EconPol
WORKING PAPER

12
2018

July
Vol. 2

The Role of Pre-Opening Mechanisms in Fragmented Markets

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EUROPE
econPOL
European Network for Economic
and Fiscal Policy Research

headed by

ifo INSTITUTE
Leibniz Institute for Economic Research
at the University of Munich








EconPol Working Paper
A publication of EconPol Europe
European Network of Economic and Fiscal Policy Research

Publisher and distributor: ifo Institute
Poschingerstr. 5, 81679 Munich, Germany
Telephone +49 89 9224-0, Telefax +49 89 9224-1462, Email Dolls@ifo.de
Editors: Mathias Dolls, Clemens Fuest

EconPol Europe: www.econpol.eu

The role of pre-opening mechanisms in fragmented markets [1]

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[1]We are very grateful to Paul Besson (from Kepler-Chevreux), Dion Bongaerts, Catherine d'Hondt, Thierry Foucault, Carole Gresse, Alexander Guembel, Marius Zoican and seminar participants at the 3rd Forum "Market Microstructure: Confronting Many Viewpoints" (Paris) for providing useful comments. We especially thank Eurofidai-Bedofih for providing us the data. Laurence Lescourret is research fellow at CREST. Financial support from the ANR (ANR-16-CE26-0008) is gratefully acknowledged. Part of this research was carried out while Sophie Moinas was appointed Judith C. and William G. Bollinger Visiting Professor at the Wharton School, University of Pennsylvania, and benefited from the support from the CNRS.

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Abstract

To facilitate price discovery, Euronext Paris has always relied on a transparent pre-opening phase and on a call auction to open continuous markets. Fast trading, competition from alternative trading venues and the poor volume at the open (2%) however question the role of these non-trading sessions. Using a unique dataset of stocks cross-traded on Euronext Paris, BATS and Chi-X, we explore the behavior of traders during the preopen based on their speed and nature of orders (proprietary, agency or market-making). We show that slow brokers submit orders very early, and most of them are executed within the day. In contrast, fast prop traders or dedicated liquidity providers only participate in the last half-hour. Interestingly the pre-opening activity of slow brokers is strongly related to the price discovery process across trading venues. Finally, we show that although tentative clearing prices of the preopen contain information, they are followed by a reversal in the following 15 minutes across the different platforms, reflecting price pressure and liquidity issues around the open.

Keywords: pre-opening period, market fragmentation, liquidity, price discovery

JEL Classification code: G12, G14, G20

1 Introduction

Liquidity issues in financial markets arise because of two main factors: asymmetric information (Kyle, 1985) and cost of market participation (Grossman and Miller, 1988). To alleviate these frictions, several exchanges start with a pre-opening period characterized by the accumulation of orders and the absence of trade execution. Since its very beginning in 1986, Euronext Paris has implemented a transparent pre-opening phase followed by a call auction to open continuous trading sessions. During the pre-opening period, each time a new message is posted, an indicative clearing price is determined and publicly disseminated, similar to a tâtonnement process. The release of this pre-trade information aims at reducing information asymmetries. In a seminal paper, Biais et al. (1999) show that this tâtonnement process facilitates price discovery by reducing price uncertainty after the market has been temporarily closed.

In the last decade, changes in technologies and in regulation have profoundly reshaped financial markets. The decreasing volume at the open (down from 10% to 2%), the complex role of fast traders and the increasing competition of alternative trading platforms put into question the findings of Biais et al. (1999). In particular, during the period we study in 2012 and 2013, Euronext Paris offers a pre-opening period from 07:15 to 09:00 am, while BATS and Chi-X Europe, the two main competitors, directly start trading in a continuous limit order book without holding opening call auction.[1,2] This paper uses the difference in opening mechanisms across trading venues to empirically investigate the role of the pre-opening offered by Euronext Paris. Beyond this difference, we also exploit detailed information on the order submission during the pre-call period (i.e., speed and the nature of the order) to analyze the price formation process on the exchange itself and on the two competing trading venues (BATS and Chi-X Europe).

Our sample is composed of the cross-traded French stocks of the SBF 120 index, and spans from May 2, 2012 to December 31, 2013. Data are provided by Eurofidai-Bedofih and consist of messages (new orders, modifications and cancellations) submitted

[1] An opening call auction with a random end period has been implemented on BATS on January 30, 2015. It consists of a 10-minute pre-opening period from 8:50am (Paris time) to 9:00am.

[2] These platforms operate continuously from 9:00am until 5:30pm (Paris time). They use market data from the primary market for example the tick size, or the Primary Best Bid Best Offer (PBBO) which corresponds to the midpoint of the relevant Best Bid and Offer quoted on the listing (or primary) market. To guarantee attractive prices to investors, the matching of orders on all three trading venues is subject to a price check. However, the alternative platforms apply different tolerance levels. Generally, an order will be rejected if it executes a certain percentage above the European Best Bid or below the European best offer. Trading rules may thus differ from one venue to another.

to Euronext Paris (including the pre-opening period), and trades and quotes observed every 15 minutes on Euronext Paris, BATS and Chi-X Europe. The Euronext messages dataset includes two proprietary variables: i. a flag provided by the French Market Authorities (AMF, Autorité des Marchés Financiers) that identifies fast traders (High-Frequency Traders, HFT), slow traders (NON-HFT), or MIXED financial institutions that implement both HFT and NON HFT strategies; ii. the account used by the member to post the order, which identifies whether the order is submitted on behalf of a client (client), on the member's own account (prop trader), or as dedicated market-maker (liquidity provider). We relate measures of market liquidity and price discovery on each trading venues to the pre-opening behavior of traders on Euronext. This enables us to address the following questions: Do pre-opening periods still contribute to the overall price discovery and to liquidity formation in fragmented markets? Do differences across traders' behavior during the preopening explain the economic role of the pre-open?

Our main results are as follows. First, opening clearing prices contain information on end-of-the-day prices, and the volume cleared at the opening call auction on Euronext is positively correlated with the daily trading volume on all venues, Euronext, BATS and Chi-X. Second, the pre-opening order submission is very different across traders' categories. In particular, we find that slow brokers submit messages very early in the pre-opening session, namely in the first half-hour from 7:15 to 7:45am. Their activity then declines to rebound in the last half-hour before the opening. More than half of the orders submitted in the first half-hour are filled at least partially either during the opening call auction or during the day. This suggests that slow brokers may participate early in order to gain time priority or to advertise trading needs, possibly to compensate their speed disadvantage. By contrast, MIXED prop traders are very active in the last 15 minutes before the opening call auction, and updates and cancellations represent more than a third of their messages, consistent with an important monitoring activity. Strikingly, dedicated market-makers (in particular fast liquidity suppliers) hardly supply liquidity at the open.

Third, we compute tentative clearing prices and volumes during the pre-opening, that is, prices at which the largest number of shares would trade given orders standing in the book. We use snapshots of the limit order book rebuilt by Eurofidai-Bedofih every 15 minutes during the pre-open to build cumulated demand and supply functions. When the highest bid and the lowest ask cross, we report the tentative opening price and tentative opening volume. When they don't, we use the lowest ask and highest bid quotes to

compute a pre-opening midquote, provided that limit orders exist on both sides of the limit order book. We then investigate whether pre-opening prices contribute to the daily price discovery. We find that the return from the close to time τ of the pre-open is significantly positively related to the close-to-close return, and that the economic and statistical significance of this relation increases over time during the pre-opening period. We interpret this as evidence that tentative prices contain information. The fact that prices observed late at the end of the pre-opening period are related to end-of-the-day prices has first been documented by Biais et al. (1999). Interestingly, this result also holds, to a lesser extent, to tentative midquotes, that is, when demand and supply do not cross. However, even though pre-opening tentative clearing prices contain information on the end-of-the-day prices, we find a significant negative relation between the return from the close to time τ of the pre-open and the return from the open to 9:15am. By contrast, when there is no cross during the pre-opening period, the evolution of prices based on tentative midquotes is not followed by a price reversal during the day.

Fourth, we investigate the correlations between the activity measured by the tentative clearing volume during the pre-open and the subsequent trading activity in the continuous session across the three venues. We document a positive and significant relation between the tentative opening volume and the daily volume for each of the three trading venues. This is consistent with various economic mechanisms (order splitting, new strategies tested, sunshine trading, or information leakage on liquidity needs). We also find a negative and significant relation between tentative clearing volumes and average daily spreads across the three platforms.

Finally, we relate measures of liquidity and price discovery during the day for each of the three venues with the pre-opening behaviors of market participants on Euronext. We find that daily spreads are negatively related to the number of preopening messages submitted MIXED prop traders. We also find that the pre-opening activity of slow brokers and slow liquidity suppliers is significantly positively related to the informational content of opening prices, and significantly and negatively related to price reversals.

Our paper contributes to papers analyzing the pre-opening and opening of trading venues. Several papers show that the pre-call phase significantly contributes to price discovery (see, among others, Biais et al. (1999) for the Paris Bourse, Cao et al. (2000) for the NASDAQ, Davies (2003) for the Toronto Stock Exchange, Ellul et al. (2005) for the London Stock Exchange, or Madhavan and Panchapagesan (2000) for the NYSE).

Using data related to limit order books, Hoffmann and Van Bommel (2009) show that the transparent opening call auction used by Euronext leads to more price discovery than the opaque mechanism implemented by Xetra, the German Exchange. Recently, using detailed data on HFT vs. NON HFT participants, Bellia et al. (2016) show that the pre-opening activity of fast traders on the Tokyo Stock Exchange significantly improves both liquidity and price efficiency of the subsequent opening call auction. Our paper enriches this strand of literature by showing that even if the opening call auction on Euronext attracts less liquidity than when the market was consolidated, it is still an efficient mechanism for discovering prices not only on the exchange itself but also, by externality, on other competing venues without call auctions.

The paper is organized as follows. Section 2 describes the role of the pre-opening period and develops the testable hypotheses. Section 3 describes data, sample selection and provides descriptive statistics related to the pre-opening and opening auctions on Euronext. Section 4 presents the main empirical results. Section 5 concludes.

2 The role of the pre-opening period

2.1 The trading environment

Euronext is the seventh largest market in the world (World Federation of Exchange, 2015). Euronext was formed in September 2000 from the merger of the Amsterdam, Brussels and Paris stock exchanges.[3] Euronext Paris, formerly known as the Paris Bourse, has always relied on call auction mechanisms, in particular to perform the opening when it started to use continuous electronic limit order book in 1986.

In the aftermath of MiFID (Market in Financial Instruments Directive) implementation, new trading venues have appeared in 2007 and 2008. These Multilateral Trading Facilities (MTF) have invested in trading technology such as matching engines and trade processing times (i.e., decreased latency) and offer attractive trading fees (known as maker/taker model).[4] These new trading venues provide facilities for secondary equity trading (and not primary listing). Among the most successful platforms in terms of market share during the period we study are BATS and Chi-X.[5]

[3]The Portuguese stock exchange was acquired in 2002.

[4]MTFs have adopted maker/taker fees, which implies providing a rebate to customers that provide liquidity and charging customers who remove or "take" liquidity.

[5]Some other trading platforms exist such as Turquoise. Their market share is however negligible.

BATS Trading Limited (BATS) operates an order-driven platform on which stocks are traded from 9:00am to 5:30pm (Paris time).[6] BATS operates both a "lit" (or transparent) order book and a dark order book. Like BATS, Chi-X operates a lit and a dark order book from 9:00am to 5:30pm through the Chi-X MTF.[7] Chi-X was acquired by BATS in December 2011.[8] Both platforms do not use call auction to open or close the market during the time of our study.

2.2 Pre-opening mechanism and opening call auction on Euronext

Euronext operates as a single electronic limit order book (known as the Universal Trading Platform, UTP) integrating all trades from the Amsterdam, Brussels, Paris and Lisbon markets. Trading takes place continuously from 9:00am to 5:30pm. Call auctions are held at the opening and closing of the trading day, that is, respectively at 9:00am and 5:35pm. Each auction is made of two phases: a pre-call auction phase during which orders accumulate in the limit order book, and a call phase. The pre-closing phase lasts five minutes from 5:30pm to 5:35pm, while the pre-opening phase lasts one hour and forty-five minutes from 7:15am to 9:00am. At 9:00am and at 5:35pm the opening and closing prices are set by crossing the cumulated supply and demand functions based on the orders pending in the book, so as to maximize the trading volume. Price and time priorities are enforced.[9] After the opening auction, the market operates continuously as a limit order book.

Every morning at 7:15am, Euronext opens the limit order book to market participants in preparation for the opening auction. Since orders are good till canceled ('GTC') on Euronext, the limit order book starts with left over orders, unlike BATS and Chi-X which both have a end-of-day convention.[10] During the pre-call auction phase orders may be submitted, modified, or canceled, but no transactions take place. Each time an order is

[6]BATS Trading Limited is a UK-based subsidiary of the US company, BATS Inc, founded in 2005.

[7]Chi-X was a UK company established in 2007 by Instinet, a subsidiary of the Japanese company Nomura Holdings.

[8]The consortium BATS-Chi-X Europe changed its status and has been recognized as "Exchange" in May 2013, allowing BATS and Chi-X to compete on primary listings. BATS Inc. (and thus BATS-Chi-X Europe) have merged with CBOE in March 2017.

[9]From August 19, 2015, the opening and closing auctions occur randomly between 9:00:00am and 9:00:30am and 5:35:00pm and 5:35:30pm, respectively.

[10]At the end of each trading session, all orders on BATS or on CHI-X are canceled. The limit order book starts empty the next day.

submitted by a member and transmitted to the Euronext Trading Platform, a tentative call auction and an *indicative* equilibrium price is disseminated to the public (along with the the potentially executable volume).[11] Market participants trading on BATS or Chi-X benefit from the public dissemination of tentative prices and volumes. Do the Euronext pre-opening and call auction help the price discovery on competing platforms?

2.3 Hypothesis development

2.3.1 Opening auction

Opening call auctions take place after an overnight trading halt, during which new information has accumulated. By concentrating buying and selling interests, the objectives of call auctions include (i) discovering the price after a period of no trade (see, for instance, the model of Vives (1995)) and (ii) improving quantity discovery (Chakraborty et al. (2012)). Corroborating these theoretical predictions, some empirical studies (e.g., Biais et al. (1999) or Comerton-Forde (1999)) find that call auctions make opening prices more informative. The Euronext market opening is very active and accounts, on average, for 1.3% (resp. 1.9%) of total trading volume for large stocks (resp. small stocks) (see Table 3 presented below). This percentage is however much lower than the 10% found by Biais et al. (1999). The lower trading volume reveals a much smaller liquidity concentration at the open which could reduce the efficiency of the opening call auction. Whether the opening call auction on Euronext is still an efficient way to discover opening price is thus an empirical question:

Hypothesis 1 *The existence of an opening call auction facilitates price discovery on Euronext.*

The lower trading activity at the open on Euronext could be the result of market fragmentation. Stocks in our sample simultaneously trade on Euronext, as well as on BATS and Chi-X. Traders could thus have shifted trading from Euronext to BATS and Chi-X. Moreover the call auction is totally transparent on Euronext which could deter informed trading preferring less transparent venues at the open. The opening mechanisms are however different across platforms since BATS and Chi-X don't have opening call auctions. Because call auctions provide a mechanism which limits price impact and transaction costs (see, for instance, Stoll, 1985), some market participants trading for

[11] Source: Trading manual for the universal trading platform, May 2016.

liquidity reasons (like portfolio rebalancing) might prefer to trade on Euronext. Informed traders could thus also prefer trading on Euronext to benefit from liquidity concentration (Admati and Pfleiderer (1988)). Due to these differences, price and quantity discovery across venues at the open might be different:

Hypothesis 2 *Opening prices on BATS and Chi-X are less informative than opening prices on Euronext.*

Because call auctions make transaction costs lower, liquidity traders could use the opening call to trade more efficiently. Following Admati and Pfleiderer (1991) or Dia and Pouget (2011), traders may engage into sunshine trading in order to reduce price impact. By trading large amounts at the open, they would advertise their liquidity needs to attract traders ready to absorb their position. We thus deduce that there might exist a significant positive correlation between the activity at the open and the activity during the following continuous trading session across all platforms. This relation could however only be mechanical and not the outcome of strategic order submission decisions from liquidity traders. An increase in the trading needs of participants during the overnight trading halt may translate simultaneously into an increase in the volume traded at the call and during the day without any causality. It is only due to the fact that a fraction of trades is executed at the open. Moreover, to the extend that trading on Euronext is anonymous, it may be difficult to rationalize that traders would benefit from a sunshine trading disclosure strategy during the call auction period. We thus formulate the following hypothesis:

Hypothesis 3 *The activity at the open (measured by trading volume and liquidity) is correlated with the daily activity of the following continuous trading session.*

Due to the potential presence of liquidity traders searching for reduced price impact at the open, liquidity suppliers (endogenous market-makers like high frequency traders or designated market-makers) could find profitable to trade at the opening. Supplying liquidity at the call might generate opening price reversals (Nagel, 2012). At the extreme, opening price reversal could also be due to some manipulative activities aiming at artificially inflating opening prices for a short period (a practice known as "marking the open"). Even if call auctions make manipulation more costly, Medrano and Vives (2001) show that an informed trader may choose to follow a contrarian strategy to manipulate

prices during a preopening session. Because BATS and Chi-X do not have preopening nor opening call auctions, we thus test the following hypothesis:

Hypothesis 4 *Opening price reversals are observed on Euronext and not on BATS nor on Chi-X.*

2.3.2 Pre-opening period

Although no trades take place and orders can be canceled at no cost, empirical studies show that non-binding pre-opening orders submitted late in the pre-opening improve price discovery (Biais et al. (1999), Cao et al. (2000)). The study of the order submission process during the pre-opening phase should help understanding how the opening call auction on Euronext contributes to discovering opening prices and whether it has an impact on other trading venues deprived of this mechanism. In particular, signaling vs. manipulative behaviors could be detected using the timing of orders during the pre-open or the category of accounts/traders submitting orders (client, liquidity supplier or prop trader/HFT or non-HFT).

