sarah Zhang. Public information arrival: Price discovery and liquidity in electronic limit order markets. *Journal of Banking & Finance*, 37(4):1148–1159, 2013.

[70] Ailsa Röell. Comparing the performance of stock exchange trading systems. *The Internationalisation of Capital Markets and the Regulatory Response. Kluwer, Amsterdam*, 1992.

[71] Paul S Schreiber and Robert A Schwartz. Price discovery in securities markets. *The Journal of Portfolio Management*, 12(4):43–48, 1986.

[72] Robert A Schwartz. Dark pools, fragmented markets, and the quality of price discovery. *The Journal of Trading*, 5(2):17–22, 2010.

[73] SEC. Memorandum. https://www.sec.gov/spotlight/emsac/memo-rule-611-regulation-nms.pdf, 2015. [Online; accessed 13-August-2018].

[74] George J Stigler. Public regulation of the securities markets. *The Journal of Business*, 37(2): 117–142, 1964.

[75] James H Stock and Mark W Watson. Testing for common trends. *Journal of the American statistical Association*, 83(404):1097–1107, 1988.

[76] Hans R Stoll. Presidential address: friction. *The Journal of Finance*, 55(4):1479–1514, 2000.

[77] Bingcheng Yan and Eric Zivot. A structural analysis of price discovery measures. *Journal of Financial Markets*, 13(1):1–19, 2010.

[78] Susana Yu, Richard Lord, Robert Schwartz, Avner Wolf, and Jacob Paroush. The dynamic process of price discovery in an equity market. *Managerial Finance*, 36(7):554–565, 2010.

APPENDIX A

Table A.1. MiFID II affects the most trading lifecycle(Source Bloomberg (2017))

Pre-Trade Workflow	
Order Flow Management	UTC clock synchronisation
	Time stamp granularity
Pre-trade analytics and price discovery	Real-time market data to be provided to public on reasonable commercial basis
	Pre-trade liquidity characteristic and trade venue assessment and selection diligence for order routing and execution
	Incorporation of historical best execution metrics and diligence requirements
	Historical trade cost analysis for improved decision support and execution strategy
	Consolidated data aggregating quotes and pricing from all venues: RMs, OTFs, APAs, SIs, and CTPs
Execution and Trading Workflow	
Pre-Trade transparency	Investment firms and designated Systematic Internalisers (SI) mandated to report Actionable Indications of Interest to the market via Approved Publication Arrangements(APA)
	Must capture non electronic orders and quotes
	Reporting waiver determinations based on security liquidity categorisation and trade size (LIS, SSTI)
Routing & Execution	Routing to established Trading Venues, Regulated Markets (RM), Multilateral Trade Facilities (MTF), Organised Trade Facilities (OTF), Sis
	Current order book, multi RFQ and voice trading protocols to be reviewed, pending changes post implementation
	Monitor and manage execution quality and performance (best execution)
Post-Trade transparency	Trades in covered instruments reported by trading venue or through APA
	Delayed post-trade data available to all without charge
	Derivatives reported to Trade Repository, greater data requirements than APA for systemic risk
Post-Trade Operations	
Transaction reporting	Trades in all covered instruments reported to National Competent Authority (NCA), the local regulators, with LEIs, other identifying personal data and economic terms
	Direct reporting through ARM or venue
	Firms must prove completeness with controls and procedures for errors and corrections
Best execution	Expanded requirements to demonstrate sufficient steps to provide best execution
	Publish execution policy
	Demonstrate performance against that policy
	SIs and other trading venues required to publish reports on quality of execution
	Applicable to all MiFID II instruments accounting for size, price, cost, speed, likelihood of execution and settlement
Trade reconstruction	Market abuse surveillance by identifying suspicious execution outliers and trends
	Investigate with trade reconstruction incorporating structured and unstructured data
	Compliance workflow for documenting conclusions
	Immutable Write Once, Read Many (WORM) record keeping
Record Keeping	Immutable records of all services, activities and transactions for 5-7 years without modification or deletion in Write Once Read Many (WORM) storage
	Synchronisation of clocks to Consolidated Universal Time (UTC) to enable timestamping at granularity of up to 100 microseconds
	Requirement covers all media including: email, social media, instant messaging, telephone, written documents

Table A.2. The main evolutions of European markets since 2000

2 September 2000	Amsterdam, Brussels and Paris Exchanges merge, Euronext created
30 January 2002	Euronext group absorbs Lisbon Exchange
1st Avril 2005	Implementation of the Regulation National Market System (Reg NMS) in the USA
September 2006	Nine investment banks create BOAT, a MiFID-compliant TRF
7 March 2007	NYSE merged with Archipelago Holdings
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
12 April 2007	Chi-X extends trading to all DAX 30 constituents
13 April 2007	Chi-X extends trading to all AEX 25 constituents
13 July 2007	Chi-X extends trading to all FTSE 100 stocks
28 September 2007	Chi-X extends trading in 19 CAC 40 stocks
8 and 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
1st October 2007	LSE acquires Borsa Italiana
1st November 2007	Implementation of the directive MiFID in Europe
22 January 2008	Financial information provider Markit acquires BOAT TRF
22 September 2008	Pan European platform Turquoise launched
1st October 2008	Pan-European platform Nasdaq OMX Europe launched
31 October 2008	BATS Europe launched as MTF for LSE, Euronext and Deutsche Borse stocks
December 2008	NYSE Euronext successfully migrates its European Bond products onto its new Universal Trading Platform (UTP).
2 February 2009	NYSE-Euronext launches dark pool SmartPool in Partnership with JP Morgan, HSBC, BNP Paribas
9 March 2009	NYSE-Euronext launches MTF NYSE Arca Europe
21 December 2009	Announcement that LSE is taking 60 percents stake in Turquoise, later reduced to 51 percents
2 November 2009	Deutsche Borse extends trading to pan-European equities with Xetra International Market
21 May 2010	Nasdaq OMX closed
18 February 2011	Agreement for the sale of Chi-X Europe to BATS
7 and 14 July 2011	NYSE Euronext and Deutsche Borse receives approval for merger from shareholders but the deal was blocked by the European Commission in January 2012
20 December 2012	The boards of directors of both IntercontinentalExchange (ICE) and the NYSE Euronext approved an 8 billion dollars acquisition of NYSE Euronext.
13 November 2013	European regulators and ministries of Finance of the participating countries approved the deal and the acquisition of NYSE Euronext by the IntercontinentalExchange was completed.
June 2014	Euronext was split from ICE through an initial public offering. In order to stabilize Euronext, a consortium of eleven investors decided to invest in the company. These investors referred to as reference shareholders own 33.36 percent of Euronext´s capital and have a 3 years lockup period. They have 3 board seats.
December 2015	The Enforcement Committee handed down a penalty of 5 million euros to Virtu Financial Europe for market manipulation and ignoring Euronext market rules. It also handed down a penalty in the same amount to Euronext Paris for failing to meet its obligation to operate with neutrality and impartiality, in accordance with market integrity.

