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

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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 platforms 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 pre-open 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 platforms. 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 platforms 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 message's submission) to analyze the price formation process on the exchange itself and on the two competing trading platforms (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 trades and quotes on Euronext Paris, BATS and Chi-X Europe, but also

[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 platforms 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 platform to another.

of messages on Euronext Paris. Quotes data include complete snapshots of all levels of the limit order book of each platform observed every 15 minutes. Euronext messages are composed of new orders, modifications and cancellations submitted to Euronext Paris (including the pre-opening period). It 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 platforms 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 platforms, Euronext, BATS and Chi-X. Second, the pre-opening messages' 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 $\tau$ 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 very early tentative prices and 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 $\tau$ 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 after the opening call auction.

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 platforms. We document a positive and significant relation between the tentative opening volume and the daily volume for each of the three trading platforms. 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 platforms 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 platforms. 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) and Bellia et al. (2017) show that the pre-opening activity of fast traders lead price discovery on the Tokyo Stock Exchange and on Euronext Paris respectively. 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 platforms 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 platforms 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 platforms provide facilities for secondary

[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.

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]

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

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

[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.

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 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. 1.8%) 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, on BATS and and on 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

[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.

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

trading preferring less transparent platforms 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 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 platforms 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 on Euronext (measured by trading volume and liquidity) is correlated with the daily activity across trading platforms.*

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 platforms 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, all participants 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)). This reasoning should hold for market participants with liquidity needs (typically customers) willing to avoid parasitic traders, and informed traders (typically prop traders) willing to avoid information leakage. 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: 1. 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 platforms, and 2. a correlation between the number of pre-opening messages and market liquidity 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 across all trading venues.*

In the short term however, prices and volumes in BATS and Chi-X may have different dynamics due to the existence of different opening mechanisms in the three platforms.

# 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 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, 13 additional stocks which are not traded continuously on BATS and Chi-X during our sample period.[16] Our final sample consists of 99 stocks and 416 trading days.

[12] Bedofih stands for Base Européenne de DOnnées 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.

[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.

[16] We drop 4 trading days that are characterized by a half-day of trading (December 24 and 31, 2012 and 2013) and the subsequent days for which we cannot compute the close-to-close return, and 1 day during which Euronext faced technical issues (June 6, 2013). Besides, we drop 1 stock and 2 trading days

We identify 189 stock-day observations characterized by corporate actions or events (stock splits, stock repurchases, M&A offers, ...), and 73 additional 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 usually triggered by prices crossing price limits. We exclude these stock-day observations to avoid a potential impact on daily liquidity measures. Our final panel consists of 40,914 stock-day observations.

We split the sample in two by capitalization group. Panel A (*Index*) is composed of the 50 stocks that belong either to the CAC40 (32 stocks) or to the CACNext20 (18 stocks) indexes. Panel B (*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 platforms 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 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 platform $S$.

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

due to data reporting issues (e.g., missing quotes).

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 platform $S$ ($S = E, B$ 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 platform $S$, 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 platform $S$ and no trading halt reported by Euronext ($S = E, B$ and $C$). As a proxy for volatility, we compute the relative price range defined by Parkinson (1980) as

$$HILO_t = \frac{\left(\ln\left(\max_{i_t}\left(P_{i_t}\right)\right) - \ln\left(\min_{i_t}\left(P_{i_t}\right)\right)\right)^2}{4 \times \ln(2)} \times 100,$$

where $P_{i_t}$ is the price of transaction $i_t$ executed on day $t$.

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 platform $S$ ($S = E, B$ 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 $MODIF_i$, 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 $\%SUBM_i$, $\%MODIF_i$, 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 ($NONEXEC_i$).[17]

### 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 7:15am and 9:00am to rebuild the cumulated demand and supply functions at time $\tau$, where $\tau$ 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 $TOP_t^\tau$ that maximizes the number of shares traded, from which a tentative clearing volume $TOV_t^\tau$ results. When the cumulated demand and supply functions do not cross, especially early in the pre-opening session, we compute a preopening midquote $TMQ^\tau$ 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 $\tau$ of the preopen as follows:

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

[17] 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).

where $Dnocross\_\tau$ is a dummy variable that takes value 1 if there exists no cross at time $\tau$ 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 A ( *Index*) relates to stocks belonging to CAC40 and CACNext20, while Panel B (*Non Index*) consists of small (or non-index) stocks. Panel A shows that the average market capitalization of index stocks is 15,544 million euros representing seven times that of stocks reported in Panel B amounted to 2,230 million euros. Panel A also shows that mid stocks exhibit larger standard deviations for volatility. Regarding trading platforms, 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, the number of trades of index stocks amounts to 5,369 on average, which is five times larger than for non-index stocks (1,008 on average). 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 (18.1 bp on average). As expected, trading activity and market liquidity thus increase with market capitalization.

Comparing trading platforms, Euronext executes almost three quarters of the total trading volume, followed by Chi-X which absorbs approximately one fifth of the total trading volume. The market share of BATS is below 5%. The average trade size is also larger on Euronext than on BATS or on Chi-X, in particular 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 platforms. Interestingly, the market share of Euronext is smaller for index stocks, with an average of 72.5% while it is 78.2% 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. All differences are significant at the 1% level. For small stocks, BATS is very illiquid compared to the other platforms with an average market spread of 75.1bp, while the average relative quoted spread on Chi-X is 46.19bp and only 18.1 bp on Euronext. 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.

### 4.1.3 The opening call auction

Table 3 reports statistics on opening prices and volumes.

**Insert Table 3 here**

To address the economic importance of the opening, we standardize measures related to the opening activity by the corresponding measures computed across the total trading day. We report this proportion in the second column of the table. The opening auction volume represents only 1.6% (resp. 1.3%) of the total number of daily trades (resp. total daily trading volume) of index stocks. For non-index stocks, the opening call auction on Euronext accounts, on average, for 2.5% of the total number of daily trades and 1.8% of the total daily volume, which is slightly higher. 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 for CAC40 stocks.

Although the opening auction represents a smaller fraction of the total daily volume, it may still contribute to the price and liquidity discovery. To analyze the contribution of the opening auction to liquidity discovery, we build various time series correlations between volume resulting from the call auction and those of the continuous trading session, namely

the correlations between the volume at the open, $V_{Open}$, and the total daily volume on each of the three trading platforms, $V^S$ ($S = E, B$ and $C$). Table 3 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.[18] The correlation with the volume traded on Euronext is stronger than for the other alternative trading platforms, suggesting that the quantity discovery is better on Euronext at the open than on the other two platforms deprived of call auction, which is relevant for Hypothesis 2.

To further investigate its contribution to price 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 0.33% of the daily price change for index stocks (Panel *Index*), and 0.44% for small non-index stocks (Panel *Non Index*). We also compute the time series correlations between the close-to-close return $r^{CC}$ and the close-to-open return $r^{CO}$. 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 0.404 for index stocks (Panel *Index*), and to 0.365 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 even at 10%, 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.

### 4.1.4 Members

To better identify the key participants, we decompose the trading volume (in euros) depending on the characteristics of the members.