First, remind that price-time priority is enforced during the pre-opening period. Submitting an order very early during the pre-opening period without canceling it enables traders to gain priority in the limit order book and during the opening call auction. Liquidity traders might thus be willing to post such very early orders. Moreover posting messages very early is a way to advertise liquidity needs (consistently with Hypothesis 3). Brokers (using the client account) in particular might choose to follow such strategy:

Hypothesis 5 *Market participants with liquidity needs submit orders very early during the pre-opening period without canceling them.*

Second, informed traders (typically prop traders) willing to get their orders being executed during the opening call auction face a trade-off. On the one hand, they may choose to post their orders as late as possible to hide their trading intentions and to avoid being "picked off" or sniped by faster traders (like HFT prop traders). On the other hand, the probability of execution of their orders decreases the closer they get to the opening time (either due to price then time priority, or due to a stochastic failure, as modeled by Calcagno and Lovo (2010)). We thus formulate the following hypothesis:

Hypothesis 6 *Order submission increases with time during the pre-opening period. Orders' contribution to price discovery steadily increases.*

Third, since the pre-opening period is transparent and can be used by strategic agents as a pre-play signaling device, any trader might use information contained in the pre-opening game to trade across all platforms:

Hypothesis 7 *Because the transparent pre-opening period is used as a signaling device, there exists a positive correlation between tentative prices (resp. volumes) set during the pre-opening period, and the price (resp. volume) after the opening across all trading venues.*

An alternative explanation for the pre-opening activity would be an attempt to manipulate prices, an effect that has been experimentally documented by Biais et al. (2013) and theoretically shown by Medrano and Vives (2001). Manipulation might however be difficult to show. Opening price reversal due to manipulation might not be very different from a liquidity supply strategy that absorbs price pressure at the open, which might exacerbate inventory exposure (see Lescourret (2016)). Compensation is thus required for taking inventory risk, especially when liquidity concentration is weak.

Hypothesis 7.a *Tentative pre-opening clearing prices might contain information unrelated to fundamentals, causing opening prices to rebound after the opening.*

3 Data and summary statistics

3.1 Data sources

Our analysis is based on two datasets provided by Eurofidai-Bedofih.[12] The Eurofidai daily database contains daily dividends and market capitalization, as of December 31, 2011. The Bedofih-Eurofidai intraday database includes trades and quotes related to the three platforms, Euronext, BATS, and Chi-X. Quotes data consist of 15-minutes snapshots of the limit order books, between 9:00am and 5:30pm for Euronext, BATS and Chi-X.[13]

Data on Euronext further include messages (new orders, updates and cancellations). Besides, Eurofidai-Bedofih data on Euronext contain two proprietary variables related to the member who posts the message or who is part of a trade, namely: i. the nature of the message or trade (that is, on behalf of a client, prop. trading, liquidity provision, retail

[12]Bedofih stands for Base Européenne de DOnn'ees FInancières à Haute fréquence.

[13]Euronext quotes data are rebuilt by Bedofih from a replay of the market. Bedofih provides us with two quantities on each side: one quantity that does not incorporate hidden depth, and one that does.

trader, or related party), and ii. a flag indicating whether it is an HFT, a NON-HFT, or a MIXED financial entity doing fast and slow trading (as identified by the French Market Authority, AMF).[14] Biais et al. (2016) use a seemingly, yet different, classification of traders by account. They use a different definition of speed and are able to categorize each member thanks to a unique (anonymized) ID for each member that Bedofih does not have access to.[15]

3.2 Sample selection

Our sample consists of French stocks constituting the SBF120 index that are traded across Euronext Paris, BATS and Chi-X Europe, spanning twenty months from May 2, 2012 to December 31, 2013. We drop 7 stocks which do not belong to the index on January 1, 2012, and 13 additional stocks which are not traded continuously on BATS and Chi-X during our sample period. We drop 5 trading days that are characterized by a half-day of trading (December 24 and 31, 2012 and 2013) or face technical issues (June 6, 2013). Besides, we drop 1 stock, 2 trading days, and a few stock-day observations due to data reporting issues (e.g., missing quotes). We identify 75 stock-day observations characterized by a trading halt reported by Euronext, either during the continuous trading session or at the open. Those trading halts are either caused by a corporate event, or by prices crossing price limits. We also found 12 days characterized by a stock split. We exclude these stock-day observations to avoid a potential impact on daily liquidity measures. Our final panel consists of 41,569 stock-day observations, for 99 stocks and a maximum of 420 trading days. We split the sample in two by capitalization group. Panel *Index* is composed of the 50 stocks that belong either to the CAC40 (32 stocks) or to the CACNext20 (18 stocks) indexes. Panel *Non Index* contains 49 stocks that do not belong to these indexes and mainly represent small caps.

3.3 Definition of variables

In the following, we index trading venues by S, where $S = E$ for Euronext, $S = B$ for BATS and $S = C$ for Chi-X. Day is indexed by t and the subscript for stocks is omitted

[14] Related parties are often subsidiaries of a financial institution which trade with the membership ID of the latter, under its supervision.

[15] Their categorization of speed is a function of the *capacity* of the member to send multiple messages within one second. This information is provided by Euronext. The French Market Authorities additionally takes into account the effective speed and the behavior of institutions to flag a member as HFT.

for brevity.

3.3.1 Price discovery

Our main variables of interest relate to price discovery. We define the close-to-close return r_t^{CC} as

$$r_t^{CC} = \frac{CLOSEP_t + DIV_t - CLOSEP_{t-1}}{CLOSEP_{t-1}}, \tag{1}$$

where $CLOSEP_t$ is the closing price on day t and DIV_t is the dividend paid on day t. Similarly, we define the close-to-open return r_t^{CO} as

$$r_t^{CO} = \frac{OPENP_t - CLOSEP_{t-1}}{CLOSEP_{t-1}}, \tag{2}$$

where $OPENP_t$ is the opening price on day t, and finally the open-to-9:15am return as

$$r_t^{O,9:15^S} = \frac{MQ_t^{9:15^S} - OPENP_t}{OPENP_t}, \tag{3}$$

where $MQ_t^{9:15^S}$ is the midquote at 9:15am on the trading venue S.

To investigate the impact of the pre-opening messages activity in the pre-opening period on price discovery, we define the following dummy variables: D_IC is a dummy variable that takes value 1 if the close-to-open return and the close-to-close returns have the same sign, and 0 otherwise, that is

$$D\_IC_t = \mathbb{1}_{r_t^{CO} \times r_t^{CC} \geq 0}. \tag{4}$$

D_REV^S is a dummy variable that takes value 1 if the close-to-open return and the open-to-9:15am return have opposite signs, and 0 otherwise, that is

$$D\_REV_t^S = \mathbb{1}_{r_t^{CO} \times r_t^{O,9:15^S} < 0}, \tag{5}$$

where midquotes at 9:15am are taken from the trading venue S ($S = E, B$ and C).

3.3.2 Liquidity and trading activity of the day

We construct measures of trading activity, for each stock, each day, and each trading venue S, namely: the number of trades $NBTR_t^S$, the trade size TS_t^S in €, the traded volume V_t^S in million €, the market share defined as $MS_t^S = V_t^S / \sum_S V_t^S$, and the transaction price

P_t^S. We set volumes and number of trades to zero when there is no trading in the trading venue S and no trading halt reported by Euronext ($S = E, B$ and C). As a proxy for volatility, we compute $HILO_t$ as the daily price range (that is, high minus low) defined by Parkinson (1980).

We also use information contained in the proprietary variables provided by Eurofidai-Bedofih, namely the account's type and the HFT flag, to construct measures of trading activity by member's category. The traded volume for each category of member (client, prop trader, liquidity provider, retail client, related party / HFT, NON-HFT, MIXED) is measured in absolute terms and relative to the total traded volume.

We measure market liquidity by using the relative quoted spread $RSPD_t^S$ defined as the difference between the highest bid and the smallest ask divided by the mid-quote. We also use the depth in euro $Depth_t^S$, defined as the average between the € volume available at the best bid and the € volume available at the best ask in the limit order book of the trading venue S ($S = E, B$ and C).

3.3.3 Preopening messages activity

In order to be able to investigate the dynamics of the pre-opening period, we define seven 15-minute intervals between 7:15am and 9:00 am, which we index by i, where i = [7:15-7:30], [7:30-7:45], [7:45-8:00], [8:00-8:15], [8:15-8:30], [8:30-8:45], and [8:45-9:00]. For each 15-minutes interval i, we define measures of messages activity in absolute value, that is, the number of new orders submitted $SUBM_i$, the number of updates $UPDATES_i$, the number of cancellations $CANCEL_i$, and their value relative to the total number of messages MSG_i defined as the sum of the three categories of messages (new, update and cancellation), that is, respectively $\%SUBM_i$, $\%UPDATES_i$, and $\%CANCEL_i$. We build measures related to the life of pre-opening messages. For each new order submitted during the pre-opening period, we identify whether the order has been (at least partially) executed at the opening ($EXECOPEN_i$), or (at least partially) executed during the day ($EXECDAY_i$), or not executed ($NONEXEC_i$).[16]

[16]The last case may correspond to situations in which the order has been eliminated (due to corporate event, supervision, or day validity), canceled or modified, or in which the order remains standing for execution after the daily closing auction ('GTC' convention on Euronext).

3.3.4 Preopening and opening prices and volumes

We compute tentative clearing price and volume that would prevail if the opening call auction would occur at that time. We use 15-min snapshots of Euronext limit order book between 7:15 and 9:00 to rebuild the cumulated demand and supply functions at time τ, where τ corresponds to 7:30am, 7:45am, 8:00am, 8:15am, 8:30am or 8:45am. More precisely, we rank the orders according to price and time priority.

When the cumulated demand and supply functions cross, we select the tentative clearing price TOP_t^τ that maximizes the number of shares traded, from which a tentative clearing volume TOV_t^τ results. When the cumulated demand and supply functions do not cross, especially early in the pre-opening session, we compute a preopening midquote TMQ^τ as the average between the best ask price and the best bid price if both sides of the book are not empty. In the latter case, the corresponding tentative opening volume is equal to zero. Then we compute the return from the close to time τ of the preopen as follows:

$$r_t^{CP_\tau} = \frac{TOP_t^\tau - CLOSEP_{t-1}}{CLOSEP_{t-1}} \mathbb{1}_{Dnocross\_\tau=0} + \frac{TMQ_t^\tau - CLOSEP_{t-1}}{CLOSEP_{t-1}} \mathbb{1}_{Dnocross\_\tau=1}. \quad (6)$$

where $Dnocross\_\tau$ is a dummy variable that takes value 1 if there exists no cross at time τ and zero otherwise and $CLOSEP_{t-1}$ is the closing price of the previous trading day.

Notice that these pre-opening prices and volumes may be computed by Euronext members with the information that they have at their disposal.

Finally, the Bedofih-Eurofidai intradaily dataset contains a variable that flags trades which are executed during the opening call auction. We thus use this variable to define the opening volume $V_{open,t}$, expressed in € or in number of trades.

4 Empirical results

4.1 Summary statistics

4.1.1 Stocks description

Table 1 reports standard summary statistics for stocks in sample. Panel *Index* relates to stocks belonging to CAC40 and CACNext20, while Panel *Non Index* consists of small (or non-index) stocks. Panel *Index* shows that the average market capitalization of index

stocks is 15,544 million euros representing seven times that of stocks reported in Panel *Non Index* amounted to 2,230 million euros. Panel *Non Index* also shows that mid stocks exhibit larger standard deviations for volatility and number of trading days. Regarding trading venues, stocks trade more frequently on Euronext than on Chi-X or BATS (with BATS having the lowest number of trading days). This effect is stronger for small and more illiquid stocks.

Insert Table 1 here

4.1.2 Market activity and market liquidity

Table 2 reports summary statistics related to market activity and market liquidity across all stock-day observations in panel.

Insert Table 2 here

Table 2 shows that, on Euronext, relative spreads of index stocks amount, on average, to 6.8 bp (Panel *Index*), while non-index stocks (Panel *Non Index*) are three times more illiquid (18.5 bp on average). The number of trades of index stocks amounts to 5,386 on average, which is five times larger than for non-index stocks (1,005 on average). As expected, trading activity and market liquidity thus increase with market capitalization.

Comparing trading venues, Euronext executes more than 72% of the total trading volume, followed by Chi-X which absorbs approximately 20% of the total trading volume. The market share of BATS is below 5%. Interestingly the market share of Euronext is smaller for index stocks, with an average of 72.8% while it is 78.4% for non-index stocks. For index stocks, relative quoted spreads on Chi-X amount to 7.7 bp (not very different from Euronext), and are almost half as large as on BATS. For small stocks, BATS is very illiquid compared to the other venues with an average market spread of 76.8bp, while the average relative quoted spread on Chi-X is 43.4bp and only 18.5 bp on Euronext. Average trade size is also larger on Euronext than on BATS or on Chi-X. This effect is even stronger for index stocks. This suggests that the need for immediacy or for executing larger orders should be more easily accommodated on the Euronext exchange than on any other alternative venues. All measures show that, despite market fragmentation, Euronext remains the dominant market in terms of liquidity and trading activity for French stocks, followed by Chi-X and then by BATS. We also find that the proportion of orders or messages submitted by HFT in Euronext increases in market capitalization.

Interestingly though, the proportion of updates, (defined as the number of modifications or cancellations divided by the number of messages), which is often viewed as a proxy for monitoring, is relatively stable across stocks (92.5%).

4.1.3 The opening call auction

Insert Table 3 here

Table 3 reports statistics on opening prices and volumes. To address the economic importance of the opening, we standardize measures related to the opening activity by the corresponding measures computed across the entire trading day. We report this proportion in the second column of the table. For non-index stocks, the opening call auction on Euronext accounts, on average, for 2.3% of the total number of daily trades and 1.9% of the total daily volume. The opening auction volume however decreases with the market capitalization and represents only 1.6% (resp. 1.3%) of the total number of daily trades (resp. total daily trading volume) of index stocks. These numbers strikingly contrast with Biais et al. (1999) who find that trading at the opening represents about 10% of the total daily trading volume.

Although the opening auction represents a smaller fraction of the daily volume, it may still contribute to the price and liquidity discovery. We compute the ratio of the close-to-open return, r^{CO} to the close-to-close return, r^{CC}. If opening prices are informative, we expect the ratio to be positive. The closer the ratio is from one, the more informative the opening price would be. When the ratio is larger than one, there is some price reversal during the continuous trading session.

Table 3 shows that opening clearing prices incorporate on average 17.3% of the daily price change for index stocks (Panel *Index*), and 16.7% for small non-index stocks (Panel *Non Index*). To further investigate this point, we build various time series correlations between prices and volume resulting from the call auction and those of the continuous trading session. Namely we compute the correlation between the close-to-close return r^{CC} and the close-to-open return r^{CO}, and the correlations between the volume at the open, V_{Open}, and the daily volume on each of the three trading venues, V^S ($S = E, B$ and C).

We find that the correlation between the close-to-close return, r^{CC}, and the close-to-open return, r^{CO}, is on average positive and equal to 0.437 for index stocks (Panel *Index*), and to 0.388 for non-index stocks (Panel *Non Index*), suggesting that opening prices tend to move in the same direction as daily prices. This correlation is not significantly

different from zero for non-index stocks and is significantly different from zero at the 5% level for index stocks, as indicated by the result of a t-test based on the cross-section of correlations. These results suggest that the opening call auction still contributes to the daily price discovery, corroborating Hypothesis 1.