Table A.3. Composition of the CAC40 Index with the sector allocation

ISIN Code (Ticker Symbol)	CAC40 Firm	Sector (ICD)	Years in the CAC40
FR0000045072 (ACA)	**CREDIT AGRICOLE**	Banks	2006, 2007, 2011, 2012
FR0000120073 (AI)	**AIR LIQUIDE**	Chemicals	2006, 2007, 2011, 2012
FR0000045072 (BN)	**DANONE**	Food and Beverage	2006, 2007, 2011, 2012
FR0000131104 (BNP)	**BNP PARIBAS**	Banks	2006, 2007, 2011, 2012
FR0000120172 (CA)	**CARREFOUR**	Retail	2006, 2007, 2011, 2012
FR0000125338 (CAP)	**CAP GEMINI**	Technology	2006, 2007, 2011, 2012
FR0000125486 (DG)	**VINCI**	Construction and Materials	2006, 2007, 2011, 2012
FR0000121667 (EI)	**ESSILOR INTERNATIONAL**	Health Care	2006, 2007, 2011, 2012
FR0000120503 (EN)	**BOUYGUES**	Construction and Materials	2006, 2007, 2011, 2012
FR0000120271 (FP)	**TOTAL**	Oil and Gas	2006, 2007, 2011, 2012
FR0000133308 (FTE)	**FRANCE TELECOM - ORANGE**	Telecommunications	2006, 2007, 2011, 2012
FR0000130809 (GLE)	**SOCIETE GENERALE**	Banks	2006, 2007, 2011, 2012
FR0010208488 (GSZNV)	**GDF - SUEZ**	Utilities	2006, 2007, 2011, 2012
FR0000121014 (MC)	**LVMH**	Personal and Household Goods	2006, 2007, 2011, 2012
FR0000121261 (ML)	**MICHELIN**	Automobiles and Parts	2006, 2007, 2011, 2012
FR0000121485 (PP)	**KERING ex-PPR**	Retail	2006, 2007, 2011, 2012
FR0000120693 (RI)	**PERNOD RICARD**	Food and Beverage	2006, 2007, 2011, 2012
FR0000131906 (RNO)	**RENAULT**	Automobiles and Parts	2006, 2007, 2011, 2012
FR0000125007 (SGO)	**SAINT-GOBAIN**	Construction and Materials	2006, 2007, 2011, 2012
FR0000120578 (SAN)	**SANOFI**	Health Care	2006, 2007, 2011, 2012
NL0000226223 (STM)	**STMICROELECRONICS**	Technology	2006, 2007, 2011, 2012
FR0000121972 (SU)	**SCHNEIDER**	Industrial goods and Services	2007, 2011, 2012
FR0000124141 (VIE)	**VEOLIA ENVIRONNEMENT**	Utilities	2006, 2007, 2011, 2012
FR0000127771 (VIV)	**VIVENDI UNIVERSAL**	Media	2006, 2007, 2011, 2012
FR0010242511 (EDF)	**EDF**	Utilities	2006, 2007, 2011, 2012
NL0000235190 (EAD)	**EADS AIRBUS**	Industrial goods and Services	2006, 2007, 2011, 2012
FR0000120321 (OR)	**L´ORÉAL**	Personal and Household Goods	2006, 2007, 2011, 2012
FR0000120537 (LG)	**LAFARGE**	Construction and Materials	2006, 2007, 2011, 2012

Table A.4. Evolution of Information Share for the CAC40 stocks in December 2012

December 2012							
		Maximum			Minimum		
CAC40 Stocks	**Information Share**	**Chi-X**	**BATS**	**Euronext Paris**	**Chi-X**	**BATS**	**Euronext Paris**
Air Liquide (AI)	IS MAX	0.953	0.985	0.251	0.927	0.944	0.166
	IS MEAN	0.197	0.825	0.066	0.124	0.744	0.048
	IS MIN	0.006	0.072	0.001	0.004	0.047	0.000
	N	18.000	18.000	18.000	18.000	18.000	18.000
	STD	0.217	0.202	0.067	0.210	0.210	0.047
BNP Paribas (BNP)	IS MAX	0.881	0.877	0.193	0.764	0.860	0.168
	IS MEAN	0.408	0.590	0.076	0.348	0.526	0.055
	IS MIN	0.082	0.045	0.000	0.071	0.026	0.000
	N	18.000	18.000	18.000	18.000	18.000	18.000
	STD	0.202	0.200	0.058	0.177	0.220	0.046
Bouygues (EN)	IS MAX	0.770	0.943	0.203	0.605	0.934	0.130
	IS MEAN	0.354	0.694	0.046	0.269	0.606	0.033
	IS MIN	0.060	0.324	0.003	0.046	0.101	0.003
	N	18.000	18.000	18.000	18.000	18.000	18.000
	STD	0.215	0.187	0.050	0.169	0.229	0.033
Cap Gemini (CAP)	IS MAX	0.789	0.889	0.381	0.648	0.841	0.329
	IS MEAN	0.369	0.573	0.165	0.291	0.475	0.130
	IS MIN	0.031	0.237	0.002	0.028	0.103	0.001
	N	18.000	18.000	18.000	18.000	18.000	18.000
	STD	0.249	0.214	0.122	0.201	0.245	0.101
Carrefour (CA)	IS MAX	0.959	0.902	0.360	0.860	0.860	0.278
	IS MEAN	0.468	0.515	0.146	0.365	0.395	0.114
	IS MIN	0.040	0.096	0.006	0.025	0.009	0.004
	N	18.000	18.000	18.000	18.000	18.000	18.000
	STD	0.255	0.202	0.109	0.205	0.248	0.087
Credit Agricole (ACA)	IS MAX	0.874	0.963	0.854	0.838	0.957	0.844
	IS MEAN	0.169	0.693	0.207	0.135	0.630	0.168
	IS MIN	0.000	0.067	0.015	0.000	0.010	0.011
	N	18.000	18.000	18.000	18.000	18.000	18.000
	STD	0.209	0.264	0.242	0.194	0.292	0.213
Danone (BN)	IS MAX	0.609	0.996	0.523	0.420	0.995	0.402
	IS MEAN	**0.245**	**0.712**	**0.157**	**0.154**	**0.622**	**0.119**
	IS MIN	0.000	0.287	0.000	0.000	0.088	0.000
	N	18.000	18.000	18.000	18.000	18.000	18.000
	STD	0.169	0.211	0.155	0.136	0.255	0.124
Eads Airbus Groupe (EAD)	IS MAX	0.833	0.994	0.225	0.651	0.992	0.163
	IS MEAN	0.213	0.793	0.060	0.155	0.731	0.049
	IS MIN	0.007	0.236	0.001	0.005	0.063	0.001
	N	19.000	19.000	19.000	19.000	19.000	19.000
	STD	0.208	0.177	0.058	0.159	0.228	0.045
EDF (EDF)	IS MAX	0.851	1.000	0.258	0.637	0.991	0.176
	IS MEAN	0.254	0.738	0.069	0.206	0.686	0.048
	IS MIN	0.009	0.120	0.000	0.000	0.002	0.000
	N	18.000	18.000	18.000	18.000	18.000	18.000
	STD	0.255	0.242	0.075	0.203	0.279	0.049
Essilor International (EI)	IS MAX	0.818	0.867	0.369	0.730	0.762	0.204
	IS MEAN	0.450	0.539	0.133	0.342	0.452	0.092
	IS MIN	0.170	0.180	0.029	0.073	0.000	0.024
	N	18.000	18.000	18.000	18.000	18.000	18.000
	STD	0.214	0.210	0.093	0.193	0.229	0.059
Orange SA (FTE)	IS MAX	0.868	0.954	0.456	0.856	0.946	0.424
	IS MEAN	0.219	0.720	0.121	0.176	0.665	0.101
	IS MIN	0.027	0.129	0.010	0.026	0.118	0.008
	N	18.000	18.000	18.000	18.000	18.000	18.000
	STD	0.211	0.219	0.133	0.198	0.247	0.120
Gaz de France- Engie SA (GSZ)	IS MAX	0.952	0.946	0.435	0.841	0.934	0.283
	IS MEAN	0.313	0.712	0.099	0.214	0.602	0.065
	IS MIN	0.035	0.117	0.002	0.025	0.020	0.001
	N	18.000	18.000	18.000	18.000	18.000	18.000
	STD	0.238	0.223	0.104	0.206	0.262	0.068
Kering (PP)	IS MAX	0.827	0.764	0.347	0.672	0.681	0.221
	IS MEAN	0.503	0.518	0.142	0.363	0.391	0.092
	IS MIN	0.233	0.231	0.002	0.081	0.106	0.001
	N	18.000	18.000	18.000	18.000	18.000	18.000
	STD	0.198	0.164	0.095	0.190	0.191	0.070
Lafarge (LG)	IS MAX	0.994	0.758	0.735	0.963	0.693	0.641
	IS MEAN	0.453	0.338	0.289	0.392	0.275	0.255
	IS MIN	0.102	0.033	0.005	0.081	0.002	0.000
	N	18.000	18.000	18.000	18.000	18.000	18.000
	STD	0.257	0.165	0.254	0.256	0.164	0.233