**Insert Table 4**

Table 4 Panel (b) reports the decomposition of the trading volume during the continuous trading session, by members' account (in row) and type (in column). The last column indicates the total proportion of the total volume traded during the day by account (across

[18] 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.

speed categories). Prop. traders are the largest contributors to the daily trading volume (with 45% for index stocks and 53% for non-index stocks), followed by brokers trading on behalf of clients and liquidity providers. The latter represent 29% of the volume for index stocks, but only 5% for non-index stocks. This finding may be surprising given that liquidity programs were initially designed by Euronext to guarantee the liquidity of smaller caps; it can be explained by Euronext's Supplemental Liquidity Provider (SLP) program implemented for a subset of stocks (mainly large caps), that offers lower fees for program participants as a counterpart for liquidity provision.

The last row indicates the total proportion of the volume open by type (across accounts). MIXED members are involved in almost half of the trades. HFTs trade a larger fraction of volume for index stocks (25%) than for non-index stocks (14%), while the reverse holds for NON-HFT participants (19% for index stocks and 37% for non-index stocks).

Recouping both dimensions of account (i.e., 5 categories) and type (i.e., 3 categories) enables us to identify the most active participants among the fifteen categories. The daily trading activity mainly comes from four categories. First, HFT (or fast) prop. traders or liquidity providers represent a total of 25% of the activity for index stocks and 13% for non-index stocks, with prop. traders being more active in trading non-index stocks while liquidity providers are more active in index stocks. Second, NON-HFT (or slow) brokers represent 13% (resp. 29%) of the trading of index (resp. non-index stocks). Third, MIXED traders trading on their own account represent 35% of the activity for index and non-index stocks; for index-stocks, MIXED liquidity suppliers have also a large market share with 8% of the daily volume. Fourth, MIXED brokers represent around 10% of the activity whether for index or non-index stocks. These findings are consistent with the those of Biais et al. (2016) (who however use a different definition for the categorization of members).

To better understand the behavior of members at the open, we now contrast the decomposition of the volume by member's account and type during the open (Panel (a)) with the one we have for the continuous trading session (Panel (b)), and during the close (Panel (c)). When comparing with the continuous trading session, three striking facts emerge. First, while being major participants during the day, HFTs barely participate to the opening auction, and represent less than 6% of the volume at the open. This may not be surprising as speed does not provide them with a key advantage in an auction. In

line with this explanation, they do not participate to the closing auction either (with less than 4% of the closing volume). Second, the proportion of transactions involving liquidity suppliers (whether HFT or MIXED) is quite low at the open, even for index stocks (i.e., it drops from 29% to 3%). This finding is consistent with the previous one: HFT who are mainly liquidity providers in index stocks do not trade at the open; finally, most of the HFTs who participate in the opening auction trade on their own account. This further suggests that MIXED traders use their fast connections when acting as liquidity providers. Third, NON-HFT brokers and MIXED prop. traders are the largest contributors to the opening trading volume. With 30% of the volume for index stocks and even 45% for non-index stocks, the former in particular exhibit an abnormally high activity during the call auction, relative to their daily activity. For them, the closing call auction is also very different: transactions involving slow brokers only amount to 9.08% (resp. 15.29%) of the closing trading volume of index stocks (resp. of non-index stocks). By contrast, the latter trade half of the closing volume. This is consistent with portfolio rebalancing and liquidity needs characterizing the end of the day (inventory layoff) of financial institutions.

Regarding other members, we observe that the participation of both retail traders and related parties is very small (whether, HFT, NON-HFT or MIXED) in the three different sessions. For this reason, we will neglect them in the remaining analysis. Finally, our analysis below will focus on the following categories of members: i. HFT prop. traders and liquidity suppliers, ii. NON-HFT brokers, iii. MIXED prop. traders and liquidity suppliers, and iv. MIXED brokers. All reminding categories including retail traders and related parties are pooled together in a control variable for running regressions.

### 4.1.5 Pre-opening order submission process

Figure 1a illustrates the average daily number of orders newly submitted, modified or canceled posted during each 15-min interval of the pre-open, in value ($NBx_i$) and in proportion of the total number of messages ($\%x_i$) ($x = SUBM, MODIF$ 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 cancellations (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 cancellations, 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 cancellations 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 consistently with Hypothesis 5. By contrast, MIXED traders, either as prop traders or clients, are mainly active during the last 15 minutes (new orders, updates or cancellations). 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 (submissions, modified, cancelled), 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.

**Insert Figure 2 here**

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.

Figure 3 illustrates the life of pre-opening orders, for each 15-min interval. A breakdown by members' type and account is also reported.

**Insert Figure 3 here**

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 cancellations 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 cancellations during the last 15-min.

Figure 4a plots orders' aggressiveness by 15-min interval. We label market and market-to-limit orders as aggressive orders.

**Insert Figure 4 here**

Figure 4a shows that early orders are more aggressive than late ones. The breakdown by member's type in Figures 4b and 4c 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.

## 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 $\tau$ of the pre-open, $r^{CTOP_\tau}$, and the close-to-open return, $r^{CO}$, is positive and increases over time to reach 0.446 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 $\tau$ of the preopen, $r^{CTOP_\tau}$, and the return from the open to 9:15am is negative in each of the three platforms, showing some price reversal on each trading platforms.

Results also indicate that the correlation between the tentative clearing volume and the daily volume traded either on Euronext or on the other competing platforms, 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 $r^{CP_\tau}$ is the return from the previous close to time $\tau$ and $r^{CC}$ is the close-to-close return, and $\tau$ = 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 $\tau$ varying between 7:30am to 8:45am.[20]

**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.

[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 $\tau$. The WPC is a proxy for the proportion of the close-to-close price evolution that is discovered during interval $\tau$. 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 App.1 in the Online Appendix. Results of regressions without fixed effects are qualitatively similar.

### 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 platform $S$ 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 $\tau$ 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 $\tau$ ($\tau$ = 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 platforms. 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.

## 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

[21] The exact values of the estimates of these regressions can be found in Table App.2 in the Online Appendix. Results of regressions without fixed effects are qualitatively similar.

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 $\tau$ ($\tau$ = 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 platforms, 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 platform $S$, 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 the three platforms for each value of $\tau$ between 7:30 and 8:45am.[23]

First, results show that a larger tentative clearing volume is related to lower spreads for the three platforms. 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 platforms, 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 platform.

[22]The exact values of the estimates of these regressions can be found in Table App.3 in the Online Appendix. Results of regressions without fixed effects are qualitatively similar.

[23]The exact values of the estimates of these regressions are found in Table App.4 in the Online Appendix. Results of regressions without fixed effects are qualitatively similar.

**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 platform $S$ 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 platforms. Interestingly, daily spreads are significantly and negatively related to the activity of MIXED prop traders across the three platforms, 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 platforms.