Table 3 also reports a positive and significant correlation between the opening clearing volume, and the daily volume traded on Euronext, or on BATS or on Chi-X, in line with Hypothesis 3.[17] The correlation with the volume traded on Euronext is stronger than for the other alternative trading venues, suggesting that the quantity discovery is better on Euronext at the open than on the other two venues deprived of call auction, which is relevant with Hypothesis 2.

To better understand the opening trading activity across members, we classify the opening trade euro volume according to the member's type and account, and compare the trading activity at the open to the other periods, namely the continuous trading session and the closing auction. Table 4 Panel (a) reports the decomposition of the trading volume by members for the opening call auction, while Panel (b) reports the same decomposition for the continuous trading session and Panel (c) for the closing call auction.

Insert Table 4

Table 4 Panel(a) shows that 44.24% (resp. 49.05%) of the opening trade volume of index stocks involve orders from brokers trading on behalf of clients (resp. prop. traders). For non-index stocks, pre-opening orders posted by brokers are even more involved in the opening trading volume, reaching 55.69% (while the proportion of pre-opening orders sent by prop. traders executed at the open decreases to 39.69%). Strikingly, dedicated market-makers hardly supply liquidity at the open (2.62% for index stocks and 4.40% for non-index stocks). Panel (a) also shows that very few fast members (only fast prop traders) take part to the opening call auction, with 5.25% (resp. 6.01%) only of orders involved in the opening trading volume of index stocks (resp. of non-index stocks). Actually the opening trading activity mainly comes from MIXED prop traders or brokers, and slow (or NON-HFT) members (mainly slow brokers), which is consistent with the findings of Biais et al. (2016).

[17] We also exclude the volume executed at the open in Euronext before computing the correlation with the pre-opening volume and results are qualitatively and quantitatively similar.

In particular, the proportion of pre-opening orders executed at the open involving only slow (or NON-HFT) brokers amounts to 30.33% for index stocks and 45.21% for non-index stocks. This contrasts with their smaller market share during the day which represents 13.36% of the trades for index stocks and 29.79% for non-index stocks. The closing call auction is also very different: transactions involving slow brokers only amount to 9.08% (resp. 15.37%) of the closing trading volume of index stocks (resp. of non-index stocks).

Transactions involving MIXED prop traders represent 36.53% (resp. 27.65%) of the opening clearing volume of index stocks (resp. non-index stocks). During the trading day, the proportion of transactions involving MIXED prop traders is around 35% of the volume of the continuous trading session (for index or non-index stocks). At the close, this proportion reaches 53.55% of the closing clearing volume of index stocks and 49.42% of non-index stocks. This is consistent with portfolio rebalancing and liquidity needs characterizing the end of the day (inventory layoff) of financial institutions. The proportion of transactions involving MIXED brokers is quite stable and fluctuates around 10% across the day (opening, continuous or closing), and across stocks (index or non-index).

Finally, the proportion of transactions involving liquidity suppliers (HFT, NON-HFT or MIXED) is quite low at the open. The market share of MIXED liquidity suppliers is always below 0.6% of the trading volume of non-index stocks (whether considering the opening, continuous or closing session). MIXED liquidity suppliers trade more in index stocks. Their transactions are involved in 2.27% of the opening clearing volume of index stocks. This proportion increases to 7.59% of the volume of the continuous trading session, and goes down to 3.36% at the closing call auction. The trading activity of fast (or HFT) liquidity suppliers in index stocks is very contrasted: while 21.10% of the volume of the continuous trading session involve their orders, their market share is almost nonexistent during call auctions (0.04% at the open and 0.2% at the close). The activity of fast (or HFT) liquidity suppliers in non-index stocks is also low or even nonexistent (0% at the open, 2.25% of the continuous trading session and 0.02% of the closing call auction).

Regarding other members, we observe that the participation of both retail traders and related parties is very small (whether, HFT, NON-HFT or MIXED). For this reason, we will neglect them in the remaining analysis.[18]

[18]Retail traders and related parties are pooled together in a control variable for running regressions.

4.1.4 Pre-opening order submission process

Figure 1a illustrates the average daily number of orders newly submitted, updated or canceled posted during each 15-min interval of the pre-open, in value (NBi) and in proportion of the total number of messages ($\%x_i$) ($x = ORD, MODIF$ and $CANCEL$).

Insert Figure 1 here

Even though there is no trading during the pre-open and pre-opening orders can be canceled at no cost, Figure 1a shows that some traders submit messages very early, between 7:15 and 7:45am. Very early messages consist of submission of new orders (above 40%) and cancelations (maybe of stale orders from the previous trading session). No updates take place. The activity related to new order submissions then decreases and increases the last 30 minutes of the pre-open (in line with Hypothesis 6). The activity of updates and cancelations, by contrast, peaks up the very last 15-min interval of the pre-open.

Figure 1b decomposes messages activity by members' type (HFT, MIXED and NON-HFT), while Figure 1c breaks it down by members' account (clients, prop traders, and liquidity providers). Combining both Figures 1b and 1c shows that there exists a U-shape pattern for new orders and cancelations posted by slow brokers (in value): they are very active early and late in the pre-opening. The fact that slow brokers submit new orders very early is striking and consistent with a willingness to gain time priority or to advertise liquidity needs. By contrast, MIXED traders, either as prop traders or clients, are mainly active during the last 15 minutes (new orders, updates or cancelations). New orders posted by HFT prop traders peaks up earlier (between 8:30-8:45am). Interestingly, their update activity is very low during the entire pre-opening period, and reaches a maximum of 10% of their messages during the last 15 minutes. During this last interval, HFT prop traders still submit a lot of new orders (but less than during the previous 15 minutes) and cancel 30% of their orders.

Figure 2 reports the same information as Figures 1b and 1c respectively but from a different perspective: relative to the total number of messages posted in each category (new order, update, cancelation), we compute the proportion of messages involving a type of member (HFT, NON-HFT, MIXED illustrated in Figure 2a) or involving a type of account (client, prop trader or liquidity supplier, illustrated in Figure 2b). In addition, the market share at the opening call auction for each member's category (detailed in Table

4) is also represented both in Figure 2a and Figure 2b. Figure 2 shows that the proportion of messages involving slow brokers steadily decreases during the pre-open, with the last 15-min interval being the less active one (in proportion of total messages). By contrast, MIXED prop traders are the most active during the last 15 minutes before the opening call auction (across the three categories of messages). Figure 2 also confirms that fast (or HFT) prop traders submit the largest proportion of new orders between 8:30-8:45am and update or cancel in the lowest proportion during the last 30 minutes. Even if the activity of fast prop traders mainly consists of new order submission, their market share at the opening call auction is very low compared to the other categories, suggesting that their new orders are placed quite far from the tentative clearing price in the limit order book. As a result, new orders should not need to be monitored (in line with the quasi-absence of updates and the low cancellation rate).

In conclusion, pre-opening trading strategies seem very different across members' categories. In particular, the message activity exhibits a very different pattern across slow brokers, MIXED prop traders and fast (or HFT) prop traders.

Insert Figure 2 here

Figure 3 illustrates the life of pre-opening orders, for each 15-min interval. A breakdown by members' type and account is also reported. Figure 3 shows that very early messages (from slow brokers as revealed by Figures above) are either executed at the opening call auction or during the day (very few are not executed or canceled). The last 15-min interval's orders have also more executions at the opening call auction or during the day than cancelations or non-executions. By contrast, most of new orders submitted between 8:30-8:45am (mainly from HFT prop traders) are not executed or are canceled during the day. The breakdown by member's type and account confirms previous intuitions. HFT prop traders submit a lot of new orders during the last interval and even more during the last-but one interval (between 8:30 and 8:45am). Almost none of them is however executed during the opening call auction nor during the day, consistently with the fact that they don't need to monitor these orders by updating or canceling them during the pre-open (activities which tend to be nonexistent or very low). In contrast with HFT prop traders' orders, pre-opening orders from slow brokers are quasi-all executed at the opening call auction or during the day, except some of the new orders posted during the last 15-min interval. This is consistent with Hypothesis 5, that is, some traders with liquidity needs are willing to submit orders very early in the pre-opening period to gain

time priority or/and to advertise their needs. Orders involving MIXED brokers (more active during the last 15 minutes of the pre-open, thanks to their speed advantage) are executed at the open, or during the day, showing that the call auction is an important mechanism for executing trades. Finally, MIXED prop traders, very active during the last 15-min interval across all categories of messages, have pre-opening orders of the last 15-min mainly executed at the opening call auction, or during the day, which corroborates their intense activity of monitoring through updates or cancelations during the last 15-min.

Insert Figure 3 here

Figure 4a plots orders' aggressiveness by 15-min interval. We label market and market-to-limit orders as aggressive orders. Figure 4a shows that early orders are more aggressive than late ones. The breakdown by member's type shows that MIXED traders are more tempted to submit aggressive orders while the breakdown by members' account shows that liquidity providers in particular early during the pre-opening submit more aggressive orders than late ones.

Insert Figure 4 here

4.2 Price discovery during the pre-opening period

4.2.1 Tentative prices and volumes

Table 5 reports descriptive statistics for tentative clearing prices and volumes in the pre-opening session.

Insert Table 5 here

Table 5 shows that the number of crosses increases as the opening approaches, which is quite consistent with the replenishment of the book during that period. When a tentative clearing price exists, the correlation between the return from the close to time τ of the pre-open, r^{CTOP_τ}, and the close-to-open return, r^{CO}, is positive and increases over time to reach 0.507 at 8:45am. This reflects that tentative clearing prices are a good predictor of the opening price and contribute to the opening price discovery. The same holds for the correlation with the close-to-close return, r^{CC}, suggesting that tentative clearing prices also contribute to the daily price discovery. Interestingly, even when there is no cross,

tentative midquotes are also positively correlated with the opening and closing clearing prices. This correlation increases over time, showing that the pre-opening limit order book contains information favoring price discovery.

By contrast, the correlation between the return from the close to time τ of the preopen, r^{CTOP_τ}, and the return from the open to 9:15am is negative in each of the three venues, showing some price reversal on each trading venues.

Results also indicate that the correlation between the tentative clearing volume and the daily volume traded either on Euronext or on the other competing venues, BATS and CHI-X, increases with time. This is consistent with a pre-opening mechanism on Euronext which favors quantity discovery over the three platforms.

4.2.2 Informational content of pre-opening tentative prices

We formally test the pre-opening price contribution to the opening price discovery by estimating a regression model based on Biais et al. (1999), i.e.:[19]

$$r_{i,t}^{CC} = \alpha_{0,\tau} + \alpha_{1,\tau} r_{i,t}^{CP_\tau} + \varepsilon_{i,t}, \tag{7}$$

where r^{CP_τ} is the return from the previous close to time τ and r^{CC} is the close-to-close return, and τ = 7:30, 7:45, 8:00, 8:15, 8:30 and 8:45am. We differentiate cases in which there is a cross and a return based on the tentative clearing price, TOP, from cases in which there is no cross and the return is determined using the pre-opening midquote price, TMQ. The coefficient $\alpha_{1,\tau}$ measures the informational content. Under the "learning hypothesis" (Biais et al. (1999)), if members act competitively, they drive the opening price to the conditional expectation of the value of the asset, which corresponds to $\alpha_1^\tau = 1$. Conversely, under the "noise" hypothesis prices have no informational content, which corresponds to the case in which $\alpha_1^\tau = 0$. The panel regression includes stock fixed effect and standard errors are clustered by stock and by day.

Figure 5 plots the coefficients of the regression, for τ varying between 7:30am to 8:45am.[20]

[19] Barclay and Hendershott (2003) and Cao et al. (2000) measure the size of the contribution of the pre-opening period to the daily price discovery by estimating the weighted price contribution (WPC) of the pre-opening interval τ. The WPC is a proxy for the proportion of the close-to-close price evolution that is discovered during interval τ. While conceptually similar, the approach followed Biais et al. (1999) is more direct and the model can easily be extended to account for additional explanatory variables.

[20] The exact values of the estimates of these regressions can be found in Table A.8 in the Appendix. Results of regressions without fixed effects are qualitatively similar.

Insert Figure 5 here

Whether there exists a cross or not, pre-opening prices have some informational content. Coefficients $\alpha_{1,\tau}$ are positive and significant. Surprisingly, this is the case even early during the pre-opening period. We also notice that the informational content of tentative clearing prices increases during the last hour, consistently with Hypothesis 6.

4.2.3 Price reversal

To examine whether the pre-opening prices contain information unrelated to fundamentals (either due to manipulation or to liquidity supply), we investigate whether there exists a significant price rebound in the 15 minutes following the opening call auction. We run the following regression:

$$r_{i,t}^{O,9:15^S} = \beta_0^{S,\tau} + \beta_1^{S,\tau} r_{i,t}^{CP_\tau} + \varepsilon_{i,t}, \tag{8}$$

where $r^{O,9:15^S}$ is return from the open to the midquote observed in venue S at 9:15 am. Regressions include stock fixed effects and standard errors are clustered by stock and by day. If pre-opening prices contain information unrelated to fundamentals, we should observe some price reversal, i.e. a negative relation between the return from the close to time τ of the preopen and the return from the open to 9:15am, or $\beta_{1,\tau} < 0$. Figure 6 plots the results of the regressions for Euronext, BATS and Chi-X for each value of τ (τ = 7:30, 7:45, 8:00, 8:15, 8:30 and 8:45am).[21]

Insert Figure 6 here

Figure 6 shows that the coefficient $\beta_{1,\tau}$ is negative and significant across all trading venues. This suggests that there is an "overshooting" in the formation of the opening price, shortly followed by a reversal. By contrast, when there is no cross between supply and demand, the coefficients $\beta_{1,\tau}$ are insignificant: the evolution of tentative midquotes is not followed by a price reversal. In this case, no order is executed, or, in other words, no order supplies liquidity. This would suggest that the price reversal observed when there is a cross would be caused by order imbalances accommodated at the opening by some orders supplying liquidity or immediacy, in line with Hypothesis 7a.

[21] The exact values of the estimates of these regressions can be found in Table A.9 in the Appendix. Results of regressions without fixed effects are qualitatively similar.

4.3 Quantity discovery

4.3.1 Daily activity and pre-opening tentative volumes

This section examines whether the pre-opening mechanism facilitates quantity discovery and liquidity formation. If some traders were to reveal information on their liquidity needs, then one has to expect that tentative clearing volumes predict daily activity and market activity. To study this effect, we run the following regression:

$$V_{i,t}^{S} = \gamma_0^{S,\tau} + \gamma_1^{S,\tau} TOV_{i,t}^{\tau} + \varepsilon_{i,t}. \tag{9}$$

The tentative opening volume is equal to zero when there is no cross between the cumulated supply and demand functions. Figure 7 plots the estimates of the regressions for Euronext, BATS and Chi-X for each value of τ (τ = 7:30, 7:45, 8:00, 8:15, 8:30 and 8:45am).[22] Results show that the tentative opening volume and the volume traded during the day are positively related, for all trading venues, and this correlation is significant at 1% after 8:15 a.m.. This is consistent with Hypothesis 7.

Insert Figure 7 here

4.3.2 Spreads and pre-opening tentative volumes

To examine the impact of the pre-opening period on the liquidity of the trading day, we estimate the following regression:

$$RSPD_{j,t}^{S} = \delta_0^{S,\tau} + \delta_1^{S,\tau} log(TOV_{i,t}^{\tau}) \times D_{cross} + \delta_{2,\tau}^{S}(1 - D_{cross}) + \varepsilon_{j,t}, \tag{10}$$

where the left-hand side variable $RSPD_{j,t}^{S}$ is the relative quoted spread in stock j on day t on venue S, and D_{cross} is a dummy that is equal to one if there is a cross in the pre-opening, and zero otherwise. The coefficient $\delta_2^{S,\tau}$ captures the relation between the absence of cross, and $\delta_1^{S,\tau}$ captures the additional relation between the tentative clearing volume and the daily relative spread when there is a cross. Figure 8 plots the estimates of the regressions for Euronext, BATS and Chi-X for each value of τ (τ = 7:30, 7:45, 8:00, 8:15, 8:30 and 8:45am).[23]

[22] The exact values of the estimates of these regressions can be found in Table A.10 in the Appendix. Results of regressions without fixed effects are qualitatively similar.

[23] The exact values of the estimates of these regressions are found in Tables **??**, **??** and **??** in the Appendix. Results of regressions without fixed effects are qualitatively similar.

First, results show that a larger tentative clearing volume is related to lower spreads for the three venues. Second, days when there is not cross during the last half-hour correspond to days where spreads are significantly higher on Euronext (consistent with our previous finding showing a lack of liquidity supply); this is however not the case on the other competing venues, BATS and CHI-X. This suggests that the absence of cross late during the pre-opening of Euronext is related to events specific to this venue.