Table A.4. Suite Evolution of Information Share for the CAC40 stocks in December 2012

December 2012							
		Maximum			Minimum		
CAC40 Stocks	**Information Share**	**Chi-X**	**BATS**	**Euronext Paris**	**Chi-X**	**BATS**	**Euronext Paris**
L'Oreal (OR)	IS MAX	0.993	0.945	0.508	0.434	0.924	0.356
	IS MEAN	0.295	0.695	0.135	0.184	0.596	0.097
	IS MIN	0.039	0.369	0.005	0.004	0.000	0.001
	N	18.000	18.000	18.000	18.000	18.000	18.000
	STD	0.225	0.186	0.149	0.125	0.262	0.116
LVMH (MC)	IS MAX	0.733	0.988	0.221	0.691	0.985	0.138
	IS MEAN	0.260	0.741	0.075	0.203	0.677	0.047
	IS MIN	0.003	0.303	0.000	0.002	0.261	0.000
	N	18.000	18.000	18.000	18.000	18.000	18.000
	STD	0.204	0.170	0.065	0.183	0.191	0.041
Michelin (ML)	IS MAX	0.899	0.870	0.515	0.830	0.830	0.473
	IS MEAN	0.447	0.421	0.250	0.358	0.333	0.194
	IS MIN	0.043	0.088	0.002	0.028	0.020	0.001
	N	18.000	18.000	18.000	18.000	18.000	18.000
	STD	0.246	0.202	0.184	0.210	0.225	0.161
Pernod Ricard (RI)	IS MAX	0.521	0.996	0.292	0.353	0.995	0.261
	IS MEAN	0.226	0.743	0.110	0.159	0.683	0.084
	IS MIN	0.001	0.370	0.003	0.001	0.320	0.002
	N	18.000	18.000	18.000	18.000	18.000	18.000
	STD	0.152	0.178	0.090	0.113	0.208	0.079
Renault (RNO)	IS MAX	0.700	0.943	0.586	0.540	0.913	0.496
	IS MEAN	0.343	0.540	0.237	0.262	0.433	0.193
	IS MIN	0.024	0.154	0.010	0.014	0.004	0.006
	N	18.000	18.000	18.000	18.000	18.000	18.000
	STD	0.195	0.233	0.173	0.158	0.279	0.146
Saint Gobain (SGO)	IS MAX	0.753	0.745	0.631	0.694	0.720	0.433
	IS MEAN	0.503	0.391	0.219	0.415	0.305	0.170
	IS MIN	0.057	0.096	0.029	0.050	0.028	0.026
	N	18.000	18.000	18.000	18.000	18.000	18.000
	STD	0.182	0.166	0.152	0.160	0.185	0.114
Sanofi (SAN)	IS MAX	0.814	0.934	0.457	0.503	0.909	0.259
	IS MEAN	0.354	0.644	0.123	0.257	0.537	0.088
	IS MIN	0.018	0.288	0.000	0.000	0.163	0.000
	N	18.000	18.000	18.000	18.000	18.000	18.000
	STD	0.209	0.183	0.125	0.164	0.206	0.078
Schneider Electric (SU)	IS MAX	0.972	0.859	0.422	0.935	0.838	0.391
	IS MEAN	0.498	0.449	0.179	0.400	0.341	0.137
	IS MIN	0.079	0.046	0.020	0.045	0.013	0.014
	N	18.000	18.000	18.000	18.000	18.000	18.000
	STD	0.187	0.186	0.101	0.181	0.198	0.087
Societe Generale (GLE)	IS MAX	0.962	0.954	0.384	0.956	0.943	0.328
	IS MEAN	0.316	0.667	0.080	0.266	0.606	0.066
	IS MIN	0.040	0.037	0.001	0.032	0.031	0.000
	N	18.000	18.000	18.000	18.000	18.000	18.000
	STD	0.251	0.236	0.091	0.245	0.240	0.077
STMicroelectronics (STM)	IS MAX	0.703	0.939	0.400	0.388	0.861	0.362
	IS MEAN	0.416	0.723	0.178	0.126	0.426	0.145
	IS MIN	0.086	0.384	0.008	0.014	0.072	0.007
	N	18.000	18.000	18.000	18.000	18.000	18.000
	STD	0.175	0.146	0.110	0.103	0.200	0.097
Total (FP)	IS MAX	0.794	0.987	0.364	0.718	0.969	0.321
	IS MEAN	0.188	0.794	0.099	0.125	0.721	0.077
	IS MIN	0.000	0.093	0.000	0.000	0.061	0.000
	N	18.000	18.000	18.000	18.000	18.000	18.000
	STD	0.214	0.213	0.102	0.176	0.240	0.087
Veolia Environnement (VIE)	IS MAX	0.830	0.948	0.631	0.738	0.884	0.479
	IS MEAN	0.363	0.475	0.247	0.307	0.402	0.208
	IS MIN	0.007	0.215	0.004	0.005	0.119	0.003
	N	18.000	18.000	18.000	18.000	18.000	18.000
	STD	0.220	0.193	0.186	0.202	0.200	0.157
Vinci (DG)	IS MAX	0.937	0.964	0.422	0.648	0.959	0.338
	IS MEAN	0.226	0.736	0.115	0.170	0.670	0.087
	IS MIN	0.000	0.220	0.007	0.000	0.008	0.006
	N	18.000	18.000	18.000	18.000	18.000	18.000
	STD	0.213	0.177	0.099	0.161	0.213	0.079
Vivendi (VIV)	IS MAX	0.707	0.957	0.351	0.670	0.937	0.291
	IS MEAN	0.314	0.660	0.116	0.245	0.576	0.090
	IS MIN	0.056	0.008	0.008	0.037	0.000	0.005
	N	18.000	18.000	18.000	18.000	18.000	18.000
	STD	0.191	0.223	0.098	0.162	0.236	0.080