### 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:

$$d_{j,t} = b^S_0 + \sum_{cat} b^{S,cat}_1 ln(NBMSG^{cat}_{j,t}) + ln(\sum_{cat} NBMSG^{cat}_{j,t}) + HILO_{j,t} + \varepsilon_{j,t} \quad (12)$$

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 platform $S$ (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 platforms, but positively related to the activity of HFT clients on Euronext (not significant for the other platforms). 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 platforms 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 platform. 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 platforms. 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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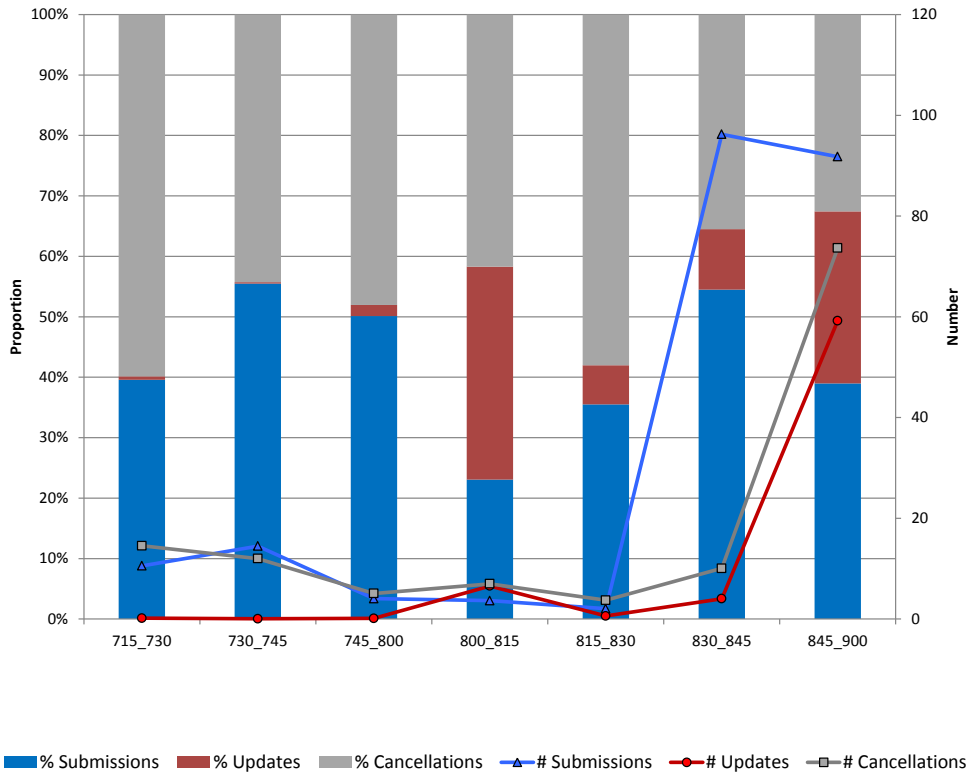
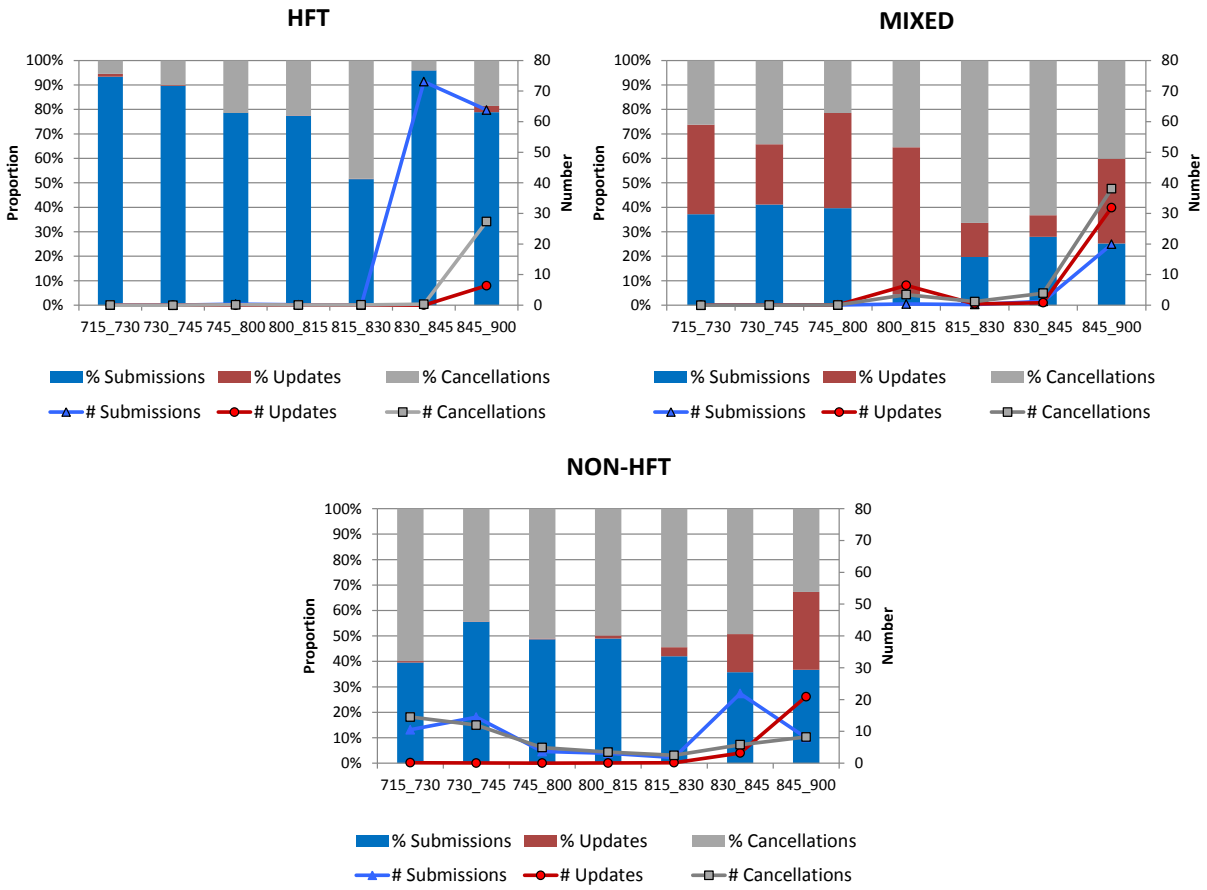
Figure 1: **Decomposition of pre-opening messages by category for each 15-min interval**