Insert Figure 8 here

4.4 Relation between market quality and pre-opening activity

4.4.1 Spreads and pre-opening activity

To investigate how the order submission process of members during the pre-opening is related to market liquidity during the day, we run the following regression:

$$RSPD^S_{j,t} = a^S_0 + \sum_{cat} b^{S,cat}_1 ln(NBMSG^{cat}_{j,t}) + ln(\sum_{cat} NBMSG^{cat}_{j,t}) + HILO_{j,t} + \varepsilon_{j,t} \quad (11)$$

where the left-hand side variable $RSPD^S$ is the daily averaged relative bid-ask spread on Euronext, BATS or Chi-X and the independent variables consist of the log of the number of messages posted by each categories of traders (HFT, NON-HFT, MIXED / client, prop trader or liquidity supplier). The remaining variables, $ln(\sum_{cat} NBMSG^{cat})$ and $HILO$ respectively control for the global level of pre-opening activity by day and by stock, and volatility.

Insert Table 6 here

Table 6 report the results of the regression for the three different venues. Interestingly, daily spreads are significantly and negatively related to the activity of MIXED prop traders across the three venues, which seem thus to supply liquidity. By contrast, spreads on BATS and CHI-X are positively and significantly related to the activity of slow brokers. Spreads are also negatively related to the level of the pre-opening activity. The more active is the pre-open, the more liquid are trading venues.

4.4.2 Price discovery and pre-opening activity

To investigate the impact of members' messages submission activity during the pre-opening period on price discovery, we run the panel logistic regression:

$$d_{j,t} = b_0^S + \sum_{cat} b_1^{S,cat} ln(NBMSG_{j,t}^{cat}) + ln(\sum_{cat} NBMSG_{j,t}^{cat}) + HILO_{j,t} + \varepsilon_{j,t} \qquad (12)$$

where d is equal to D_IC or D_REV. Remind that D_IC is a dummy that takes 1 if there is some price continuity at the open between the previous close and the close of the day (i.e., the close-to-open and the close-to-close returns have the same sign). D_REV^S is a dummy that takes 1 if there is some price reversal around the open on venue S (i.e., the close-to-open and the open-to-9:15am returns have opposite signs) ($S = E, B, C$).

Insert Table 7 here

Table 7 presents two specifications, according to whether the dependent variable is $d = D\_IC$ or $d = D\_REV$. Table 7 indicates that the higher is the pre-opening activity of NON-HFT brokers or liquidity suppliers, the more likely it is that there is a price continuation on Euronext. We also note that the higher the High-Low volatility is, the more likely opening prices contain daily information (corroborating the link between price discovery and volatility). The opening auction may be followed by a price reversal; the probability of an opening price reversal is negatively related to the activity of slow brokers and MIXED prop traders across the three trading venues, but positively related to the activity of HFT clients on Euronext (not significant for the other venues). Overall, the participation of slow brokers seems to be related to a better price discovery process.

5 Conclusion

In this paper, we analyze the role of the pre-opening mechanism implemented by Euronext on the price discovery and liquidity formation of the exchange itself and on two other competing venues deprived of such a mechanism, BATS and Chi-X. To this aim, we investigate whether there is a relationship between the pre-opening messages activity and the daily liquidity for each trading venue. Using the SBF120 index constituents, from May 2, 2012 to December 31, 2013, we find evidence that tentative clearing prices set

during the pre-opening period contribute to discover opening prices. The informational content of pre-opening tentative clearing prices increases the closer one gets to the opening. Moreover, we find that the tentative clearing volume is positively correlated with the liquidity in the three platforms. Interestingly, we find that the preopening message activity of slow brokers is significantly positively related to price discovery, unlike the preopening messages activity of fast prop traders, while the pre-opening activity MIXED prop traders is significantly related to a better liquidity across venues. A natural question which emerges is whether slow brokers (and behind, potentially, large mutual funds) have taken over the previous role of dedicated market-makers (such as the specialist) which were participating actively to the auction and to the price discovery process at the open, and which is clearly not any more the case in our data.

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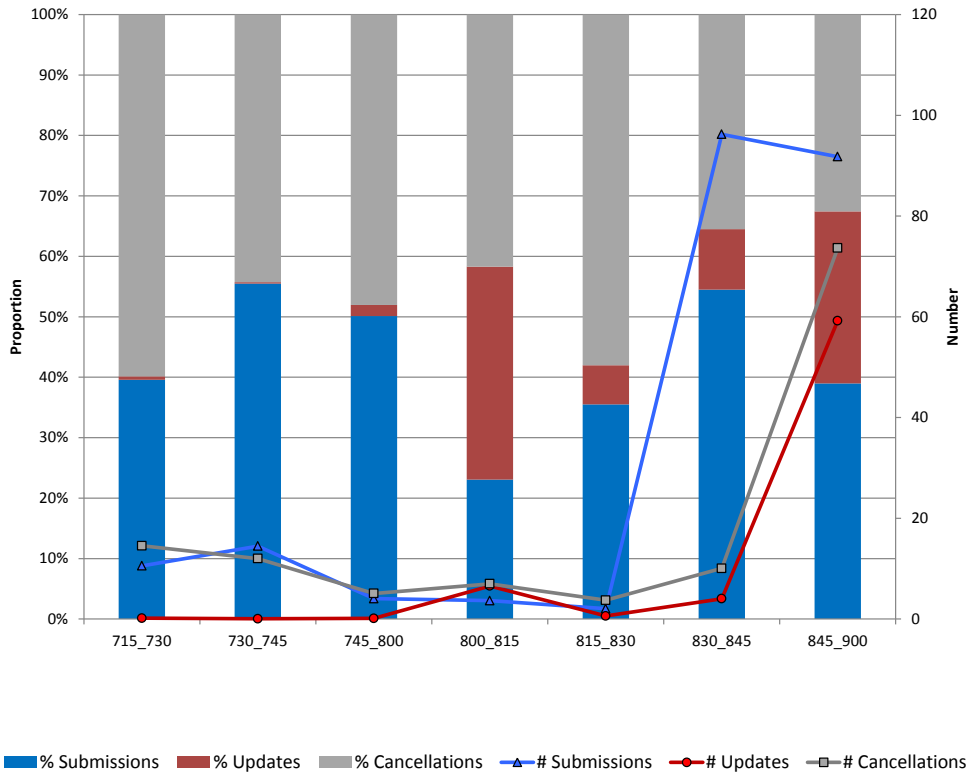
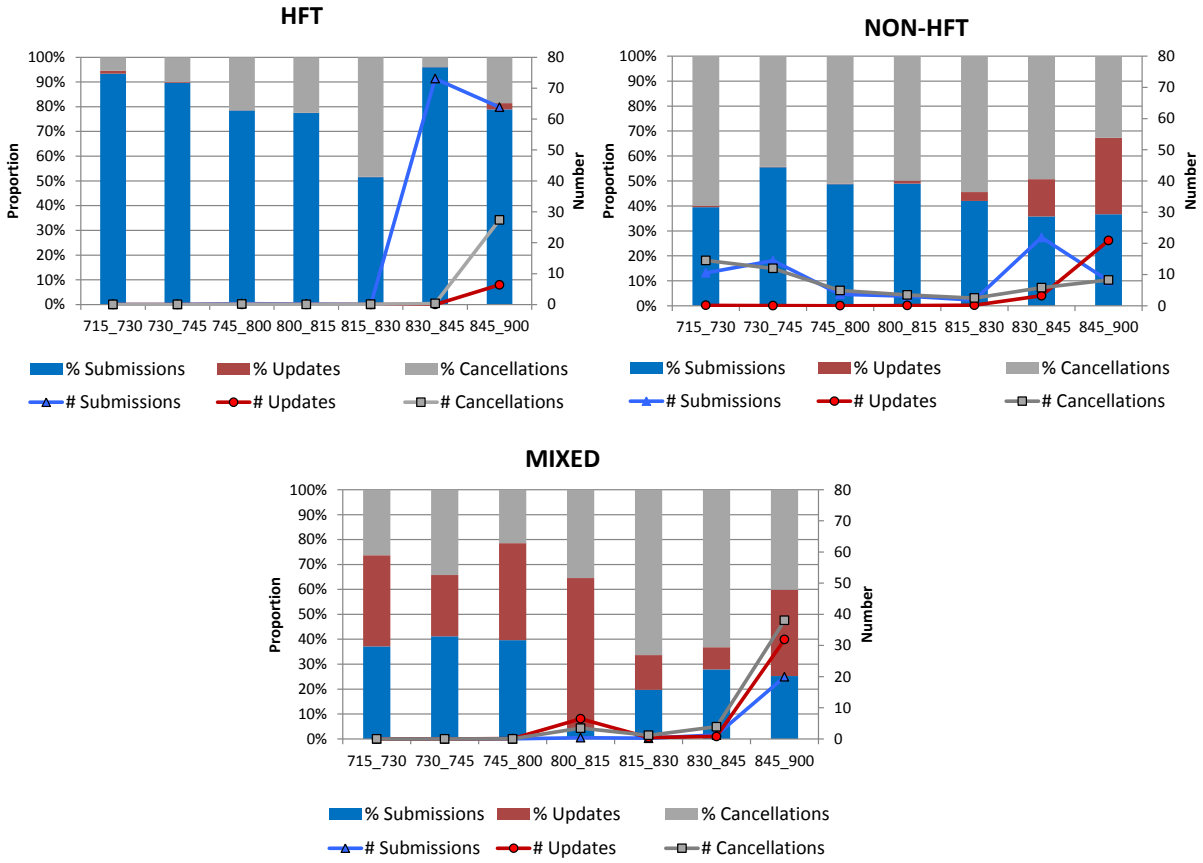
Figure 1: **Decomposition of pre-opening messages by category for each 15-min interval**

Figure 1a represents the number and proportion of pre-opening messages for each 15-min interval between 7:15am and 9:00am (before the opening call auction). Messages are broken down into three categories: new order submission, update or cancellation of an existing order. The three lines correspond respectively to the number of submissions ($NBORD$ in blue), updates ($NBMODIF$ in red), and cancellations ($NBCANCEL$ in grey) per 15-min interval averaged across stocks and days. We also compute the proportion of messages in each category per stock and day. The bars represent these proportions averaged across days and stocks, using the same color code.
In Figure 1b measures are split by trader's type (HFT, NON-HFT or MIXED).
In Figure 1c measures are split by trader's account (Clients, Prop traders, Liquidity Providers).

(a) Decomposition of preopening messages by category (submissions, updates or cancelations)



(b) Decomposition of pre-opening messages by member's type:



(c) Decomposition of pre-opening messages by member's account

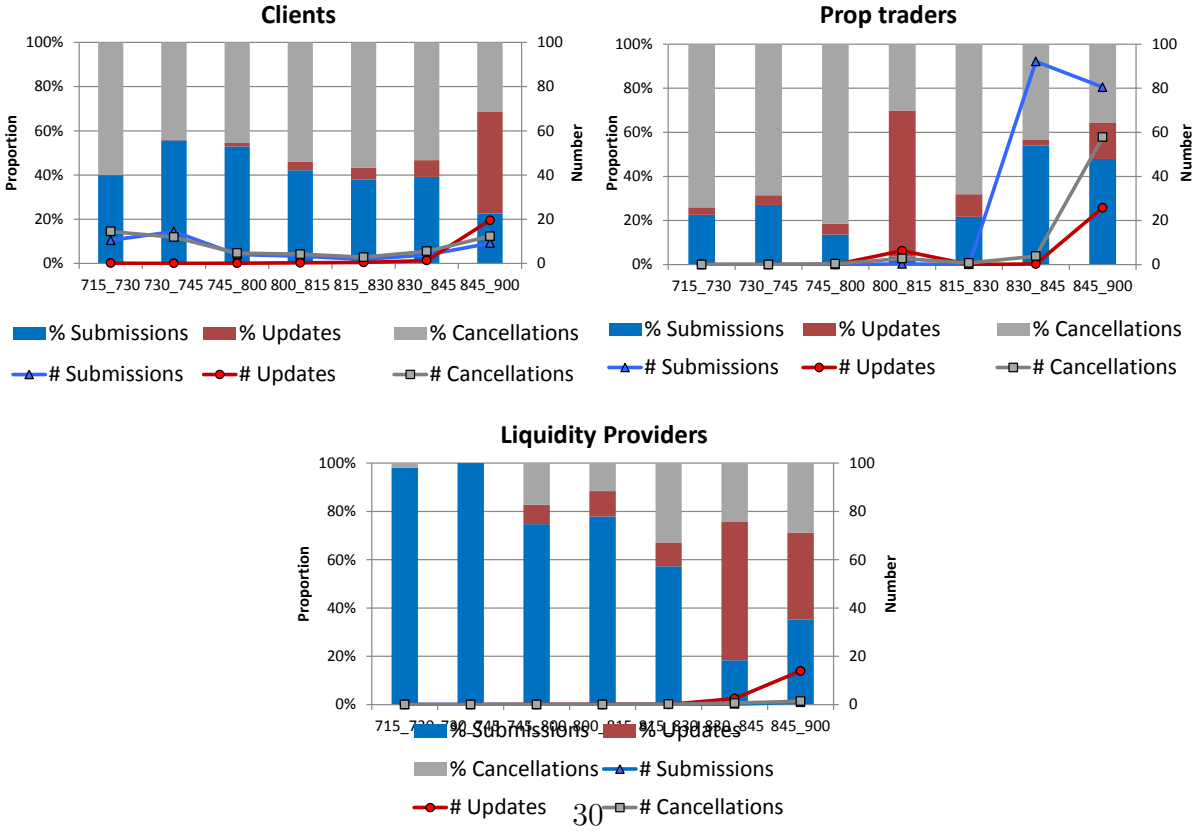
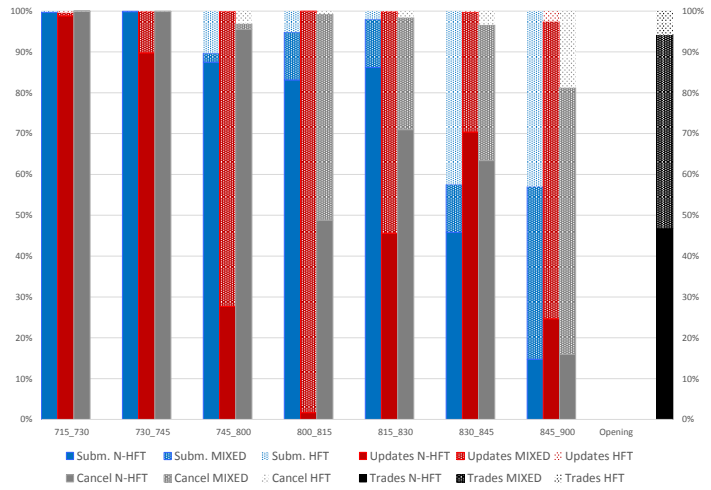


Figure 2: **Relative decomposition of categories of messages**

Figure 2 shows the relative decomposition of the pre-opening messages activity along two dimensions: by category of messages, and by category of members. New order submissions are represented in blue, updates in red, and cancelations in grey. Shades of color correspond to member's types or to member's accounts.
Figure 2a shows the relative breakdown of messages i by trader's types (HFT, MIXED, NON-HFT) for each 15-min interval of the pre-open, where i =new orders, updates, and cancelations. The last bar in black represents the proportion of opening clearing volume involving each types of traders. NON-HFT are represented in dark color, HFT in light color, and MIXED traders in medium color.
Figure 2b shows the relative breakdown of messages i by trader's account (clients, prop traders, liquidity providers) for each 15-min interval of the pre-open, where i =new orders, updates, and cancelations. The last bar in black represents the proportion of the opening clearing volume involving each type of accounts.