Table A.5. Evolution of Information Share for the CAC40 stocks in February 2013

February 2013							
		Maximum			Minimum		
CAC40 Stocks	Information Share	Chi-X	BATS	Euronext Paris	Chi-X	BATS	Euronext Paris
Air Liquide (AI)	IS MAX	0.540	0.989	0.292	0.484	0.982	0.231
	IS MEAN	0.220	0.749	0.085	0.177	0.702	0.068
	IS MIN	0.000	0.286	0.001	0.000	0.209	0.000
	N	19.000	19.000	19.000	19.000	19.000	19.000
	STD	0.162	0.201	0.075	0.142	0.216	0.063
BNP Paribas (BNP)	IS MAX	0.987	0.975	0.128	0.982	0.965	0.108
	IS MEAN	0.311	0.723	0.058	0.227	0.636	0.047
	IS MIN	0.002	0.005	0.003	0.001	0.002	0.002
	N	19.000	19.000	19.000	19.000	19.000	19.000
	STD	0.244	0.229	0.039	0.228	0.245	0.032
Bouygues (EN)	IS MAX	0.584	0.997	0.271	0.544	0.995	0.238
	IS MEAN	0.271	0.663	0.116	0.230	0.620	0.100
	IS MIN	0.004	0.336	0.001	0.003	0.303	0.001
	N	19.000	19.000	19.000	19.000	19.000	19.000
	STD	0.196	0.206	0.083	0.178	0.218	0.071
Cap Gemini (CAP)	IS MAX	0.895	0.835	0.519	0.760	0.783	0.452
	IS MEAN	0.341	0.543	0.215	0.259	0.458	0.188
	IS MIN	0.057	0.221	0.016	0.052	0.034	0.013
	N	19.000	19.000	19.000	19.000	19.000	19.000
	STD	0.262	0.216	0.151	0.224	0.248	0.138
Carrefour (CA)	IS MAX	0.652	0.970	0.502	0.615	0.961	0.439
	IS MEAN	0.330	0.586	0.169	0.258	0.516	0.143
	IS MIN	0.016	0.198	0.000	0.012	0.117	0.000
	N	19.000	19.000	19.000	19.000	19.000	19.000
	STD	0.174	0.203	0.131	0.149	0.227	0.114
Credit Agricole (ACA)	IS MAX	0.344	0.970	0.229	0.310	0.957	0.210
	IS MEAN	0.145	0.821	0.073	0.115	0.784	0.063
	IS MIN	0.021	0.689	0.000	0.014	0.641	0.000
	N	19.000	19.000	19.000	19.000	19.000	19.000
	STD	0.095	0.087	0.066	0.080	0.101	0.059
Danone (BN)	IS MAX	0.607	0.950	0.729	0.477	0.926	0.686
	IS MEAN	0.193	0.678	0.229	0.123	0.592	0.189
	IS MIN	0.025	0.219	0.001	0.018	0.049	0.001
	N	19.000	19.000	19.000	19.000	19.000	19.000
	STD	0.170	0.223	0.178	0.128	0.241	0.164
Eads Airbus Groupe (EAD)	IS MAX	0.833	0.994	0.225	0.651	0.992	0.163
	IS MEAN	0.213	0.793	0.060	0.155	0.731	0.049
	IS MIN	0.007	0.236	0.001	0.005	0.063	0.001
	N	19.000	19.000	19.000	19.000	19.000	19.000
	STD	0.208	0.177	0.058	0.159	0.228	0.045
EDF (EDF)	IS MAX	0.833	0.994	0.225	0.651	0.992	0.163
	IS MEAN	0.213	0.793	0.060	0.155	0.731	0.049
	IS MIN	0.007	0.236	0.001	0.005	0.063	0.001
	N	19.000	19.000	19.000	19.000	19.000	19.000
	STD	0.208	0.177	0.058	0.159	0.228	0.045
Essilor International (EI)	IS MAX	0.836	0.923	0.504	0.732	0.914	0.465
	IS MEAN	0.388	0.463	0.229	0.322	0.413	0.188
	IS MIN	0.007	0.039	0.006	0.005	0.000	0.004
	N	19.000	19.000	19.000	19.000	19.000	19.000
	STD	0.222	0.257	0.140	0.195	0.263	0.122
Orange SA (FTE)	IS MAX	0.526	0.981	0.582	0.376	0.974	0.559
	IS MEAN	0.251	0.719	0.124	0.165	0.631	0.111
	IS MIN	0.012	0.148	0.012	0.006	0.040	0.008
	N	19.000	19.000	19.000	19.000	19.000	19.000
	STD	0.171	0.232	0.162	0.114	0.286	0.153
Gaz de France- Engie SA (GSZ)	IS MAX	0.999	0.982	0.560	0.627	0.978	0.328
	IS MEAN	0.264	0.804	0.085	0.133	0.665	0.059
	IS MIN	0.014	0.299	0.002	0.010	0.000	0.001
	N	19.000	19.000	19.000	19.000	19.000	19.000
	STD	0.275	0.196	0.138	0.176	0.303	0.093
Kering (PP)	IS MAX	0.982	0.945	0.823	0.527	0.929	0.251
	IS MEAN	0.308	0.633	0.167	0.220	0.581	0.102
	IS MIN	0.032	0.196	0.007	0.018	0.017	0.001
	N	19.000	19.000	19.000	19.000	19.000	19.000
	STD	0.238	0.232	0.187	0.161	0.253	0.084
Lafarge (LG)	IS MAX	0.710	0.945	0.515	0.641	0.924	0.481
	IS MEAN	0.329	0.493	0.230	0.286	0.457	0.207
	IS MIN	0.030	0.084	0.021	0.025	0.060	0.017
	N	19.000	19.000	19.000	19.000	19.000	19.000
	STD	0.214	0.269	0.164	0.192	0.268	0.153