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

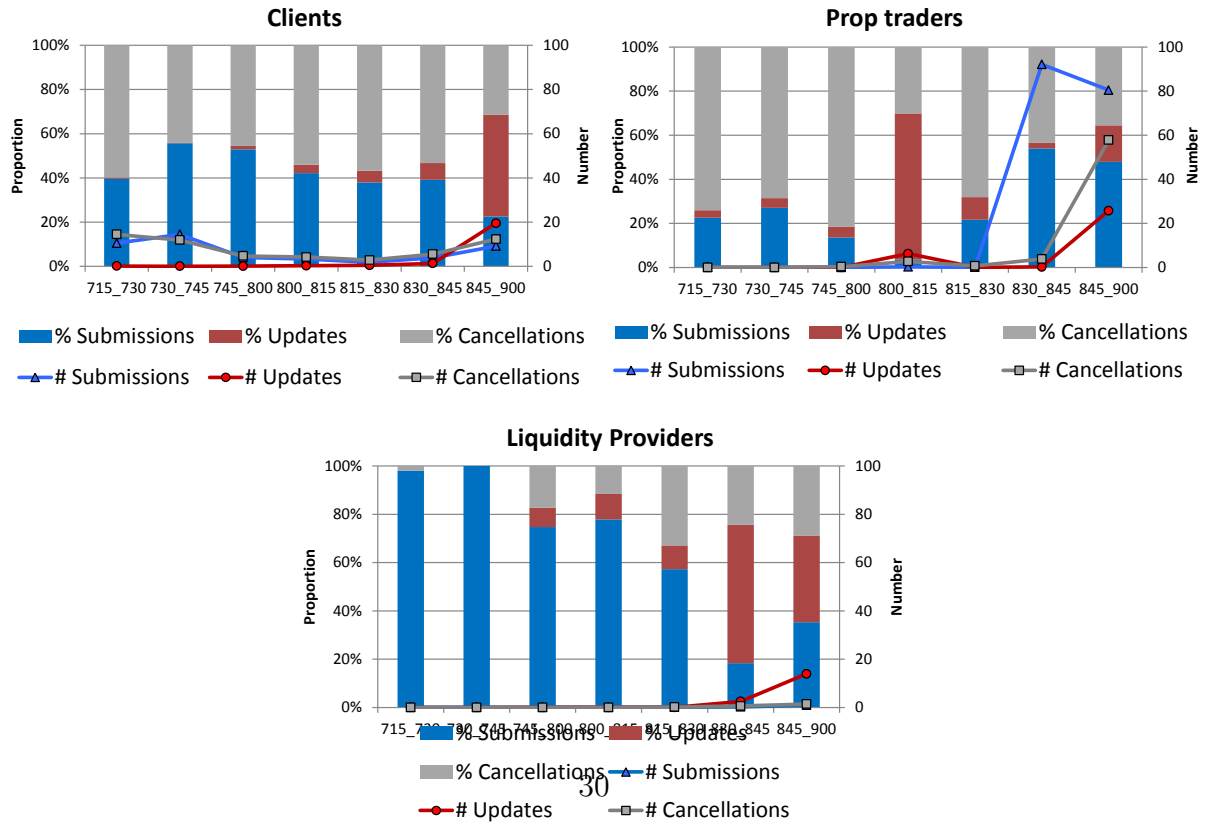
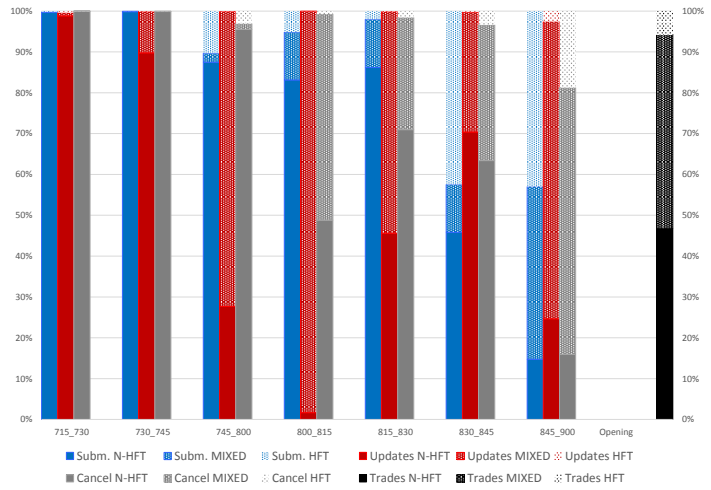


Figure 2: **Relative decomposition of categories of messages**

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**

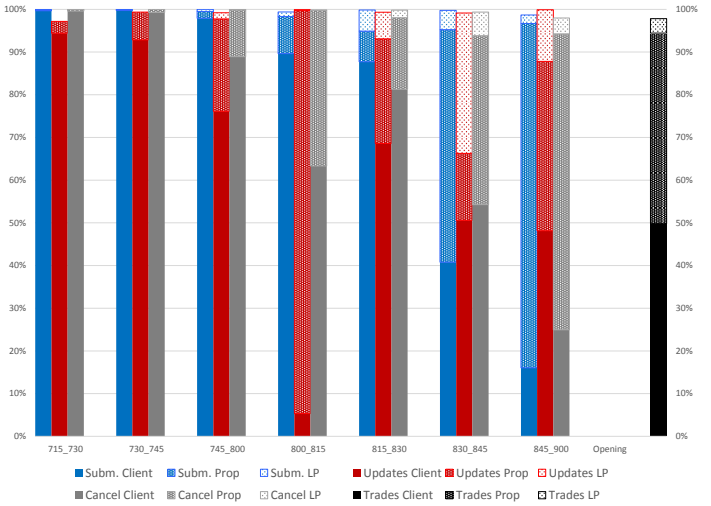
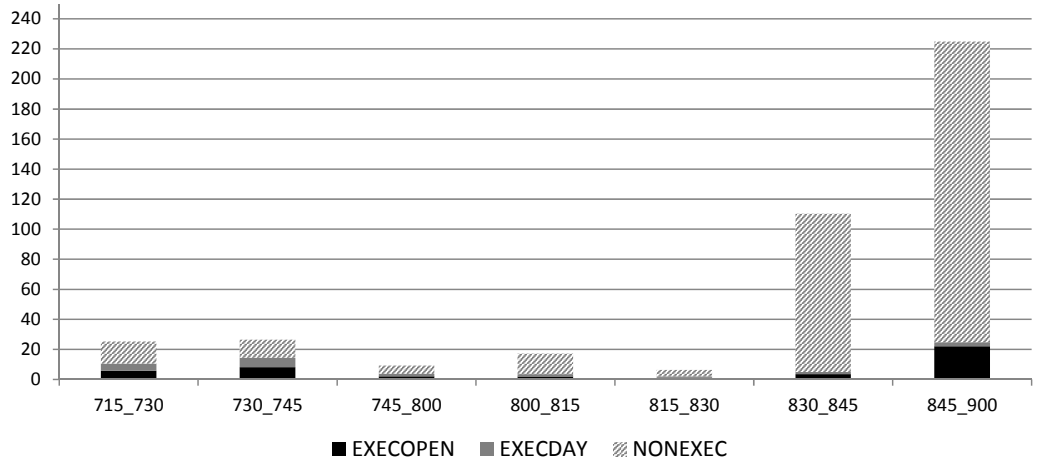