(a) **Relative breakdown of messages by trader's type**



(b) **Relative breakdown of messages by trader's account**

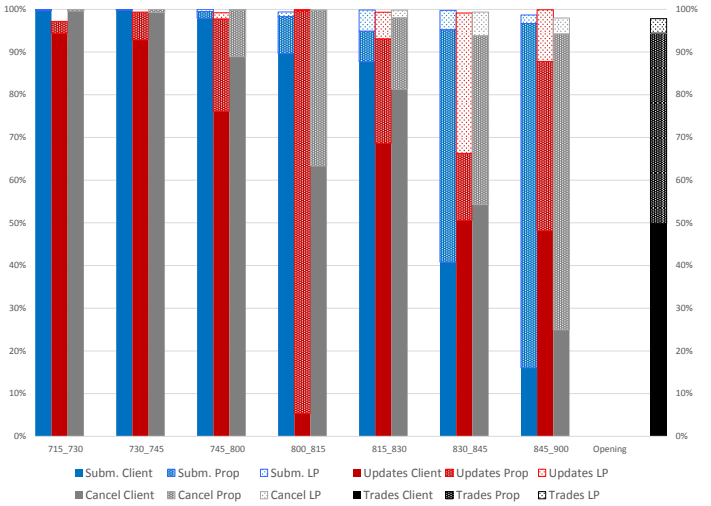
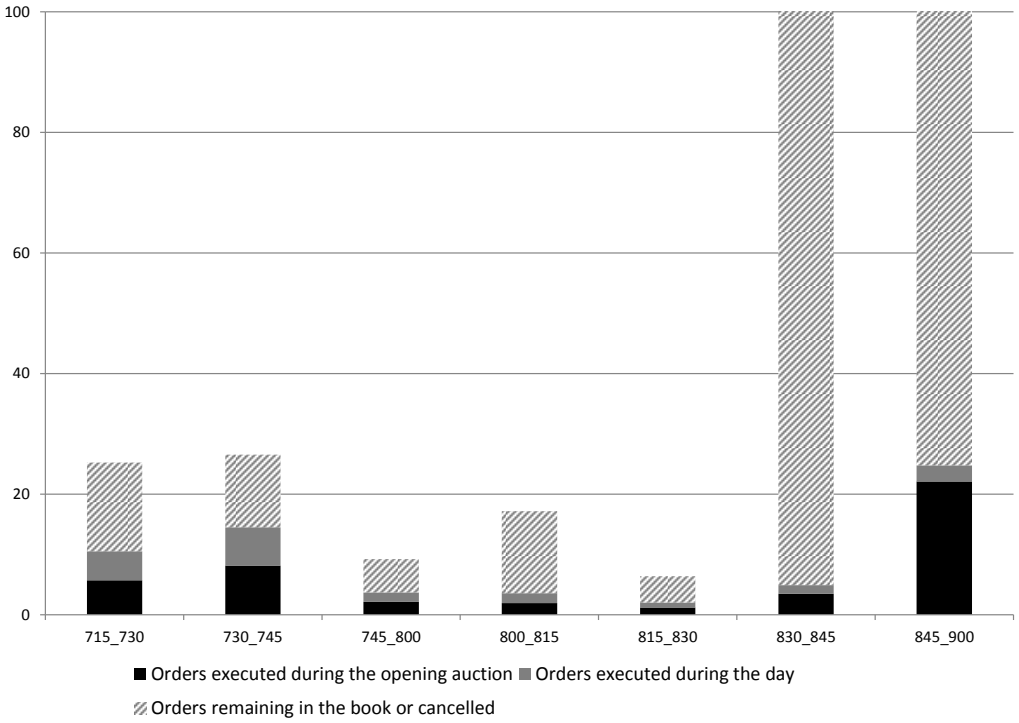


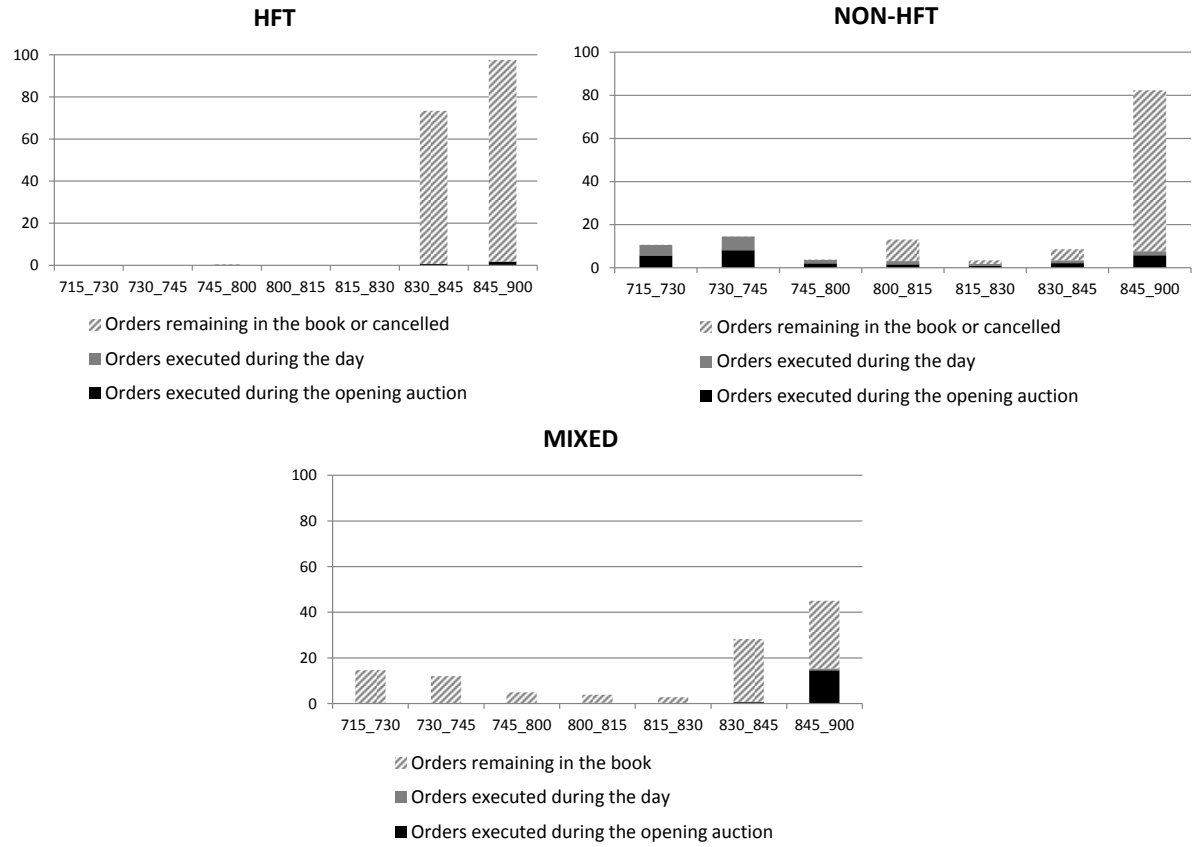
Figure 3: **Final execution status of pre-opening orders**

Figure 3 shows the final execution status of each newly submitted order by 15-min interval. There are three possible status: (i) the order has been executed, at the opening call auction (in black); (ii) the order has been executed within the day (in grey); (iii) the order has not been executed (in hatched black). In the latter case, the order might have been canceled, modified or not and remains in the limit order book. Each bar represents the total number of submissions received during the 15-min interval and it is decomposed into the three possible execution status.
Figure 3b decomposes the execution status of pre-opening orders by trader's type (HFT, MIXED or NON-HFT). Figure 3c decomposes the execution status by trader's account (clients, prop traders, or liquidity providers).

(a) Final execution status of pre-opening orders by 15-min interval



(b) By member's type



(c) By member's account

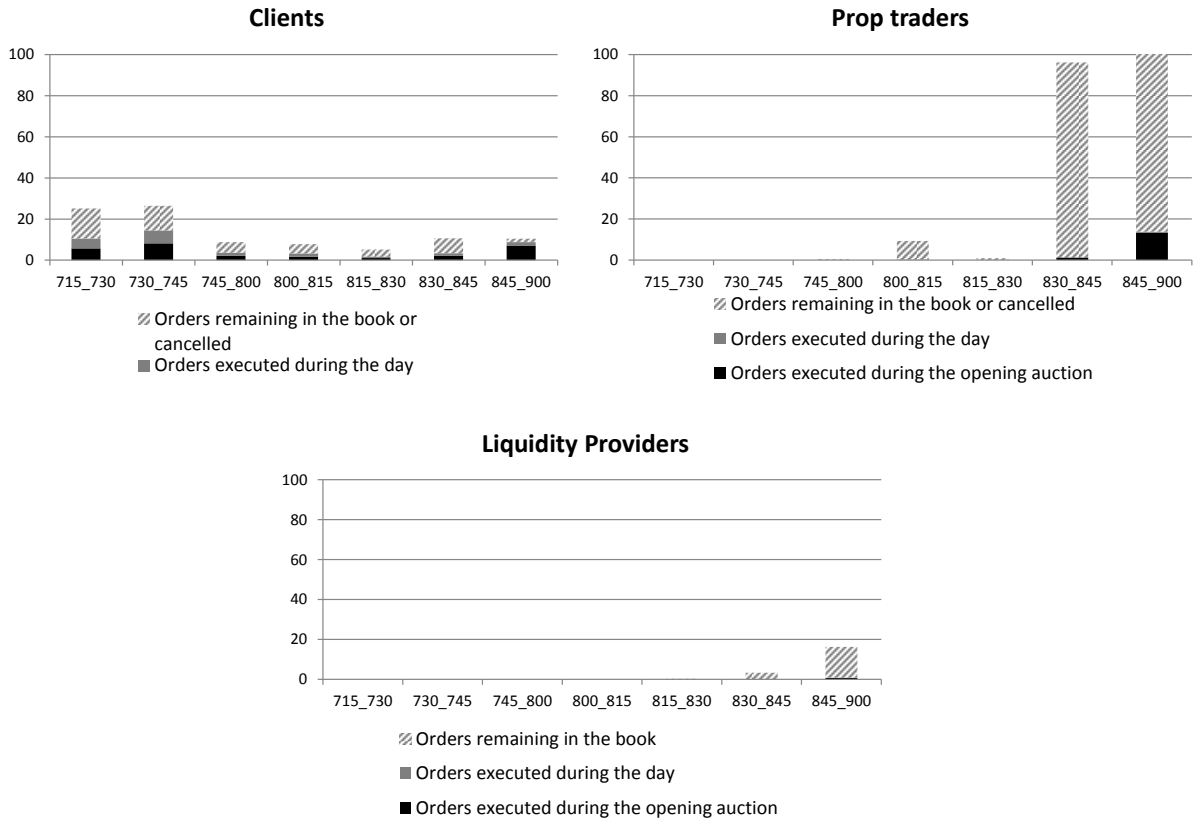
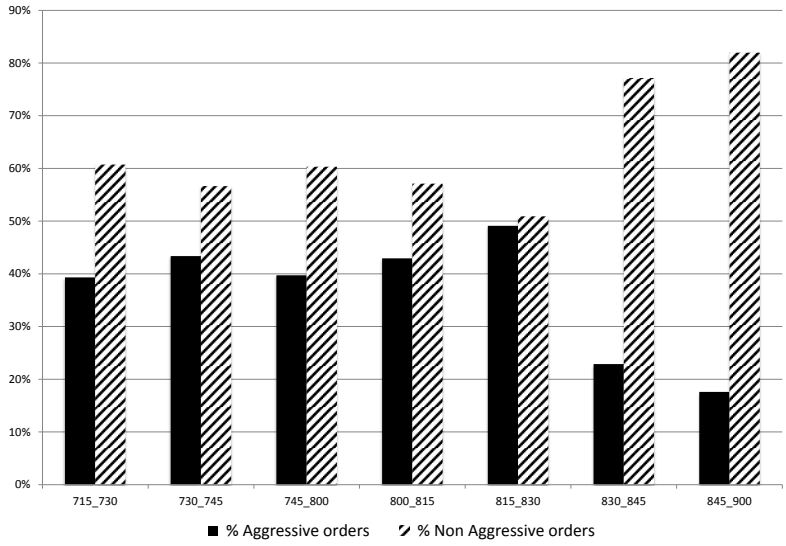
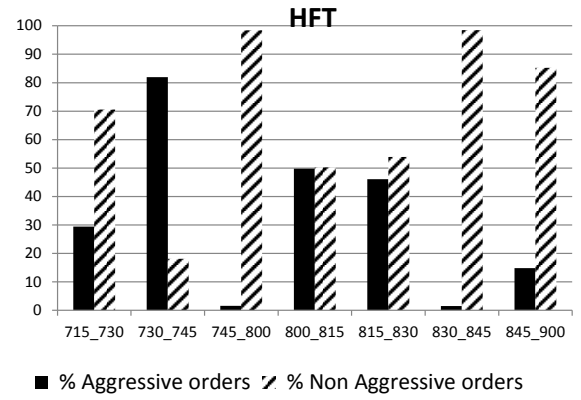


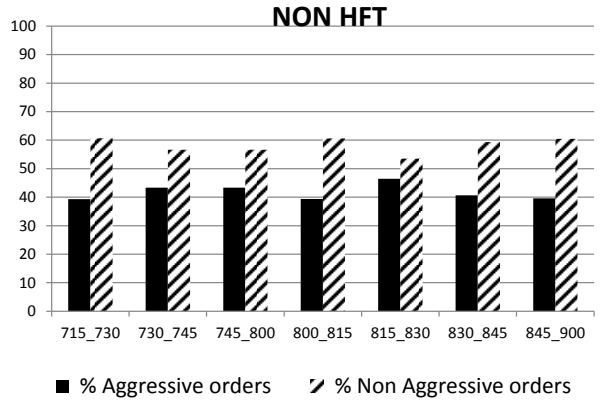
Figure 4: **Characteristics of new pre-opening orders by 15-minute interval**

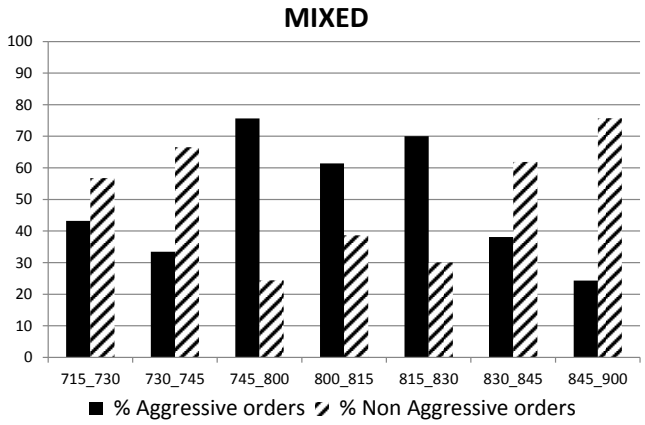
Figure 4a splits pre-opening new orders into aggressive versus non-aggressive orders. Aggressive orders (in plain black) consist of market or market-to-limit orders. Non-aggressive orders (hatched in black) consist of all the remaining types of orders (e.g., limit orders,...). Figure 4b decomposes the aggressiveness of pre-opening new orders by trader's type (HFT, MIXED or NON-HFT). Figure 4c decomposes the aggressiveness of pre-opening orders by trader's account (clients, prop traders, or liquidity providers).

(a) **Aggressiveness of new orders**

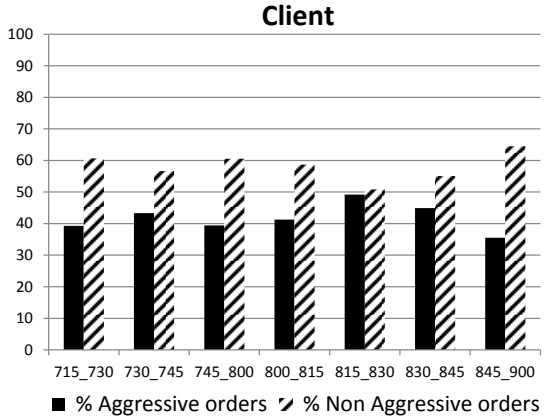


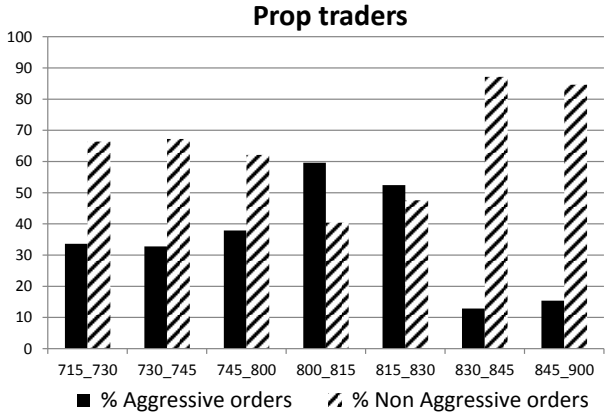


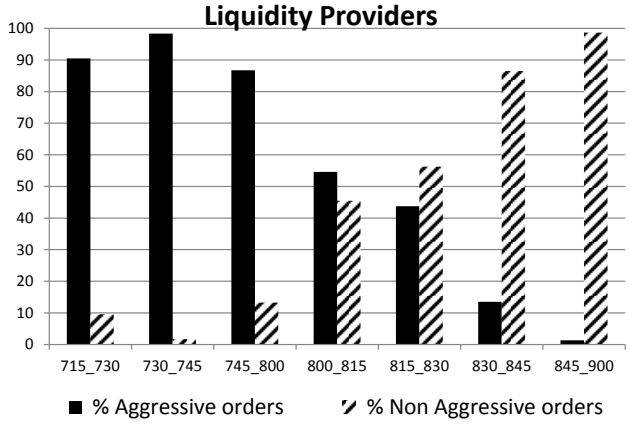




(a) **By member's type**







(b) **By member's account**

Figure 5: **Informational content of tentative clearing prices and midquotes**

Figure 5 illustrates the informational content of pre-opening prices or midquotes. The dependent variable is the close-to-close return. The independent variable is the return from the previous close to a pre-opening price set at the end of each 15-min interval of pre-opening session: $r_{i,t}^{CC} = \alpha_0^\tau + \alpha_1^\tau r_{i,t}^{CP\text{-}\tau} + \varepsilon_{i,t}$.
Bars correspond to estimates of the regression when there is a cross at time τ, and there exists a tentative clearing price, TOP^τ. Squares correspond to estimates when there is no cross at time τ and pre-opening returns are computed using a tentative midquote, TMQ^τ, that is, an average price between the best ask and the best bid quotes if the book is not empty, where τ =7:30, 7:45, 8:00, 8:15, 8:30, and 8:45am. Fill patterns (plain, medium hatched, and lightly dotted) indicate significance at 1%, 5% and 10% level, respectively. The exact values of the estimates of these regressions can be found in Table A.8 in the Appendix.