Table A.5. Suite Evolution of Information Share for the CAC40 stocks in February 2013

		February 2013					
		Maximum			Minimum		
CAC40 Stocks	Information Share	Chi-X	BATS	Euronext Paris	Chi-X	BATS	Euronext Paris
L'Oreal (OR)	IS MAX	0.607	0.882	0.189	0.392	0.854	0.147
	IS MEAN	0.237	0.757	0.102	0.159	0.670	0.077
	IS MIN	0.054	0.587	0.026	0.037	0.376	0.011
	N	19.000	19.000	19.000	19.000	19.000	19.000
	STD	0.131	0.106	0.052	0.092	0.132	0.042
LVMH (MC)	IS MAX	0.876	0.960	0.398	0.679	0.949	0.275
	IS MEAN	0.344	0.717	0.116	0.197	0.558	0.078
	IS MIN	0.023	0.279	0.002	0.012	0.073	0.002
	N	19.000	19.000	19.000	19.000	19.000	19.000
	STD	0.241	0.155	0.098	0.164	0.224	0.071
Michelin (ML)	IS MAX	0.701	0.958	0.364	0.553	0.934	0.327
	IS MEAN	0.305	0.635	0.136	0.242	0.570	0.113
	IS MIN	0.006	0.302	0.001	0.004	0.196	0.001
	N	19.000	19.000	19.000	19.000	19.000	19.000
	STD	0.203	0.212	0.101	0.170	0.233	0.086
Pernod Ricard (RI)	IS MAX	0.442	0.980	0.639	0.363	0.976	0.618
	IS MEAN	0.147	0.764	0.147	0.103	0.712	0.128
	IS MIN	0.000	0.290	0.017	0.000	0.145	0.015
	N	19.000	19.000	19.000	19.000	19.000	19.000
	STD	0.104	0.154	0.145	0.083	0.184	0.138
Renault (RNO)	IS MAX	0.593	0.854	0.691	0.572	0.751	0.646
	IS MEAN	0.353	0.477	0.269	0.274	0.401	0.231
	IS MIN	0.081	0.201	0.030	0.053	0.132	0.027
	N	19.000	19.000	19.000	19.000	19.000	19.000
	STD	0.178	0.194	0.202	0.163	0.194	0.185
Saint Gobain (SGO)	IS MAX	0.685	0.982	0.708	0.433	0.975	0.684
	IS MEAN	0.234	0.707	0.137	0.169	0.637	0.118
	IS MIN	0.002	0.228	0.000	0.002	0.207	0.000
	N	19.000	19.000	19.000	19.000	19.000	19.000
	STD	0.186	0.216	0.175	0.140	0.237	0.166
Sanofi (SAN)	IS MAX	0.682	0.989	0.313	0.411	0.962	0.268
	IS MEAN	0.245	0.753	0.115	0.154	0.652	0.085
	IS MIN	0.002	0.385	0.001	0.000	0.174	0.001
	N	19.000	19.000	19.000	19.000	19.000	19.000
	STD	0.218	0.186	0.092	0.138	0.243	0.075
Schneider Electric (SU)	IS MAX	0.783	0.785	0.515	0.715	0.757	0.473
	IS MEAN	0.390	0.518	0.209	0.292	0.423	0.174
	IS MIN	0.005	0.181	0.016	0.003	0.122	0.014
	N	19.000	19.000	19.000	19.000	19.000	19.000
	STD	0.193	0.185	0.144	0.178	0.197	0.128
Societe Generale (GLE)	IS MAX	0.803	0.974	0.319	0.630	0.901	0.143
	IS MEAN	0.258	0.818	0.059	0.148	0.694	0.034
	IS MIN	0.069	0.341	0.000	0.010	0.169	0.000
	N	19.000	19.000	19.000	19.000	19.000	19.000
	STD	0.203	0.181	0.074	0.171	0.215	0.035
STMicroelectronics (STM)	IS MAX	0.831	0.850	0.568	0.454	0.713	0.500
	IS MEAN	0.481	0.536	0.240	0.243	0.304	0.206
	IS MIN	0.021	0.289	0.050	0.013	0.014	0.042
	N	19.000	19.000	19.000	19.000	19.000	19.000
	STD	0.230	0.177	0.136	0.136	0.228	0.124
Total (FP)	IS MAX	0.562	0.982	0.401	0.186	0.947	0.304
	IS MEAN	0.171	0.856	0.087	0.075	0.750	0.067
	IS MIN	0.019	0.548	0.001	0.002	0.291	0.000
	N	19.000	19.000	19.000	19.000	19.000	19.000
	STD	0.148	0.111	0.110	0.060	0.211	0.085
Veolia Environnement (VIE)	IS MAX	0.856	0.733	0.677	0.647	0.670	0.644
	IS MEAN	0.497	0.435	0.226	0.349	0.296	0.201
	IS MIN	0.242	0.160	0.003	0.140	0.080	0.002
	N	19.000	19.000	19.000	19.000	19.000	19.000
	STD	0.197	0.163	0.190	0.152	0.178	0.178
Vinci (DG)	IS MAX	0.852	0.990	0.293	0.579	0.986	0.219
	IS MEAN	0.335	0.703	0.106	0.217	0.580	0.072
	IS MIN	0.010	0.294	0.004	0.007	0.102	0.003
	N	19.000	19.000	19.000	19.000	19.000	19.000
	STD	0.250	0.203	0.083	0.175	0.271	0.056
Vivendi (VIV)	IS MAX	0.663	0.990	0.373	0.308	0.964	0.178
	IS MEAN	0.168	0.849	0.073	0.100	0.767	0.047
	IS MIN	0.022	0.484	0.000	0.006	0.138	0.000
	N	19.000	19.000	19.000	19.000	19.000	19.000
	STD	0.158	0.124	0.095	0.085	0.201	0.054