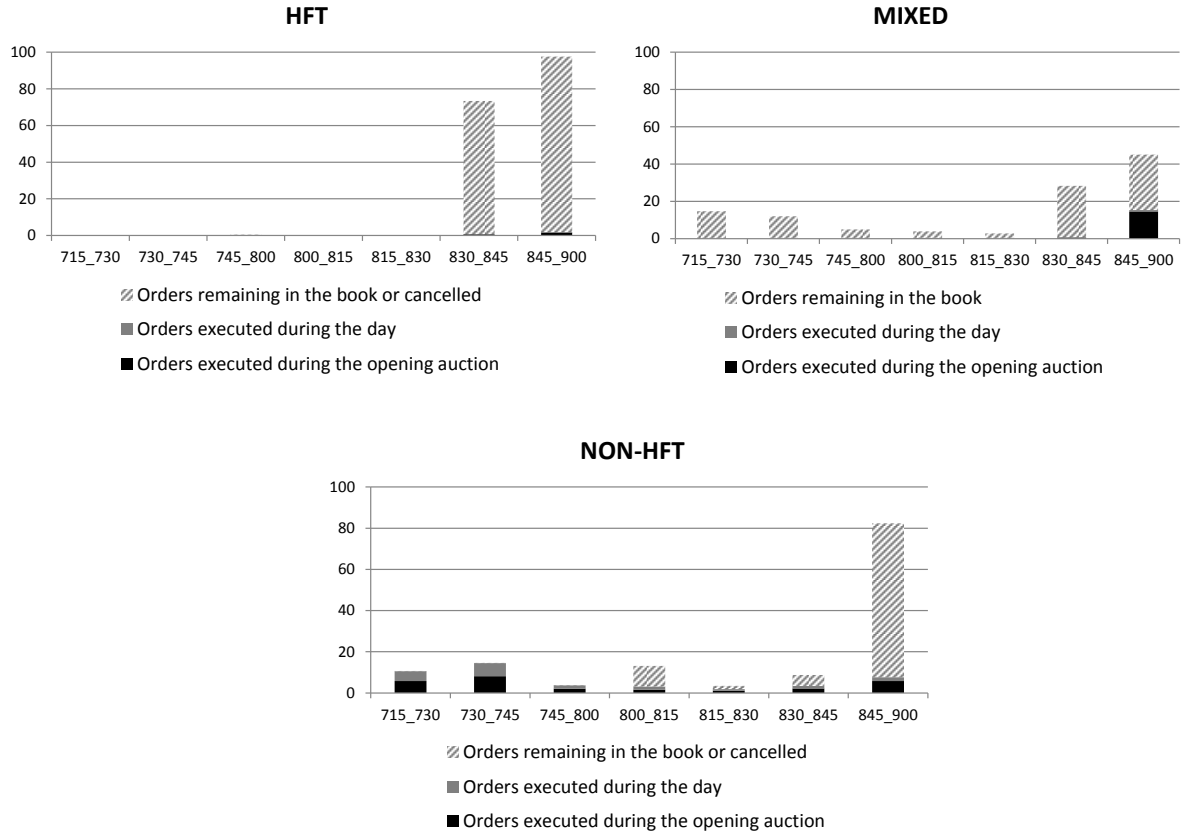
Figure 3: **Final execution status of pre-opening orders**

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

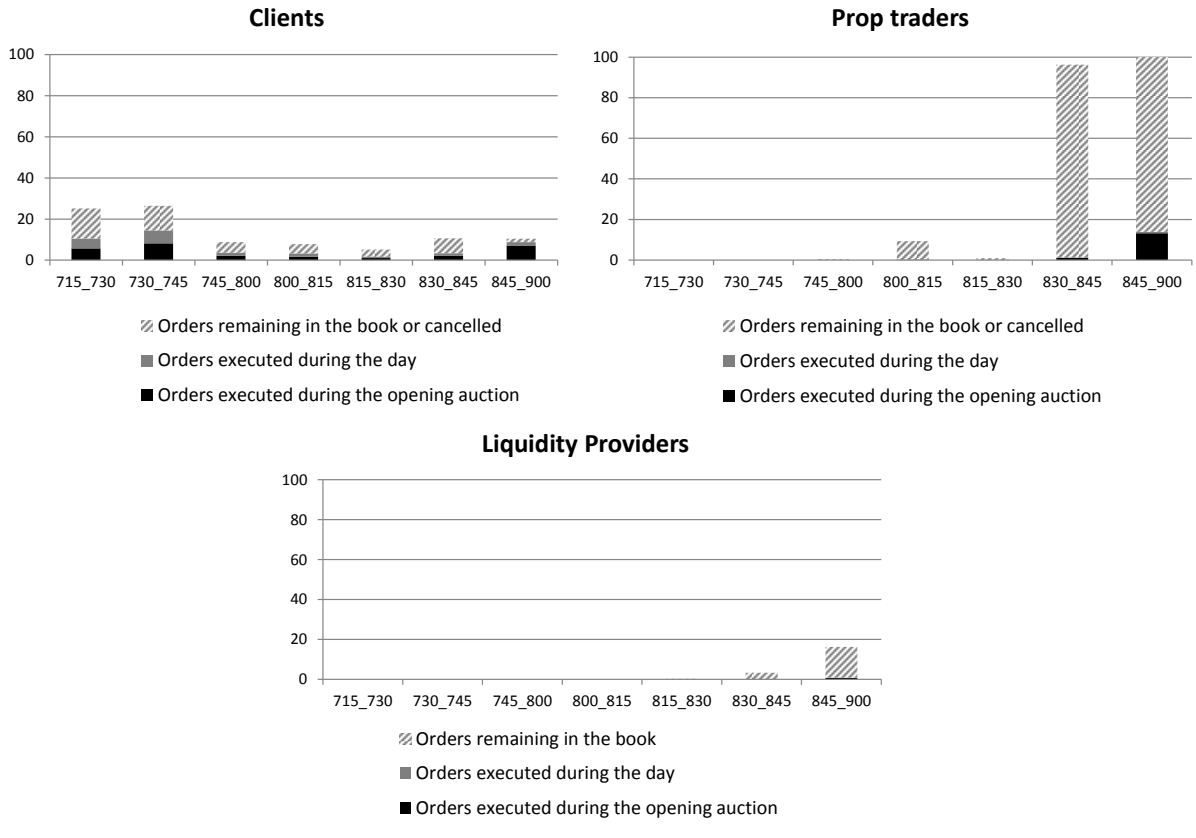
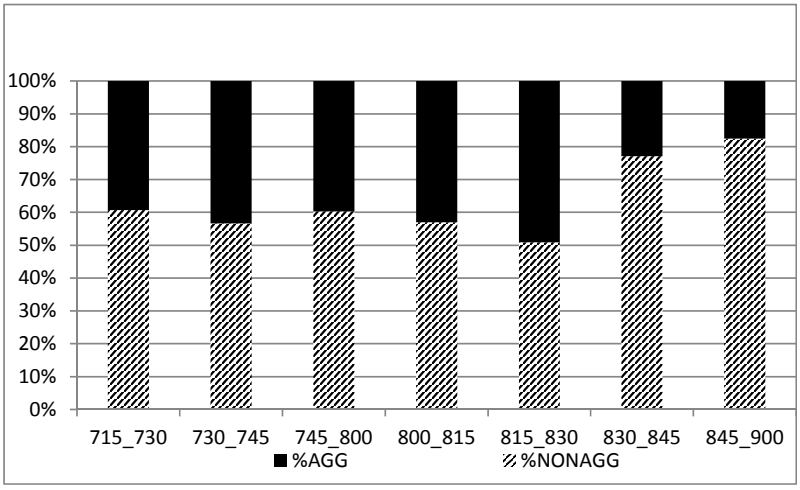
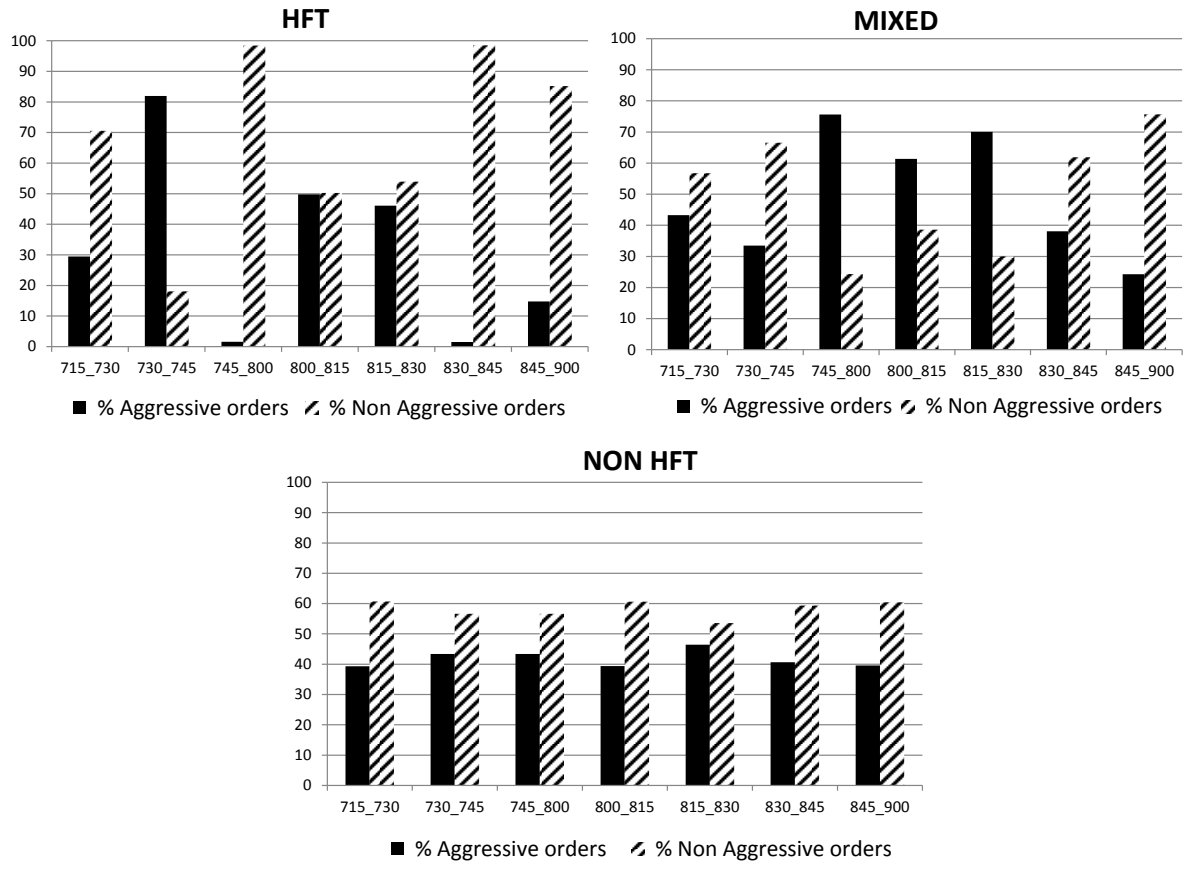