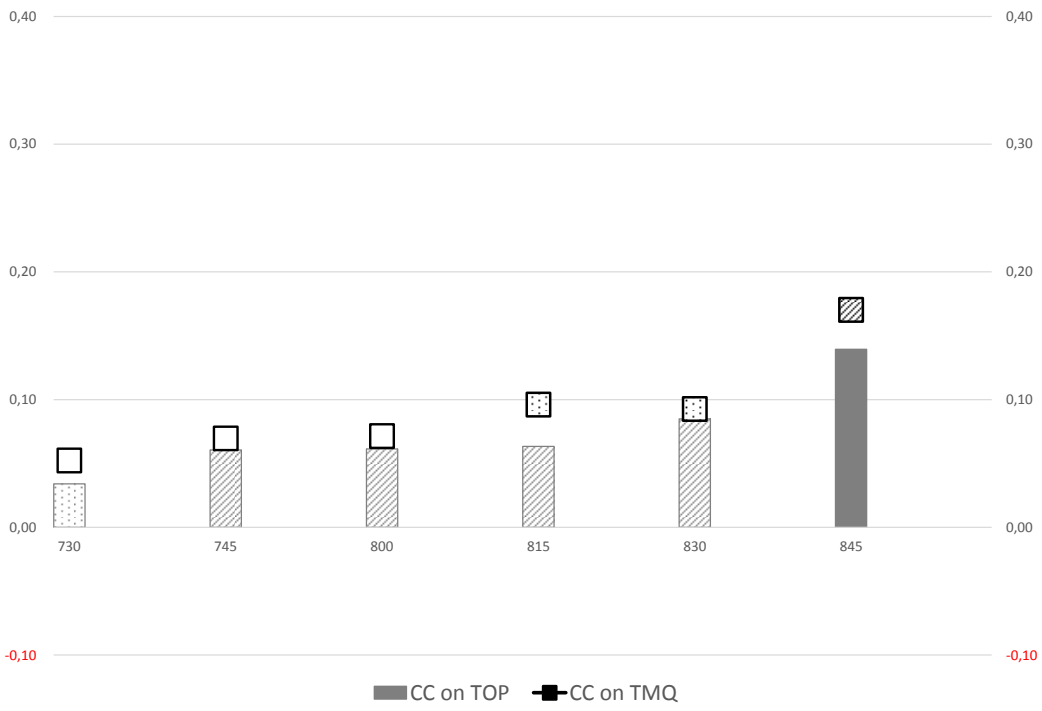


Figure 6: **Reversal around the opening on Euronext, BATS and Chi-X**

Figure 6 reports the estimates of the price reversal between pre-opening prices and midquotes observed 15 minutes after the opening at 9:00am. We run a regression for each preopening prices computed every 15 minutes, and for each trading venue S on which the midquote at 9:15am is observed, where $S = E, B, C$. The dependent variable corresponds to the open-to-9:15am return and the independent variable corresponds to the return between the close and the pre-opening price at time τ: $r_{i,t}^{O,9:15^S} = \beta_0^{S,\tau} + b_1^{S,\tau} r_{i,t}^{CP\text{-}\tau} + \varepsilon_{i,t}$, where $r^{O,9:15^S}$ is the return from the opening price to the midquote at 9:15am observed on venue S. Bars correspond to estimates of the regression when the pre-opening price is the tentative opening price, TOP^τ, that is, when supply and demand function cumulated during the interval ending at time τ cross. Colors correspond the trading venue: dark grey for $S = E$ (Euronext), medium grey for $S = B$ (BATS), and light grey for $S = C$ (Chi-X). Triangles, circles and diamonds correspond to estimates when the pre-opening price is the tentative midquote, TMQ^τ, that is, when there is no cross at time τ for τ =7:30, 7:45, 8:00,8:15, 8:30 and 8:45am. In both cases, fill patterns (plain, medium hatched, and lightly dotted) indicate significance at 1%, 5% and 10% level, respectively. The exact values of the estimates of these regressions are in Table A.9 in the Appendix.

Figure 7: **Tentative volumes and daily trading activity in Euronext, BATS and Chi-X**

Figure 7 reports the estimates of the relation between the tentative volume during the pre-opening and the daily volume traded on Euronext, BATS and Chi-X. We run the following regression $V_{i,t}^{S} = \gamma_0^{S,\tau} + \gamma_1^{S,\tau} TOV_{i,t}^{\tau} + \varepsilon_{i,t}$ for each time τ, where τ =7:30, 7:45, 8:00,8:15, 8:30 and 8:45am. The dependent variable V^S corresponds to the volume traded during the day on venue S expressed in million €. The independent variable, TOV^{τ}, corresponds to the tentative volume expressed in million €and computed at time τ. All regressions include stock fixed effects and day clustering. Bars correspond to estimates of the regression. Colors correspond the the platform: dark grey for $S = E$ (Euronext), medium grey for $S = B$ (BATS), and light grey for $S = C$ (CHI-X). Fill patterns (plain, medium hatched, and lightly dotted) indicate significance at 1%, 5% and 10% level, respectively. The exact values of the estimates of these regressions can be found in Table A.10 in the Appendix.

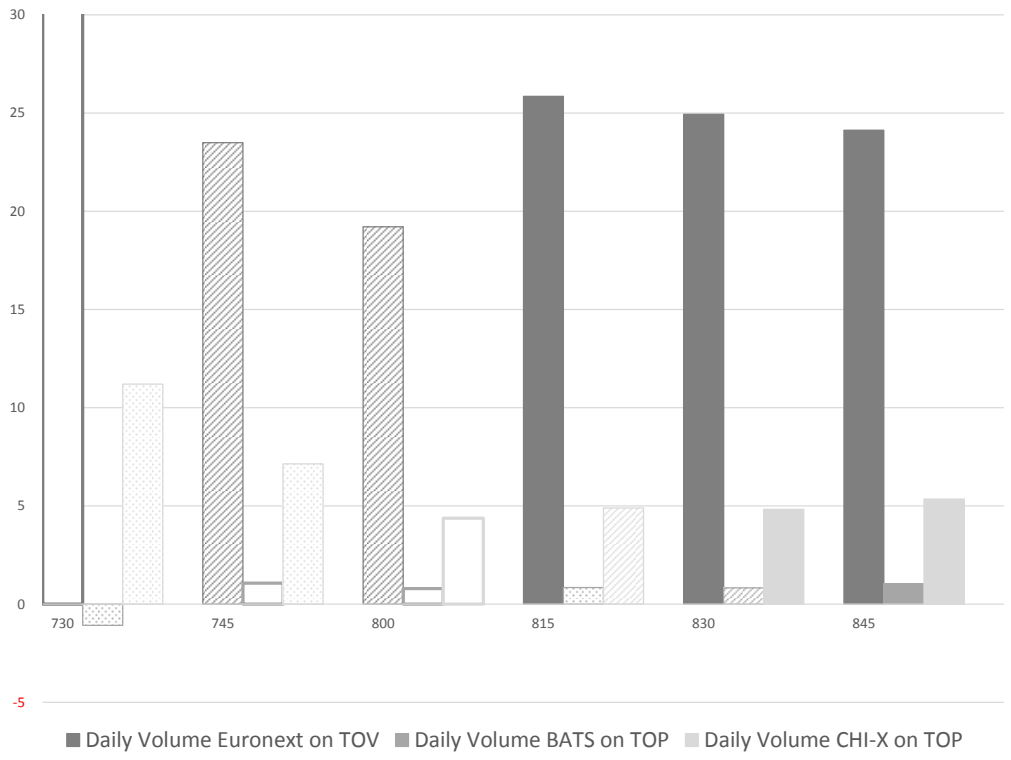


Figure 8: **Tentative volumes and relative spreads in Euronext, BATS and Chi-X**

Figure 8 reports the estimates of the relation between the tentative volume during the pre-opening and the daily relative quoted bid-ask spread. We run the following regression $RSPD^S_{i,t} = \delta^S_{0,\tau} + \delta^S_{1,\tau} ln(TOV\_\tau_{i,t}) \times Dcross\_\tau + \delta^S_{2,\tau} Dnocross\_\tau + \varepsilon_{i,t}$, for each time τ, where τ =7:30, 7:45, 8:00,8:15, 8:30 and 8:45am. The dependent variable $RSPD^S$ corresponds to the daily averaged relative bid-ask spread on venue S. The independent variables correspond to the log of the tentative pre-opening volume at time τ expressed in million €. $Dcross$ is a dummy that takes value 1 when there is a cross and 0 otherwise, and $Dnocross\_\tau = 1 - Dcross\_\tau$. All regressions include stock fixed effects and day clustering. Bars correspond to estimates of the regression when the tentative price is the tentative opening price, TOP, that is, when demand and supply cross at time τ. Colors correspond the the platform: dark grey for S =Euronext, medium grey for S =BATS, and light grey for S =CHI-X. Triangles, circles and diamonds correspond to estimates when the tentative price is the tentative midquote, TMQ, that is, when demand and supply do not cross at time τ. In both cases, fill patterns (plain, medium hatched, and lightly dotted) indicate significance at 1%, 5% and 10% level, respectively. The exact values of the estimates of these regressions can be found in Tables A.11 in the Appendix.

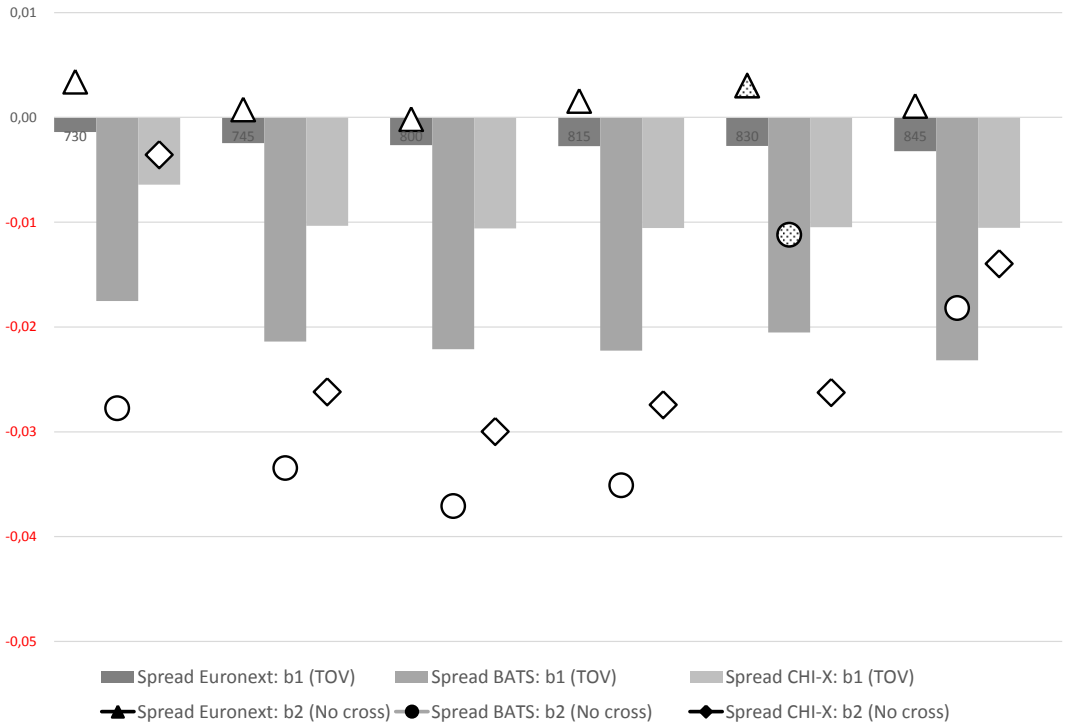


Table 1: **Summary statistics on the stock sample**

This table reports summary statistics for the sample of stocks used in this study. The sample consists of French stocks belonging to the SFB120 index, which are traded continuously and simultaneously on Euronext Paris, BATS and Chi-X. The period of study spans twenty months from May 2, 2012 to December 31, 2013. Data are obtained from the daily Eurofidai-Bedofih dataset. The sample is split in two by capitalization group. Panel *Index* represents stocks that belong to the CAC40 or to the CACNext20 index. Panel *Non Index* represents the other non-index stocks which are mainly small capitalization. Panel *Index* reports the number of stocks belonging to each index (CAC40 or CACNext20). Market Capitalization, in millions of euros, corresponds to the number of outstanding shares multiplied by the closing price as of December 31, 2011. The close-to-close return is defined as: $\frac{CLOSEP_t+DIV_t-CLOSEP_{t-1}}{CLOSEP_{t-1}}$, where $CLOSEP_t$ is the closing price on day t and DIV_t is the dividend paid on day t. HILO is the daily price range (that is, high minus low) defined by Parkinson (1980). In Panel *Index*, we also include the % of stocks that belong to CAC40 index and those that belong to the CAC Next20 index. The number of trading days on Euronext, BATS and Chi-X is reported. All measures are averaged first by stock then across stocks in the Panel.

	Mean	**Std. Dev.**	**Min.**	**Max.**	**N**
Panel *Index*: CAC40 or CACNext20 stocks					
Stocks in CAC40 index					32
Stocks in Next20 index					18
Market Capitalization (in mio €)	15,544	18,568	1,088	85,261	50
Close-to-close return	0.1%	0.1%	-0.1%	0.2%	50
HILO	0.928	0.739	0.083	4.432	50
Nb trading days in Euronext	420	0.274	419	420	50
Nb trading days in BATS	416	0.274	415	416	50
Nb trading days in Chi-X	416	0.274	415	416	50
Panel *Non Index*: Non-index stocks					
Market Capitalization (in mio €)	2,230	1,561	358	6,298	49
Close-to-close return	0.1%	0.1%	-0.2%	0.2%	49
HILO	0.999	1.073	0.081	6.095	49
Nb trading days in Euronext	420	0.866	414	420	49
Nb trading days in BATS	403	54.152	51	416	49
Nb trading days in Chi-X	410	37.266	155	416	49

Table 2: **Summary statistics on the stock-day panel**

This table reports summary statistics for the stocks used in this study. Data are obtained from the intradaily dataset provided by Eurofidai-Bedofih. Trading activity is represented by the number of trades per day. Volume, in millions of euros, is the total value of shares traded for the day. The market share of each trading venue S is defined as $MS_t^S = \frac{V_t^S}{\sum_S V_t^S}$, where S = Euronext, BATS and Chi-X. Trade size is the absolute value of shares of a trade expressed in €. Relative Spread is the difference between the best ask and the best bid, divided by the mid-quote which is the average between the best ask and the best bid. Depth corresponds to the average quantity available at the best ask and at the best bid, expressed in euros. All measures are averaged across stock-day observations.