Table A.6. Evolution of Information Share for the CAC40 stocks in April 2013

April 2013							
		Maximum			Minimum		
CAC40 Stocks	**Information Share**	**Chi-X**	**BATS**	**Euronext Paris**	**Chi-X**	**BATS**	**Euronext Paris**
Air Liquide (AI)	IS MAX	0.955	0.813	0.475	0.616	0.787	0.435
	IS MEAN	0.435	0.451	0.198	0.361	0.393	0.163
	IS MIN	0.000	0.218	0.000	0.000	0.002	0.000
	N	21.000	21.000	21.000	21.000	21.000	21.000
	STD	0.199	0.170	0.138	0.155	0.188	0.127
BNP Paribas (BNP)	IS MAX	0.805	0.878	0.421	0.803	0.804	0.359
	IS MEAN	0.402	0.517	0.176	0.324	0.440	0.146
	IS MIN	0.000	0.170	0.000	0.000	0.103	0.000
	N	21.000	21.000	21.000	21.000	21.000	21.000
	STD	0.196	0.210	0.126	0.197	0.200	0.106
Bouygues (EN)	IS MAX	0.966	0.796	0.612	0.815	0.774	0.569
	IS MEAN	0.446	0.365	0.263	0.381	0.310	0.236
	IS MIN	0.000	0.177	0.000	0.000	0.034	0.000
	N	21.000	21.000	21.000	21.000	21.000	21.000
	STD	0.266	0.172	0.189	0.231	0.196	0.175
Cap Gemini (CAP)	IS MAX	0.927	0.925	0.715	0.917	0.913	0.653
	IS MEAN	0.358	0.409	0.304	0.300	0.361	0.271
	IS MIN	0.000	0.045	0.000	0.000	0.004	0.000
	N	21.000	21.000	21.000	21.000	21.000	21.000
	STD	0.234	0.241	0.231	0.220	0.246	0.207
Carrefour (CA)	IS MAX	0.901	0.882	0.994	0.793	0.840	0.993
	IS MEAN	0.369	0.409	0.367	0.262	0.310	0.304
	IS MIN	0.000	0.005	0.000	0.000	0.004	0.000
	N	21.000	21.000	21.000	21.000	21.000	21.000
	STD	0.253	0.239	0.247	0.226	0.215	0.241
Credit Agricole (ACA)	IS MAX	0.810	0.994	0.536	0.792	0.991	0.478
	IS MEAN	0.137	0.715	0.185	0.118	0.683	0.163
	IS MIN	0.000	0.158	0.000	0.000	0.145	0.000
	N	21.000	21.000	21.000	21.000	21.000	21.000
	STD	0.214	0.246	0.160	0.210	0.253	0.144
Danone (BN)	IS MAX	0.956	0.883	0.547	0.794	0.843	0.494
	IS MEAN	0.227	0.631	0.225	0.173	0.564	0.185
	IS MIN	0.000	0.177	0.000	0.000	0.015	0.000
	N	21.000	21.000	21.000	21.000	21.000	21.000
	STD	0.223	0.184	0.145	0.184	0.221	0.125
Eads Airbus Groupe (EAD)	IS MAX	0.833	0.994	0.225	0.651	0.992	0.163
	IS MEAN	0.213	0.793	0.060	0.155	0.731	0.049
	IS MIN	0.007	0.236	0.001	0.005	0.063	0.001
	N	19.000	19.000	19.000	19.000	19.000	19.000
	STD	0.208	0.177	0.058	0.159	0.228	0.045
EDF (EDF)	IS MAX	0.573	0.987	0.464	0.438	0.956	0.416
	IS MEAN	0.176	0.723	0.167	0.127	0.666	0.143
	IS MIN	0.000	0.346	0.000	0.000	0.290	0.000
	N	21.000	21.000	21.000	21.000	21.000	21.000
	STD	0.144	0.187	0.161	0.109	0.210	0.142
Essilor International (EI)	IS MAX	0.765	0.735	0.774	0.656	0.677	0.743
	IS MEAN	0.310	0.416	0.342	0.253	0.369	0.312
	IS MIN	0.000	0.160	0.000	0.000	0.133	0.000
	N	21.000	21.000	21.000	21.000	21.000	21.000
	STD	0.196	0.161	0.235	0.176	0.159	0.223
Orange SA (FTE)	IS MAX	0.981	0.987	0.873	0.961	0.982	0.846
	IS MEAN	0.437	0.490	0.168	0.355	0.416	0.141
	IS MIN	0.000	0.010	0.000	0.000	0.002	0.000
	N	21.000	21.000	21.000	21.000	21.000	21.000
	STD	0.274	0.292	0.203	0.263	0.307	0.190
Gaz de France- Engie SA (GSZ)	IS MAX	0.330	0.998	0.314	0.220	0.997	0.278
	IS MEAN	0.123	0.865	0.061	0.084	0.818	0.049
	IS MIN	0.000	0.631	0.000	0.000	0.542	0.000
	N	21.000	21.000	21.000	21.000	21.000	21.000
	STD	0.094	0.098	0.076	0.063	0.129	0.066
Kering (PP)	IS MAX	0.959	0.846	0.671	0.902	0.816	0.574
	IS MEAN	0.256	0.474	0.342	0.202	0.424	0.304
	IS MIN	0.000	0.078	0.000	0.000	0.023	0.000
	N	21.000	21.000	21.000	21.000	21.000	21.000
	STD	0.201	0.226	0.223	0.194	0.220	0.200
Lafarge (LG)	IS MAX	0.879	0.768	0.677	0.826	0.730	0.651
	IS MEAN	0.301	0.420	0.333	0.258	0.382	0.307
	IS MIN	0.000	0.044	0.000	0.000	0.041	0.000
	N	21.000	21.000	21.000	21.000	21.000	21.000
	STD	0.214	0.209	0.223	0.200	0.204	0.211

Table A.6. Suite Evolution of Information Share for the CAC40 stocks in April 2013