Figure 4: **Characteristics of new pre-opening orders by 15-minute interval**

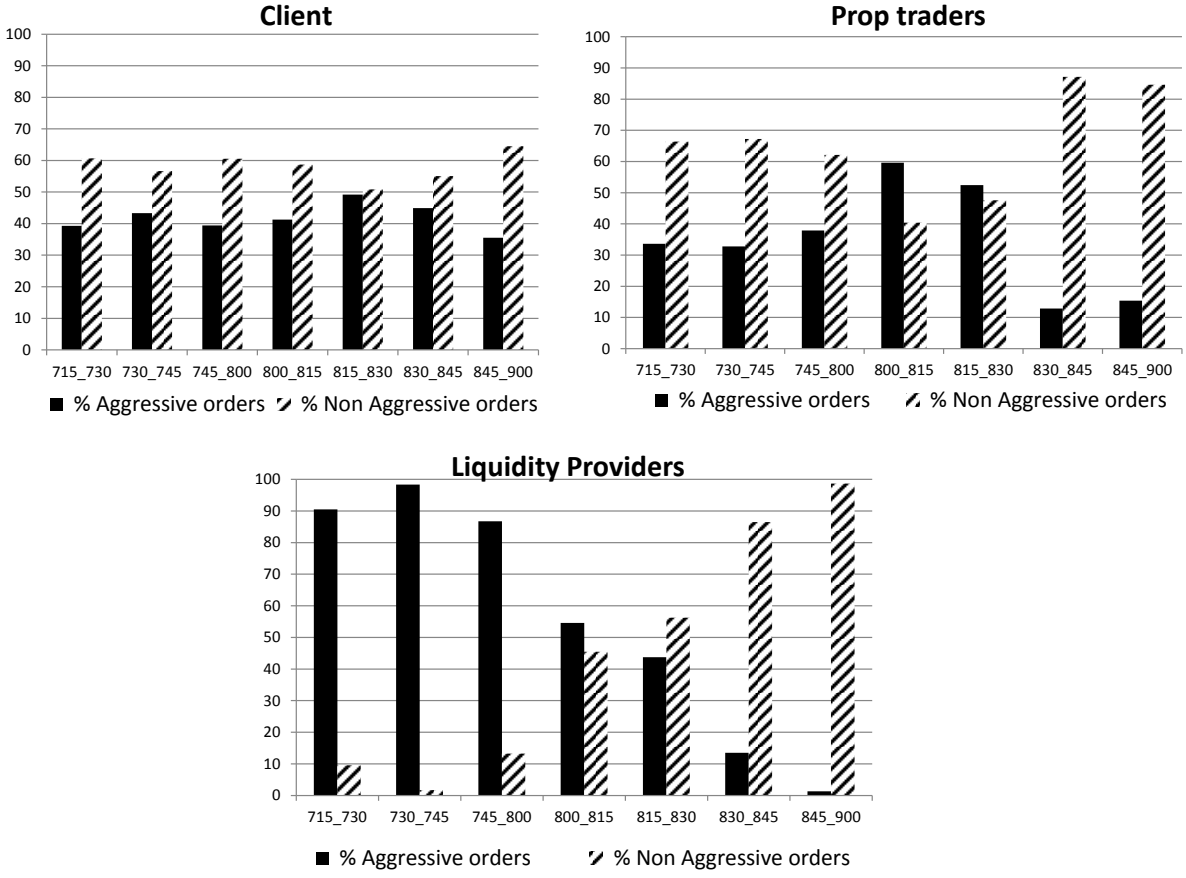
Figure 4a splits pre-opening new orders into aggressive versus non-aggressive orders. Aggressive orders (in plain black) consist of market or market-to-limit orders. Non-aggressive orders (hatched in black) consist of all the remaining types of orders (e.g., limit orders,...). Figure 4b decomposes the 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 $\tau$, and there exists a tentative clearing price, $TOP^\tau$. Squares correspond to estimates when there is no cross at time $\tau$ and pre-opening returns are computed using a tentative midquote, $TMQ^\tau$, that is, an average price between the best ask and the best bid quotes if the book is not empty, where $\tau$ =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 App.1 in the Online Appendix.