	Euronext			**BATS**			**Chi-X**		
	Mean	**Std. Dev.**	**N**	**Mean**	**Std. Dev.**	**N**	**Mean**	**Std. Dev.**	**N**
Panel *Index*: CAC40 or NextCAC20 stocks									
# trades per day	5,386	4,162	20,996	706	735	20,996	3,491	3,102	20,996
Volume (mio €)	44.18	49.39	20,996	2.753	3.662	20,996	14.614	16.581	20,996
Market share	72.4%	7.4%	20,996	4.1%	2.2%	20,996	23.4%	6.4%	20,996
Trade size (€)	7,078	3,084	20,996	3,946	2,169	20,996	4,074	1,943	20,996
Price (€)	47.16	42.17	20,996	46.633	41.136	20,492	46.951	41.639	20,722
Relative Spread (in bp)	6.8	2.6	20,996	19.2	15.8	20,796	7.7	4.7	20,771
Depth in €	37,682	24,948	20,996	10,774	9,152	20,796	13,954	11,910	20,771
Panel *Non Index*: Non-index stocks									
# trades per day	1,005	909	20,573	96	133	20,573	471	528	20,573
Volume (mio €)	3.83	5.06	20,573	0.04	0.12	20,573	0.07	0.17	20,573
Market share	78.4%	10.4%	20,573	3.60%	3.1%	20,573	18.10%	9.10%	20,573
Trade size (€)	3,396	1,733	20,573	2,153	2,245	20,573	2,238	1,889	20,573
Price (€)	48.39	51.99	20,573	45.894	46.256	14,330	46.098	47.342	16,761
Relative Spread (in bp)	18.5	11.5	20,573	76.8	102.9	20,076	43.4	69.5	20,222
Depth in €	12,528	14,530	20,573	6,447	4,060	20,076	5,361	3,505	20,222
# orders $(1,000)$	1	0.9	20,573						
# messages $(1,000)$	17	17	20,573						
Ratio updates/orders	90.5%	6.7%	20,573						
% HFT orders	25.4%	10.5%	20,573						
% HFT messages	21.1%	12.5%	20,573						
Ratio updates/orders HFT	84.5%	16.2%	20,386						

Table 3: **Summary statistics on the Euronext opening call auctions**

This table reports summary statistics on the Euronext opening call auction for the stocks and period studied in this paper. The table is split into two panels according to whether stocks belong to an index (CAC40 or CACNext20 in Panel *Index*), or not (Panel *Non Index*). The opening price is the clearing price resulting from the opening call auction (flagged with a special variable on our dataset). #trades is the number of trades resulting from the opening call auction. Volume in €is the volume cleared at the opening call auction. The close-to-open return r^{CO} is defined as $\frac{OPENP_t - CLOSEP_{t-1}}{CLOSEP_{t-1}}$, where $OPENP_t$ is the opening price of day t and $CLOSEP_{t-1}$ the closing price of the previous day. Correlation (r^{CC}, r^{CO}) corresponds to the correlation between the close-to-close return and the close-to-open return. Correlation $(V_{Open},\ V^S_{day})$ corresponds to the correlation between the volume traded at the opening, and the daily volumes traded in platform S, where $S = E$ (Euronext), B (BATS) or C (Chi-X). $V^E_{day^E\_w/o\_open}$ is a variable that exclude the volume executed at the open on Euronext. All measures are computed from the stock-day panel. We also report the % daily which corresponds to the variable recording the trading activity at the open divided by the corresponding measure computed across the trading day. The symbols ***,** and * indicate significance at 1%, 5% and 10% level, respectively.

	Mean	**% daily**	**Std. Dev.**	**N**
Panel *Index*: CAC40 or Next CAC 20 stocks				
Opening price	47.17		42.20	20,996
Close-to-open return r^{CO}	0.028%	(17.3%)	1.00%	20,795
# trades	74	(1.6%)	70	20,996
Volume (in 1,000 €)	647.26	(1.3%)	1,127.48	20,996
Correlation (r^{CC}, r^{CO})	0.437**		0.117	20,794
Correlation $(V_{Open},\ V^E_{day})$	0.509***		0.151	20,996
Correlation $(V_{Open},\ V^E_{day^E\_w/o\_open})$	0.509***		0.155	20,996
Correlation $(V_{Open},\ V^B_{day})$	0.328***		0.158	20,996
Correlation $(V_{Open},\ V^C_{day})$	0.432***		0.138	20,996
Panel *Non Index*: Non index stocks				
Opening price	48.39		51.97	20,573
Close-to-open return r^{CO}	0.036%	(16.7%)	1.00%	20,261
# trades	18	(2.6%)	19	20,573
Volume (in 1,000 €)	51.52	(1.9%)	121.75	20,573
Correlation (r^{CC}, r^{CO})	0.388		0.126	20,199
Correlation $(V_{Open},\ V^E_{day})$	0.463***		0.182	20,573
Correlation $(V_{Open},\ V^E_{day^E\_w/o\_open})$	0.464***		0.176	20,573
Correlation $(V_{Open},\ V^B_{day})$	0.283***		0.157	20,573
Correlation $(V_{Open},\ V^C_{day})$	0.385***		0.161	20,573

Table 4: **Summary Statistics on the trading volume by members' category**

This table reports summary statistics on the decomposition of the trading volume on Euronext by member's type and account. Trader's type is classified using a proprietary flag provided by the French Market Authority (AMF), which identifies three members' types: high-frequency-traders (HFT), slow traders (NON-HFT), and MIXED financial institutions which trade at high- or low-frequency depending on their activities. Using a variable provided by Eurofidai, members' trading activity may be recorded to 5 different accounts: client (or agency trades), prop trading, liquidity providing, retail trading and related parties. Panel (a) reports statistics of volumes for the opening call auction. Panel (b) reports volume statistics for continuous trading session, and Panel (c) for the closing call auction. Proportions are computed by stock and day, then averaged across stock-day observations

(a) Opening call auction trading session

Type	HFT	NON HFT	MIXED	SUM
Panel *Index*: CAC40 or Next CAC 20 stocks				
Clients	0.16%	30.33%	13.75%	44.24%
Prop traders	5.05%	7.47%	36.53%	49.05%
Liquidity providers	0.04%	0.31%	2.27%	2.62%
Retail traders	0.00%	0.09%	0.00%	0.09%
Others	0.00%	0.16%	3.84%	4.00%
SUM	5.25%	38.36%	56.39%	100%
Panel *Non Index*: Non index stocks				
Clients	0.11%	45.21%	10.37%	55.69%
Prop traders	5.90%	6.14%	27.65%	39.69%
Liquidity providers	0.00%	4.20%	0.20%	4.40%
Retail traders	0.00%	0.03%	0.00%	0.03%
Others	0.00%	0.15%	0.04%	0.19%
SUM	6.01%	55.73%	38.26%	100%

(b) Euronext continuous trading session

Type	HFT	NON HFT	MIXED	SUM
Panel *Index*: CAC40 or Next CAC 20 stocks				
Clients	0.12%	13.36%	9.02%	22.50%
Prop traders	4.14%	5.23%	35.31%	44.68%
Liquidity providers	21.10%	0.21%	7.59%	28.90%
Retail traders	0.00%	0.03%	0%	0.03%
Others	0.00%	0.03%	3.86%	3.89%
SUM	25.36%	18.86%	55.78%	100%
Panel *Non Index*: Non index stocks				
Clients	0.09%	29.79%	10.41%	40.29%
Prop traders	11.85%	5.39%	35.04%	52.28%
Liquidity providers	2.25%	2.32%	0.58%	5.15%
Retail traders	0.00%	0.02%	0.00%	0.02%
Others	0.00%	0.07%	2.19%	2.26%
SUM	14.19%	37.59%	48.22%	100%

Table 4: **Summary Statistics on the decomposition of trading volume by type and account (c'ed)**

(c) Closing call session

Type	HFT	NON HFT	MIXED	SUM
Panel *Index*: CAC40 or Next CAC 20 stocks				
Clients	0.09%	9.08%	12.78%	21.95%
Prop traders	0.99%	12.23%	53.55%	66.77%
Liquidity providers	0.20%	0.04%	3.26%	3.50%
Retail traders	0.00%	0.01%	0.00%	0.01%
Others	0.00%	0.63%	7.14%	7.77%
SUM	1.28%	21.99%	76.73%	100%
Panel *Non Index*: Non index stocks				
Clients	0.04%	15.37%	13.12%	28.53%
Prop traders	3.57%	12.59%	49.42%	65.58%
Liquidity providers	0.02%	1.57%	0.26%	1.85%
Retail traders	0.00%	0.00%	0.00%	0.00%
Others	0.00%	0.86%	3.17%	4.03%
SUM	3.63%	30.39%	65.98%	100%

Table 5: **Summary statistics on tentative prices and midquotes during the pre-opening period on Euronext**

This table reports summary statistics on tentative prices and volume during the pre-opening period of Euronext. We use 15-minute snapshots of Euronext's limit order book during the pre-opening period between 7:15 and 9:00. At each time $\tau \in \{7{:}30, 7{:}45, 8{:}00, 8{:}15, 8{:}30, 8{:}45\}$, we build the cumulated demand and supply function. # crosses is the number of times the demand and supply functions cross. # no cross is the number of times the demand and supply functions do not cross. # no cross (s.t. a midquote exists) is the number of times the supply and demand functions do not cross, the limit order book is not empty and the best ask and the best bid are used to compute a midquote. r^{CTOP_τ} is the return from the close to the tentative opening price TOP^τ calculated when supply and demand functions cross. r^{CTMQ_τ} is the return from the close to the preopening midquote TMQ^τ at time τ computed when there is no cross. The tentative opening volume is the result of the tentative call auction. The other variables are defined in the caption of Table 3. All measures are averaged across stock-day observations.

τ	7:30	7:45	8:00	8:15	8:30	8:45
When there is a cross: tentative opening prices						
# crosses	24,492	33,121	34,129	35,267	36,018	37,308
r^{CTOP_τ}	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%
Corr(r^{CTOP_τ}, r^{CO})	0.269	0.308	0.329	0.355	0.403	0.507
Corr(r^{CTOP_τ}, r^{CC})	0.068	0.079	0.086	0.089	0.118	0.162
Corr(r^{CTOP_τ}, $r^{O,MQ15^E}$)	-0.075	-0.109	-0.120	-0.122	-0.131	-0.142
Corr(r^{CTOP_τ}, $r^{O,MQ15^B}$)	-0.063	-0.090	-0.098	-0.099	-0.109	-0.120
Corr(r^{CTOP_τ}, $r^{O,MQ15^C}$)	-0.067	-0.098	-0.108	-0.110	-0.119	-0.128
When there is no cross: theoretical midquotes						
# no cross	16,998	8,371	7,364	6,227	5,476	4,186
# no cross s.t. a midquote exists	14,788	6,687	5,779	4,783	4,092	2,993
r^{CTMQ_τ}	0.0%	0.1%	0.1%	0.1%	0.1%	0.1%
Corr(r^{CTMQ_τ}, r^{CO})	0.193	0.195	0.193	0.230	0.245	0.308
Corr(r^{CTMQ_τ}, r^{CC})	0.033	0.039	0.037	0.048	0.052	0.077
Corr(r^{CTMQ_τ}, $r^{O,MQ15^E}$)	-0.007	-0.011	0.002	0.011	0.007	-0.005
Corr(r^{CTMQ_τ}, $r^{O,MQ15^B}$)	-0.02	-0.044	-0.037	-0.033	-0.037	-0.033
Corr(r^{CTMQ_τ}, $r^{O,MQ15^C}$)	-0.029	-0.035	-0.022	-0.018	-0.024	-0.033
Tentative opening volume						
Tentative volume (in $1,000$ €) when cross	8.67	21.95	27.85	37.09	44.85	68.05
Corr(Tentative volume including no cross, Daily volume)	0.082	0.103	0.111	0.137	0.164	0.208
Corr(Tentative volume including no cross, Daily volume Bats)	0.019	0.048	0.046	0.060	0.075	0.107
Corr(Tentative volume including no cross, Daily volume Chi-x)	0.084	0.097	0.095	0.117	0.133	0.170

Table 6: **Relation between market liquidity and pre-opening activity**

This table reports the estimates of the relation between the pre-opening activity of members (classified by type and account) and relative quoted spreads. The dependent variable $RSPD^S$ corresponds to the daily averaged relative bid-ask spread on venue S, where S =Euronext (E), BATS (B) or Chi-X (C). The independent variables correspond to the log of the number of messages submitted by different categories of members (HFT, NON-HFT, MIXED / clients, prop traders and liquidity suppliers). $Total\#messages$ is the total number of pre-opening messages (new orders, updates, or cancelations). HILO is the daily price range (that is, high minus low) defined by Parkinson (1980), measuring intra-daily volatility. The symbols ***,** and * indicate significance at 1%, 5% and 10% level, respectively.

Dependent variable:	(1) $RSPD^E$	(2) $RSPD^B$	(3) $RSPD^C$
Ln(# pre-opening messages by category)			
HFT, Clients	-0.00198	0.00584	0.00957
	(-1.04)	(0.34)	(0.98)
HFT, Prop traders	0.00183	0.00152	-0.00806
	(0.82)	(0.09)	(-0.87)
HFT, Liquidity suppliers	-0.000317	0.00614	0.00819
	(-0.26)	(0.41)	(1.24)
MIXED, Clients	-0.00383*	0.00651	0.00217
	(-1.99)	(0.40)	(0.22)
MIXED, Prop Traders	-0.00823*	-0.0938**	-0.0575**
	(-1.66)	(-3.05)	(-3.13)
MIXED, Liquidity suppliers	0.000760	0.00285	0.00454
	(1.07)	(0.80)	(1.97)
NON-HFT, Clients	-0.000635	0.0628**	0.0152
	(-0.30)	(3.11)	(1.59)
NON-HFT, Prop traders	0.000566	0.00387	-0.00127
	(0.39)	(0.31)	(-0.27)
NON-HFT, Liquidity suppliers	0.00194	0.0251	0.0110
	(0.65)	(1.02)	(1.32)
Total # messages	-0.0242*	-0.321***	-0.142**
	(-2.15)	(-3.83)	(-2.89)
HILO	0.000167	0.000224	0.0000992
	(1.46)	(0.29)	(0.53)
Const.	0.300***	2.387***	1.250***
	(8.72)	(5.18)	(4.34)
Obs.	39029	38352	38462
Stock FE	Yes	Yes	Yes
Stock Clust	Yes	Yes	Yes

Table 7: **Relation between price discovery or price reversal and pre-opening activity**

This table reports the estimates of the relation between the pre-opening activity of members (by type and by account), and measures of informational content or price reversals during the continuous trading session. The dependent variables are as follows: D_IC is a dummy variable that take value 1 if the close-to-open return and the close-to-close returns have the same sign, and 0 otherwise. D_REV^S is a dummy variable that take value 1 if the close-to-open return and the open-to-open plus 15 minutes returns have the opposite sign, and 0 otherwise, where midquotes at 9:15am are taken from Euronext, BATS or Chi-X. The independent variables correspond to the logarithm of the number of messages submitted by different categories of traders during the preopening session. HILO is the daily price range (that is, high minus low) defined by Parkinson (1980). All regressions include stock fixed effects and standard errors are clustered by stock. t statistics appear in parentheses. The symbols ***,** and * indicate significance at 1%, 5% and 10% level, respectively.

	Informational Content	**Price Reversal after the opening**		
Number of Messages (in ln)	D_IC	D_REV^E	D_REV^B	D_REV^C
	(1)	(2)	(3)	(4)
HFT, Clients	0.0271	0.0490*	0.0169	0.0198
	(1.30)	(2.39)	(0.84)	(0.97)
HFT, Prop traders	-0.0129	-0.00514	-0.00771	-0.0128
	(-0.95)	(-0.28)	(-0.41)	(-0.67)
HFT, Liquidity Providers	-0.00952	-0.0229	-0.0424	-0.0501
	(-0.24)	(-0.81)	(-1.53)	(-1.62)
MIXED, Clients	0.0418**	0.0158	0.0281	0.0376
	(2.78)	(0.74)	(1.32)	(1.82)
MIXED, Prop traders	0.00186	-0.109***	-0.0646*	-0.0847*
	(0.09)	(-3.38)	(-2.12)	(-2.50)
MIXED, Liquidity Providers	-0.0112	0.0127	0.00675	0.00572
	(-0.93)	(1.16)	(0.57)	(0.51)
NON-HFT, Clients	0.0768***	-0.0431*	-0.0591**	-0.0549*
	(3.52)	(-1.96)	(-2.73)	(-2.50)
NON-HFT, Prop traders	0.0193	-0.00427	-0.00366	-0.0121
	(1.60)	(-0.32)	(-0.29)	(-0.98)
NON-HFT, Liquidity Providers	0.0311***	-0.0464**	-0.0411**	-0.0469**
	(3.45)	(-3.07)	(-2.68)	(-3.07)
Total Preopening Messages	0.00903	-0.0959	-0.0488	-0.0109
	(0.20)	(-1.57)	(-0.81)	(-0.17)
High-Low	0.0113	0.0128**	0.0139**	0.0140**
	(1.87)	(2.82)	(3.15)	(3.22)
Const.	-0.0301	1.412***	0.969***	0.818***
	(-0.27)	(9.82)	(6.07)	(5.22)
Obs.	38763	38806	37203	37616

A Appendices

Table A.8: **Informational content of tentative prices and midquotes**

This table reports the informational content of tentative prices or midquotes, for stocks of the SFB120 that are traded continuously and cross-traded in Euronext Paris, BATS and Chi-X spanning twenty months from May 2, 2012 to December 31, 2013. We run a regression for each 15-min interval τ. The dependent variable corresponds to the close-to-close return and the independent variable corresponds to the return of the tentative opening price or the tentative midquote in the pre-opening session each 15-minute interval: $r_{i,t}^{CC} = \alpha_{0,\tau} + \alpha_{1,\tau} r_{i,t}^{CP\text{-}\tau} + \varepsilon_{i,t}$.
We run one regression per 15-minute interval, τ. All regressions include stock fixed effects and time clustering. The symbols ***,** and * indicate significance at 1%, 5% and 10% level, respectively. Coefficients of this table are represented graphically in Figure 5.