		April 2013					
		Maximum			Minimum		
CAC40 Stocks	Information Share	Chi-X	BATS	Euronext Paris	Chi-X	BATS	Euronext Paris
L'Oreal (OR)	IS MAX	0.894	0.848	0.536	0.565	0.810	0.491
	IS MEAN	0.299	0.632	0.188	0.203	0.528	0.154
	IS MIN	0.000	0.427	0.000	0.000	0.071	0.000
	N	21.000	21.000	21.000	21.000	21.000	21.000
	STD	0.237	0.139	0.139	0.138	0.213	0.123
LVMH (MC)	IS MAX	0.545	0.992	0.254	0.416	0.987	0.226
	IS MEAN	0.196	0.775	0.109	0.132	0.704	0.087
	IS MIN	0.000	0.488	0.000	0.000	0.355	0.000
	N	21.000	21.000	21.000	21.000	21.000	21.000
	STD	0.161	0.155	0.083	0.123	0.199	0.069
Michelin (ML)	IS MAX	0.530	0.934	0.615	0.419	0.919	0.567
	IS MEAN	0.270	0.598	0.212	0.207	0.531	0.184
	IS MIN	0.000	0.027	0.000	0.000	0.025	0.000
	N	21.000	21.000	21.000	21.000	21.000	21.000
	STD	0.153	0.242	0.177	0.129	0.244	0.168
Pernod Ricard (RI)	IS MAX	0.683	0.968	0.935	0.518	0.958	0.892
	IS MEAN	0.239	0.518	0.338	0.172	0.454	0.286
	IS MIN	0.000	0.013	0.000	0.000	0.001	0.000
	N	21.000	21.000	21.000	21.000	21.000	21.000
	STD	0.181	0.268	0.253	0.147	0.270	0.232
Renault (RNO)	IS MAX	0.776	0.812	0.758	0.573	0.763	0.716
	IS MEAN	0.296	0.509	0.286	0.224	0.434	0.253
	IS MIN	0.000	0.034	0.000	0.000	0.031	0.000
	N	21.000	21.000	21.000	21.000	21.000	21.000
	STD	0.197	0.184	0.208	0.156	0.185	0.194
Saint Gobain (SGO)	IS MAX	0.727	0.882	0.378	0.613	0.854	0.350
	IS MEAN	0.325	0.596	0.147	0.267	0.536	0.129
	IS MIN	0.000	0.085	0.000	0.000	0.057	0.000
	N	21.000	21.000	21.000	21.000	21.000	21.000
	STD	0.200	0.205	0.106	0.175	0.213	0.097
Sanofi (SAN)	IS MAX	0.861	0.965	0.400	0.784	0.960	0.364
	IS MEAN	0.318	0.600	0.170	0.246	0.525	0.144
	IS MIN	0.000	0.110	0.000	0.000	0.039	0.000
	N	21.000	21.000	21.000	21.000	21.000	21.000
	STD	0.218	0.231	0.128	0.199	0.236	0.113
Schneider Electric (SU)	IS MAX	0.626	0.942	0.691	0.525	0.916	0.629
	IS MEAN	0.347	0.435	0.321	0.265	0.362	0.275
	IS MIN	0.000	0.121	0.000	0.000	0.070	0.000
	N	21.000	21.000	21.000	21.000	21.000	21.000
	STD	0.165	0.211	0.188	0.133	0.214	0.171
Societe Generale (GLE)	IS MAX	0.995	0.996	0.211	0.994	0.994	0.179
	IS MEAN	0.425	0.549	0.086	0.371	0.497	0.073
	IS MIN	0.000	0.001	0.000	0.000	0.000	0.000
	N	21.000	21.000	21.000	21.000	21.000	21.000
	STD	0.296	0.295	0.071	0.286	0.304	0.061
STMicroelectronics (STM)	IS MAX	0.951	0.710	0.856	0.800	0.565	0.824
	IS MEAN	0.496	0.386	0.277	0.350	0.243	0.252
	IS MIN	0.000	0.060	0.000	0.000	0.011	0.000
	N	21.000	21.000	21.000	21.000	21.000	21.000
	STD	0.250	0.172	0.246	0.204	0.162	0.232
Total (FP)	IS MAX	0.942	0.935	0.434	0.926	0.916	0.374
	IS MEAN	0.316	0.626	0.135	0.252	0.560	0.113
	IS MIN	0.000	0.018	0.000	0.000	0.013	0.000
	N	21.000	21.000	21.000	21.000	21.000	21.000
	STD	0.226	0.246	0.131	0.220	0.241	0.109
Veolia Environnement (VIE)	IS MAX	0.906	0.889	0.965	0.828	0.778	0.959
	IS MEAN	0.380	0.532	0.236	0.246	0.396	0.214
	IS MIN	0.000	0.038	0.000	0.000	0.001	0.000
	N	21.000	21.000	21.000	21.000	21.000	21.000
	STD	0.255	0.248	0.239	0.206	0.263	0.232
Vinci (DG)	IS MAX	0.625	0.994	0.513	0.475	0.990	0.478
	IS MEAN	0.203	0.715	0.148	0.154	0.662	0.121
	IS MIN	0.000	0.015	0.000	0.000	0.015	0.000
	N	21.000	21.000	21.000	21.000	21.000	21.000
	STD	0.196	0.230	0.146	0.158	0.253	0.134
Vivendi (VIV)	IS MAX	0.707	0.957	0.351	0.670	0.937	0.291
	IS MEAN	0.314	0.660	0.116	0.245	0.576	0.090
	IS MIN	0.056	0.008	0.008	0.037	0.000	0.005
	N	18.000	18.000	18.000	18.000	18.000	18.000
	STD	0.191	0.223	0.098	0.162	0.236	0.080

Table A.7. Percentage of executed orders on Euronext Paris fo the buy orders- 03/12/12 (1=Market order, 2=Limit order, 3=Stop market order, 4=Stop limit order, P=Pegged order, K=Market to limit order)