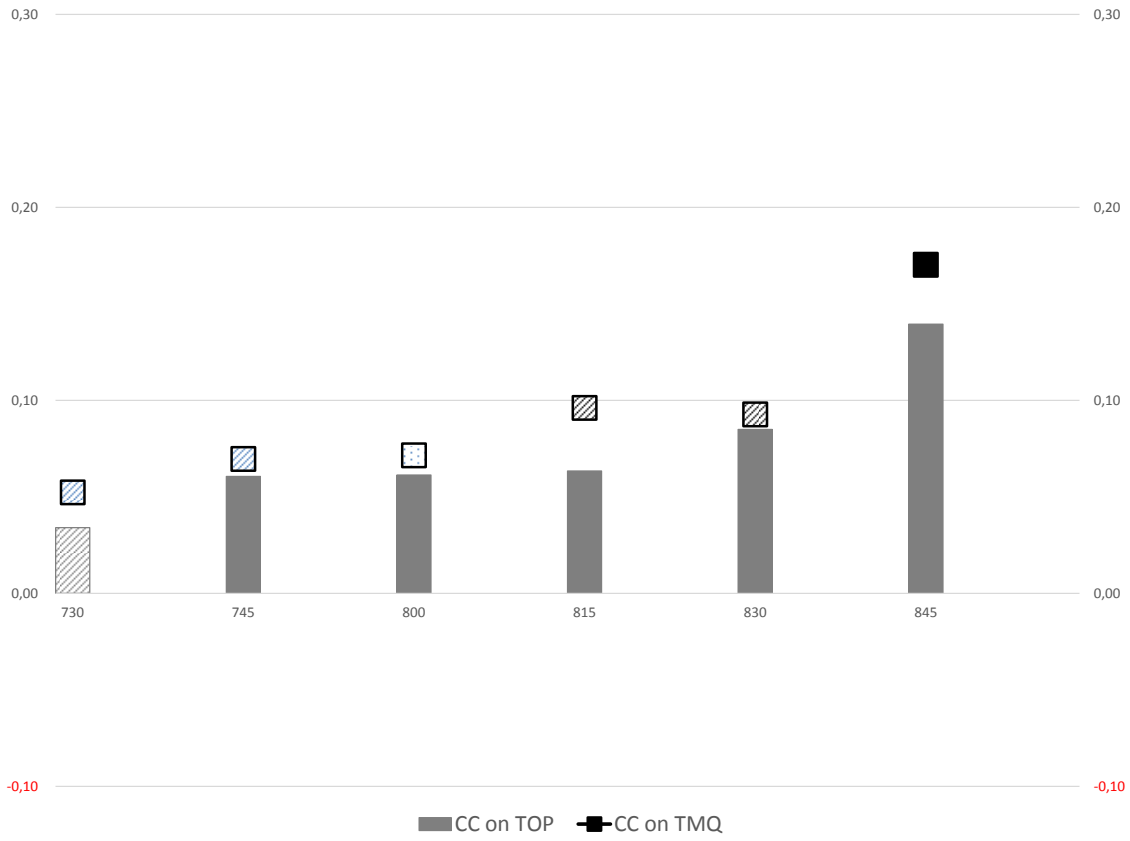


Figure 6: **Reversal around the opening on Euronext, BATS and Chi-X**

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 platform $S$ 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 $\tau$: $r_{i,t}^{O,9:15^S} = \beta_0^{S,\tau} + b_1^{S,\tau} r_{i,t}^{CP\text{-}\tau} + \varepsilon_{i,t}$, where $r^{O,9:15^S}$ is the return from the opening price to the midquote at 9:15am observed on platform $S$. Bars correspond to estimates of the regression when the pre-opening price is the tentative opening price, $TOP^\tau$, that is, when supply and demand function cumulated during the interval ending at time $\tau$ cross. Colors correspond the trading platform: 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, $TMQ^\tau$, that is, when there is no cross at time $\tau$ for $\tau$ =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 App.2 in the Online Appendix.

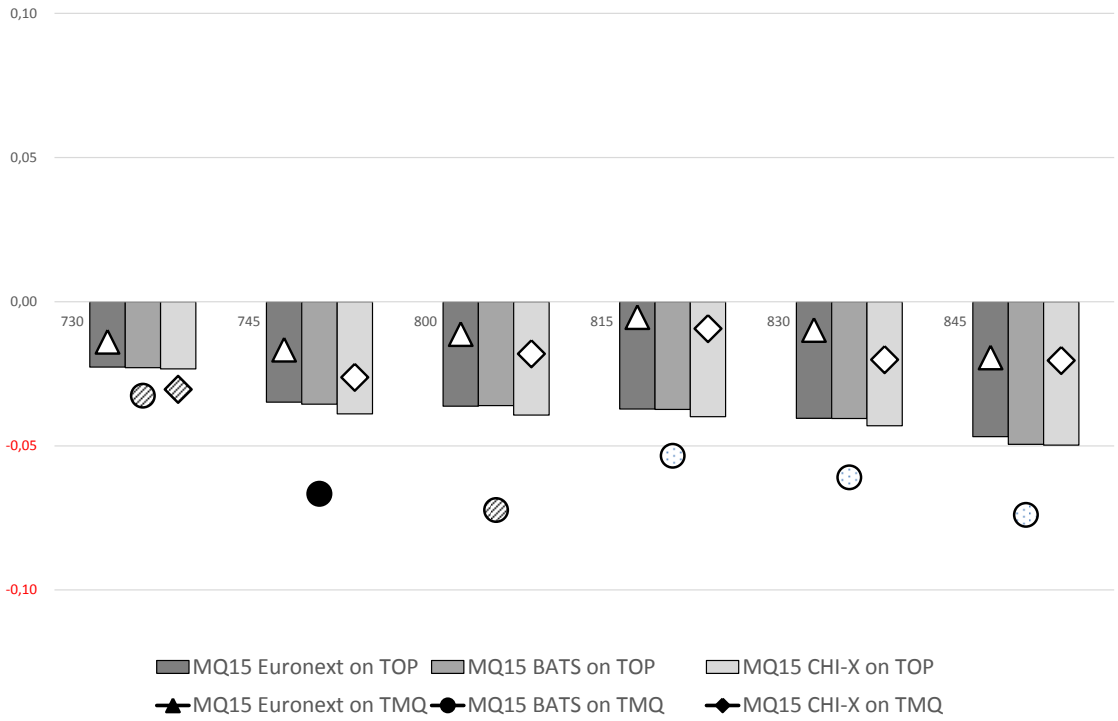


Figure 7: **Tentative volumes and daily trading activity in Euronext, BATS and Chi-X**

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 $\tau$, where $\tau$ =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 platform $S$ expressed in million €. The independent variable, $TOV^{\tau}$, corresponds to the tentative volume expressed in million €and computed at time $\tau$. 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 App.3 in the Online Appendix.