	Tentative Opening Price						**Tentative Midquote**					
	(1) r^{CC}	(2) r^{CC}	(3) r^{CC}	(4) r^{CC}	(5) r^{CC}	(6) r^{CC}	(1) r^{CC}	(2) r^{CC}	(3) r^{CC}	(4) r^{CC}	(5) r^{CC}	(6) r^{CC}
r^{CP_730}	0.293*						0.0532					
	(2.41)						(1.51)					
r^{CP_745}		0.242**						0.0768				
		(2.67)						(1.93)				
r^{CP_800}			0.202**						0.0801			
			(2.70)						(1.78)			
r^{CP_815}				0.160**						0.110*		
				(2.84)						(2.18)		
r^{CP_830}					0.218**						0.112*	
					(3.19)						(2.10)	
r^{CP_845}						0.272***						0.198**
						(4.09)						(2.88)
Const.	0.002	0.002	0.002	0.002	0.002	0.002	0.001	-0.034***	-0.034***	-0.009***	-0.031***	-0.030***
	(1.38)	(1.50)	(1.44)	(1.37)	(1.33)	(1.35)	(0.07)	(-342.54)	(-303.06)	(-17.66)	(-52.57)	(-39.39)
Obs.	24,178	32,700	33,686	34,801	35,539	36,805	14,556	6,546	5,651	4,678	3,999	2,927
Stock FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time Clust.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table A.9: **Reversal of tentative prices and midquotes 15 minutes after the opening**

This table reports the price reversal of tentative prices or midquotes within Euronext, for stocks of the SFB120 that are traded continuously and cross-traded in Euronext Paris, BATS and Chi-X spanning twenty months from May 2, 2012 to December 31, 2013. We run a regression for each 15-min interval τ. The dependent variable corresponds to the open-to-open plus 15 minutes in Euronext return and the independent variable corresponds to the return of the tentative opening price or the tentative midquote in the pre-opening session each 15-minute interval: $r_{i,t}^{O,MQ15^S} = \beta_{0,\tau}^S + \beta_{1,\tau}^S r_{i,t}^{CP\text{-}\tau} + \varepsilon_{i,t}$, where $MQ15^S$ is the midquote in platform S at 9:15am. We run one regression per 15-minute interval, τ, and per platform S. All regressions include stock fixed effects and time clustering. The symbols ***,** and * indicate significance at 1%, 5% and 10% level, respectively.

(a) Euronext

	Tentative Opening Price						**Tentative Midquote**					
	(1) $r^{O,MQ15}$	(2) $r^{O,MQ15}$	(3) $r^{O,MQ15}$	(4) $r^{O,MQ15}$	(5) $r^{O,MQ15}$	(6) $r^{O,MQ15}$	(1) $r^{O,MQ15}$	(2) $r^{O,MQ15}$	(3) $r^{O,MQ15}$	(4) $r^{O,MQ15}$	(5) $r^{O,MQ15}$	(6) $r^{O,MQ15}$
r^{CP_730}	-0.0350***						-0.0105					
	(-6.41)						(-1.16)					
r^{CP_745}		-0.0459***						-0.0123				
		(-9.16)						(-1.19)				
r^{CP_800}			-0.0456***						-0.00384			
			(-11.44)						(-0.36)			
r^{CP_815}				-0.0458***						0.0149		
				(-8.93)						(0.85)		
r^{CP_830}					-0.0474***						0.0237	
					(-11.21)						(1.00)	
r^{CP_845}						-0.0588***						0.00643
						(-11.03)						(0.32)
Const.	0.001	0.001	0.001	0.001	0.001	0.001	-0.000	0.004***	0.004***	0.004***	-0.014***	-0.005***
	(1.22)	(1.48)	(1.53)	(1.54)	(1.55)	(1.54)	(-0.09)	(142.65)	(138.19)	(54.47)	(-50.82)	(-62.19)
Obs.	24,426	33,003	33,995	35,124	35,869	37,144	14,643	6,587	5,685	4,705	4,022	2,941
Stock FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time Clust.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table A.9: **Reversal of tentative prices and midquotes 15 minutes after the opening (c'ed)**

(b) BATS

	Tentative Opening Price						**Tentative Midquote**					
	(1) $r^{O,MQ15}$	(2) $r^{O,MQ15}$	(3) $r^{O,MQ15}$	(4) $r^{O,MQ15}$	(5) $r^{O,MQ15}$	(6) $r^{O,MQ15}$	(1) $r^{O,MQ15}$	(2) $r^{O,MQ15}$	(3) $r^{O,MQ15}$	(4) $r^{O,MQ15}$	(5) $r^{O,MQ15}$	(6) $r^{O,MQ15}$
r^{CP_730}	-0.0333***						-0.0240					
	(-5.88)						(-1.96)					
r^{CP_745}		-0.0450***						-0.0446**				
		(-8.10)						(-2.89)				
r^{CP_800}			-0.0441***						-0.0438*			
			(-9.97)						(-2.37)			
r^{CP_815}				-0.0446***						-0.0336		
				(-8.26)						(-1.63)		
r^{CP_830}					-0.0462***						-0.0364	
					(-10.48)						(-1.58)	
r^{CP_845}						-0.0595***						-0.0386
						(-10.56)						(-1.17)
Const.	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.003***	0.003***	0.003***	-0.015***	-0.005***
	(1.50)	(1.84)	(1.89)	(1.92)	(1.93)	(1.93)	(0.06)	(86.62)	(72.39)	(35.16)	(-57.82)	(-35.49)
Obs.	23,943	32,138	33,060	34,108	34,787	35,954	13,515	5,876	5,048	4,145	3,520	2,552
Stock FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time Clust.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table A.9: **Reversal of tentative prices and midquotes 15 minutes after the opening (c'ed)**

(c) Chi-X

	Tentative Opening Price						**Tentative Midquote**					
	(1) $r^{O,MQ15}$	(2) $r^{O,MQ15}$	(3) $r^{O,MQ15}$	(4) $r^{O,MQ15}$	(5) $r^{O,MQ15}$	(6) $r^{O,MQ15}$	(1) $r^{O,MQ15}$	(2) $r^{O,MQ15}$	(3) $r^{O,MQ15}$	(4) $r^{O,MQ15}$	(5) $r^{O,MQ15}$	(6) $r^{O,MQ15}$
r^{CP_730}	-0.0338***						-0.0285*					
	(-5.96)						(-2.47)					
r^{CP_745}		-0.0488***						-0.0243				
		(-8.70)						(-1.73)				
r^{CP_800}			-0.0479***						-0.0130			
			(-10.78)						(-0.84)			
r^{CP_815}				-0.0477***						-0.00263		
				(-8.74)						(-0.14)		
r^{CP_830}					-0.0492***						-0.0114	
					(-10.81)						(-0.56)	
r^{CP_845}						-0.0610***						-0.00542
						(-10.80)						(-0.20)
Const.	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	-0.002	0.004***	0.004***	-0.007***	-0.017***	-0.005***
	(4.26)	(5.05)	(4.77)	(5.20)	(5.05)	(5.58)	(-0.82)	(109.34)	(98.45)	(-41.90)	(-73.41)	(-46.12)
Obs.	24,081	32,377	33,315	34,383	35,064	36,260	13,794	6,040	5,199	4,277	3,648	2,650
Stock FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time Clust.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table A.10: **Tentative volumes and daily trading activity in Euronext, BATS, and Chi-X**

This table reports the link between the tentative volume during the pre-opening and the daily volume traded in Euronext, for stocks of the SFB120 that are traded continuously and cross-traded in Euronext Paris, BATS and Chi-X spanning twenty months from May 2, 2012 to December 31, 2013. The tentative opening volume is equal to zero when there is no cross between supply and demand. We run a regression for each 15-min interval τ and each platform S. The dependent variable corresponds to the volume traded during the day in million €in platform S and the independent variable corresponds to the tentative volume at the pre-opening session each 15-minute interval in million €: $V^S_{i,t} = \gamma^S_{0,\tau} + \gamma^S_{1,\tau} TOV\_\tau_{i,t} + \varepsilon_{i,t}$. All regressions include stock fixed effects and time clustering. The symbols ***,** and * indicate significance at 1%, 5% and 10% level, respectively.

(a) Euronext

	(1) V^E	(2) V^E	(3) V^E	(4) V^E	(5) V^E	(6) V^E
TOV_730	26.39					
	(1.91)					
TOV_745		19.64**				
		(2.60)				
TOV_800			16.78**			
			(2.79)			
TOV_815				24.12***		
				(3.40)		
TOV_830					23.74***	
					(4.19)	
TOV_845						23.31***
						(6.20)
Constant	23.14***	22.96***	22.91***	22.43***	22.23***	21.70***
	(33.58)	(33.53)	(33.24)	(31.09)	(31.57)	(32.49)
Obs.	41490	41492	41493	41494	41494	41494
Stock FE	Yes	Yes	Yes	Yes	Yes	Yes
Time Clust.	Yes	Yes	Yes	Yes	Yes	Yes

Table A.10: **Tentative volumes and daily trading activity in Euronext, BATS, and Chi-X (c'ed)**

(b) BATS

	(1) V^B	(2) V^B	(3) V^B	(4) V^B	(5) V^B	(6) V^B
TOV_730	-1.492*					
	(-2.07)					
TOV_745		0.738				
		(1.55)				
TOV_800			0.585			
			(1.58)			
TOV_815				0.701*		
				(2.31)		
TOV_830					0.720**	
					(2.62)	
TOV_845						0.960***
						(4.37)
Constant	0.642***	0.593***	0.593***	0.583***	0.575***	0.539***
	(24.48)	(22.85)	(22.85)	(23.18)	(22.17)	(19.64)
Obs.	41490	41492	41493	41494	41494	41494
Stock FE	Yes	Yes	Yes	Yes	Yes	Yes
Time Clust.	Yes	Yes	Yes	Yes	Yes	Yes

Table A.10: **Tentative volumes and daily trading activity in Euronext, BATS, and Chi-X (c'ed)**

(c) Chi-X

	(1) V^C	(2) V^C	(3) V^C	(4) V^C	(5) V^C	(6) V^C
TOV_730	8.259*					
	(2.07)					
TOV_745		5.425*				
		(2.33)				
TOV_800			3.338			
			(1.84)			
TOV_815				4,151**		
				(3.03)		
TOV_830					4.258***	
					(3.83)	
TOV_845						4.925***
						(5.21)
Constant	3.385***	3.352***	3.391***	0.583***	3.282***	3.127***
	(27.34)	(26.83)	(26.64)	(23.18)	(27.78)	(25.98)
Obs.	41490	41492	41493	41494	41494	41494
Stock FE	Yes	Yes	Yes	Yes	Yes	Yes
Time Clust.	Yes	Yes	Yes	Yes	Yes	Yes

Table A.11: **Tentative volumes and daily relative bid-ask spreads in Euronext, BATS, and Chi-X**

This table reports the link between the tentative volume during the pre-opening and the daily relative bid-ask spread, for stocks of the SFB120 that are traded continuously and cross-traded in Euronext Paris, BATS and Chi-X spanning twenty months from May 2, 2012 to December 31, 2013. The tentative opening volume is equal to zero when there is no cross between supply and demand. We run a regression for each 15-min interval τ and each platform S. The dependent variable corresponds to the daily averaged relative bid-ask spread in platform S and the independent variables correspond to the log of the tentative volume at the pre-opening session each 15-minute interval in million €when there is a cross, and a dummy that takes value 1 when there is no cross and 0 otherwise: $RSPD^S_{i,t} = delta^S_{0,\tau} + \delta^S_{1,\tau} ln(TOV\_\tau_{i,t}) \times Dcross\_\tau + \delta^S_{2,\tau} Dnocross\_\tau + \varepsilon_{i,t}$, where $Dcross\_\tau$ is a dummy that takes value 1 if there is a cross at time τ and 0 otherwise, and $Dnocross\_\tau = 1 - Dcross\_\tau$. All regressions include stock fixed effects and time clustering. The symbols ***,** and * indicate significance at 1%, 5% and 10% level, respectively.

(a) Euronext

	(1) $RSPD^E$	(2) $RSPD^E$	(3) $RSPD^E$	(4) $RSPD^E$	(5) $RSPD^E$	(6) $RSPD^E$
$ln(TOV\_730) \times Dcross\_730$	-0.002***					
	(-7.13)					
$Dnocross\_730$	0.003					
	(1.83)					
$ln(TOV\_745) \times Dcross\_745$		-0.003***				
		(-9.93)				
$Dnocross\_745$		0.001				
		(0.43)				
$ln(TOV\_800) \times Dcross\_800$			-0.003***			
			(-10.58)			
$Dnocross\_800$			0.000			
			(0.10)			
$ln(TOV\_815) \times Dcross\_815$				-0.003***		
				(-10.69)		
$Dnocross\_815$				0.003		
				(1.17)		
$ln(TOV\_830) \times Dcross\_830$					-0.003***	
					(-9.89)	
$Dnocross\_830$					0.006**	
					(2.30)	
$ln(TOV\_845) \times Dcross\_845$						-0.003***
						(-10.60)
$Dnocross\_845$						0.005**
						(1.67)
Const	0.112***	0.124***	0.127***	0.128***	0.127***	0.132***
	(47.61)	(41.87)	(41.56)	(41.62)	(40.59)	(38.13)
Obs.	41,480	41,472	41,466	41,476	41,478	41,484
Stock FE	Yes	Yes	Yes	Yes	Yes	Yes
Time Clust.	Yes	Yes	Yes	Yes	Yes	Yes

Table A.11: **Tentative volumes and daily relative bid-ask spreads in Euronext, BATS, and Chi-X (c'ed)**

(b) BATS

	(1) $RSPD^B$	(2) $RSPD^B$	(3) $RSPD^B$	(4) $RSPD^B$	(5) $RSPD^B$	(6) $RSPD^B$
$ln(TOV\_730) \times Dcross\_730$	-0.019***					
	(-9.14)					
$Dnocross\_730$	-0.031					
	(-1.70)					
$ln(TOV\_745) \times Dcross\_745$		-0.022***				
		(-7.91)				
$Dnocross\_745$		-0.023				
		(-0.98)				
$ln(TOV\_800) \times Dcross\_800$			-0.024***			
			(-7.35)			
$Dnocross\_800$			-0.032			
			(-1.18)			
$ln(TOV\_815) \times Dcross\_815$				-0.025***		
				(-7.39)		
$Dnocross\_815$				-0.042*		
				(-1.39)		
$ln(TOV\_830) \times Dcross\_830$					-0.025***	
					(-7.09)	
$Dnocross\_830$					-0.034	
					(-1.08)	
$ln(TOV\_845) \times Dcross\_845$						-0.026***
						(-8.11)
$Dnocross\_845$						-0.031
						(-1.04)
Const.	0.500***	0.553***	0.574***	0.596***	0.593***	0.617***
	(22.54)	(17.99)	(16.15)	(15.74)	(15.27)	(16.47)
Obs.	40,786	40,778	40,772	40,782	40,784	40,790
Stock FE	Yes	Yes	Yes	Yes	Yes	Yes
Time Clust.	Yes	Yes	Yes	Yes	Yes	Yes

Table A.11: **Tentative volumes and daily relative bid-ask spreads in Euronexy, BATS, and Chi-X (c'ed)**

(c) Chi-X

	(1) $RSPD^C$	(2) $RSPD^C$	(3) $RSPD^C$	(4) $RSPD^C$	(5) $RSPD^C$	(6) $RSPD^C$
$ln(TOV\_730) \times Dcross\_730$	-0.007***					
	(-5.91)					
$Dnocross\_730$	-0.004					
	(-0.46)					
$ln(TOV\_745) \times Dcross\_745$		-0.010***				
		(-7.83)				
$Dnocross\_745$		-0.022				
		(-1.83)				
$ln(TOV\_800) \times Dcross\_800$			-0.010***			
			(-7.60)			
$Dnocross\_800$			-0.022			
			(-1.78)			
$ln(TOV\_815) \times Dcross\_815$				-0.011***		
				(-6.68)		
$Dnocross\_815$				-0.025*		
				(-1.62)		
$ln(TOV\_830) \times Dcross\_830$					-0.010***	
					(-6.11)	
$Dnocross\_830$					-0.015	
					(-0.94)	
$ln(TOV\_845) \times Dcross\_845$						-0.010***
						(-6.52)
$Dnocross\_845$						-0.004
						(-0.26)
Const.	0.195***	0.238***	0.241***	0.250***	0.242***	0.248***
	(19.63)	(18.52)	(17.65)	(14.87)	(14.07)	(14.60)
Obs.	40,905	40,897	40,891	40,901	40,903	40,909
Stock FE	Yes	Yes	Yes	Yes	Yes	Yes
Time Clust.	Yes	Yes	Yes	Yes	Yes	Yes

EconPol Europe

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