ACA							
Type of order	1	2	3	4	K	P	Total
Number of added orders	197	120812	12	4	34	0	121059
Number of cancelled orders	16	112952	12	4	0	0	112984
Number of executed orders	181	7860	0	0	34	0	8075
Percentage of executed orders (%)							7
AI							
Type of order	1	2	3	4	K	P	Total
Number of added orders	224	91553	1	0	0	0	91778
Number of cancelled orders	40	86993	1	0	0	0	87034
Number of executed orders	184	4560	0	0	0	0	4744
Percentage of executed orders (%)							5
BN							
Type of order	1	2	3	4	K	P	Total
Number of added orders	151	73562	1	5	0	0	73719
Number of cancelled orders	42	68593	1	0	0	0	68636
Number of executed orders	109	4969	0	5	0	0	5083
Percentage of executed orders (%)							7
BNP							
Type of order	1	2	3	4	K	P	Total
Number of added orders	336	126885	10	0	47	0	127278
Number of cancelled orders	40	111232	10	0	1	0	111283
Number of executed orders	296	15653	0	0	46	0	15995
Percentage of executed orders (%)							13
CA							
Type of order	1	2	3	4	K	P	Total
Number of added orders	188	52950	1	1	20	0	53160
Number of cancelled orders	42	47312	1	1	0	0	47356
Number of executed orders	146	5638	0	0	20	0	5804
Percentage of executed orders (%)							11
CAP							
Type of order	1	2	3	4	K	P	Total
Number of added orders	116	48181	1	0	15	0	48313
Number of cancelled orders	13	44793	1	0	0	0	44807
Number of executed orders	103	3388	0	0	15	0	3506
Percentage of executed orders (%)							7
DG							
Type of order	1	2	3	4	K	P	Total
Number of added orders	191	66320	1	23	0	0	66535
Number of cancelled orders	40	60943	1	0	0	0	60984
Number of executed orders	151	5377	0	23	0	0	5551
Percentage of executed orders (%)							8
EI							
Type of order	1	2	3	4	K	P	Total
Number of added orders	136	38655	4	0	17	0	38812
Number of cancelled orders	41	33193	4	0	0	0	33238
Number of executed orders	95	5462	0	0	17	0	5574
Percentage of executed orders (%)							14
EN							
Type of order	1	2	3	4	K	P	Total
Number of added orders	181	56797	3	0	10	0	56991
Number of cancelled orders	14	51080	2	0	0	0	51096
Number of executed orders	167	5717	1	0	10	0	5895
Percentage of executed orders (%)							10
FP							
Type of order	1	2	3	4	K	P	Total
Number of added orders	310	120568	2	0	53	0	120933
Number of cancelled orders	45	103722	2	0	4	0	103773
Number of executed orders	265	16846	0	0	49	0	17160
Percentage of executed orders (%)							14
ORA							
Type of order	1	2	3	4	K	P	Total
Number of added orders	192	113632	10	1	12	0	113847
Number of cancelled orders	45	105711	10	1	0	0	105767
Number of executed orders	147	7921	0	0	12	0	8080
Percentage of executed orders (%)							7
GLE							
Type of order	1	2	3	4	K	P	Total
Number of added orders	340	125901	23	1	30	0	126295
Number of cancelled orders	47	110304	23	1	0	0	110375
Number of executed orders	293	15597	0	0	30	0	15920
Percentage of executed orders (%)							13

Table A.7. Suite Percentage of executed orders on Euronext Paris fo the buy orders- 03/12/12 (1=Market order, 2=Limit order, 3=Stop market order, 4=Stop limit order, P=Pegged order, K=Market to limit order)

GSZ							
Type of order	1	2	3	4	K	P	Total
Number of added orders	225	52666	1	0	22	0	52914
Number of cancelled orders	41	46627	1	0	0	0	46669
Number of executed orders	184	6039	0	0	22	0	6245
Percentage of executed orders (%)							12
MC							
Type of order	1	2	3	4	K	P	Total
Number of added orders	195	34996	0	0	29	0	35220
Number of cancelled orders	42	27906	0	0	0	0	27948
Number of executed orders	153	7090	0	0	29	0	7272
Percentage of executed orders (%)							21
ML							
Type of order	1	2	3	4	K	P	Total
Number of added orders	163	46633	0	0	23	0	46819
Number of cancelled orders	17	41024	0	0	0	0	41041
Number of executed orders	146	5609	0	0	23	0	5778
Percentage of executed orders (%)							12
PP							
Type of order	1	2	3	4	K	P	Total
Number of added orders	59	24707	0	1	3	0	24770
Number of cancelled orders	14	22114	0	1	0	0	22129
Number of executed orders	45	2593	0	0	3	0	2641
Percentage of executed orders (%)							11
RI							
Type of order	1	2	3	4	K	P	Total
Number of added orders	107	51241	0	0	12	0	51360
Number of cancelled orders	14	48097	0	0	0	0	48111
Number of executed orders	93	3144	0	0	12	0	3249
Percentage of executed orders (%)							6
RNO							
Type of order	1	2	3	4	K	P	Total
Number of added orders	102	69673	9	3	4	0	69791
Number of cancelled orders	26	62285	9	3	0	0	62323
Number of executed orders	76	7388	0	0	4	0	7468
Percentage of executed orders (%)							11
SGO							
Type of order	1	2	3	4	K	P	Total
Number of added orders	173	76592	0	0	9	0	76774
Number of cancelled orders	40	71429	0	0	0	0	71469
Number of executed orders	133	5163	0	0	9	0	5305
Percentage of executed orders (%)							7
SAN							
Type of order	1	2	3	4	K	P	Total
Number of added orders	271	88622	0	0	21	0	88914
Number of cancelled orders	41	76655	0	0	0	0	76696
Number of executed orders	230	11967	0	0	21	0	12218
Percentage of executed orders (%)							14
STM							
Type of order	1	2	3	4	K	P	Total
Number of added orders	90	33474	59	0	6	0	33629
Number of cancelled orders	21	29468	59	0	1	0	29549
Number of executed orders	69	4006	0	0	5	0	4080
Percentage of executed orders (%)							12
SU							
Type of order	1	2	3	4	K	P	Total
Number of added orders	130	113068	2	0	15	0	113215
Number of cancelled orders	41	104844	2	0	0	0	104887
Number of executed orders	89	8224	0	0	15	0	8328
Percentage of executed orders (%)							7
VIE							
Type of order	1	2	3	4	K	P	Total
Number of added orders	177	81494	3	0	27	0	81701
Number of cancelled orders	13	74749	3	0	0	0	74765
Number of executed orders	164	6745	0	0	27	0	6936
Percentage of executed orders (%)							8
VIV							
Type of order	1	2	3	4	K	P	Total
Number of added orders	200	43291	6	0	16	0	43513
Number of cancelled orders	47	38231	6	0	0	0	38284
Number of executed orders	153	5060	0	0	16	0	5229
Percentage of executed orders (%)							12
EDF							
Type of order	1	2	3	4	K	P	Total
Number of added orders	158	32903	0	0	22	0	33083
Number of cancelled orders	15	29521	0	0	0	0	29536
Number of executed orders	143	3382	0	0	22	0	3547
Percentage of executed orders (%)							11
EAD							
Type of order	1	2	3	4	K	P	Total
Number of added orders	180	53582	2	46	0	0	53810
Number of cancelled orders	16	47461	2	0	0	0	47479
Number of executed orders	164	6121	0	46	0	0	6331
Percentage of executed orders (%)							12
OR							
Type of order	1	2	3	4	K	P	Total
Number of added orders	173	26722	0	0	24	0	26919
Number of cancelled orders	41	22944	0	0	0	0	22985
Number of executed orders	132	3778	0	0	24	0	3934
Percentage of executed orders (%)							15
LG							
Type of order	1	2	3	4	K	P	Total
Number of added orders	100	87778	0	0	10	0	87889
Number of cancelled orders	17	83143	0	0	0	0	83170
Number of executed orders	83	4626	0	0	10	0	4719
Percentage of executed orders (%)							5