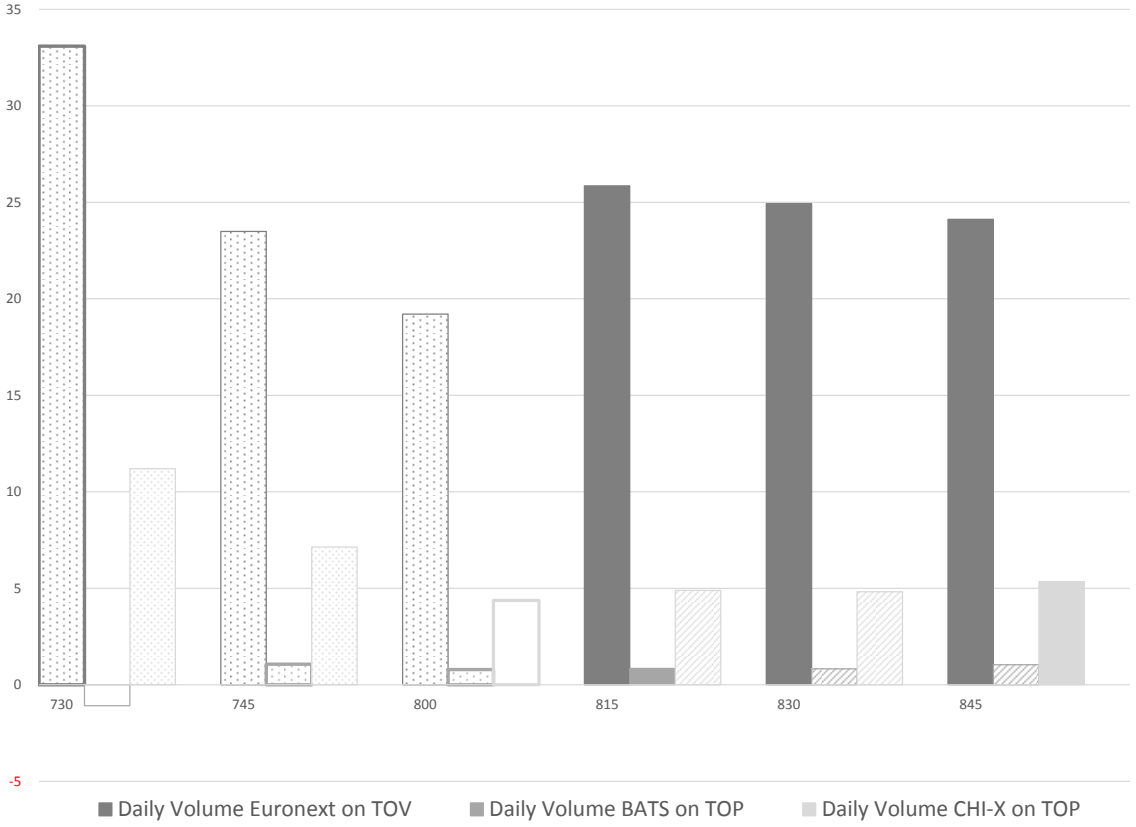


Figure 8: **Tentative volumes and relative spreads in Euronext, BATS and Chi-X**

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 $\tau$, where $\tau$ =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 platform $S$. The independent variables correspond to the log of the tentative pre-opening volume at time $\tau$ 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 $\tau$. 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 $\tau$. 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 Table App.4 in the Online Appendix.

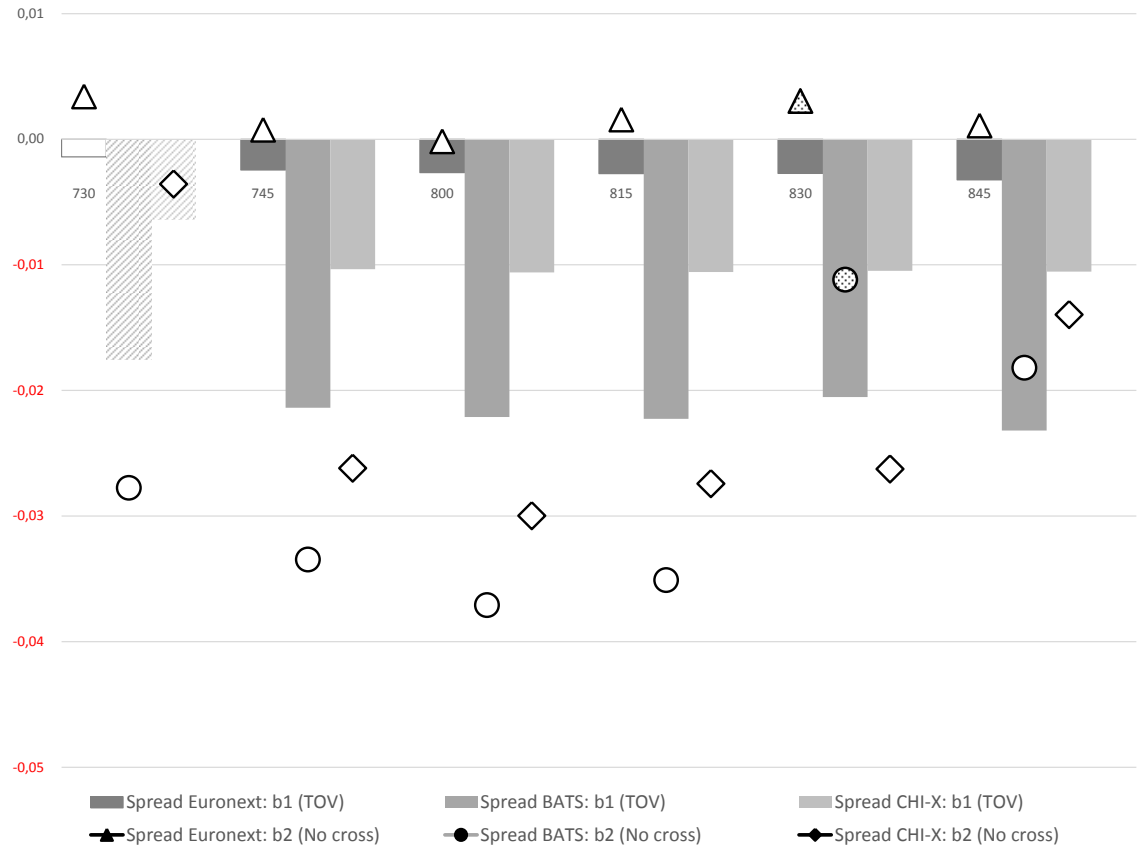


Table 1: **Summary statistics on the stock sample**

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 A(*Index*) represents stocks that belong to the CAC40 or to the CACNext20 index. Panel B (*Non Index*) represents the other non-index stocks which are mainly small capitalization. Panel A 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 $t$. $\sigma_{r^{CC}}$ is the standard deviation of daily close-to-close returns. $HILO_t$ is the daily price range defined as $HILO_t = \frac{\left(\ln\left(\max_{i_t}\left(P_{i_t}\right)\right)-\ln\left(\min_{i_t}\left(P_{i_t}\right)\right)\right)^2}{4\times\ln(2)} \times 100$, where $P_{i_t}$ is the price of transaction $i_t$ executed on day $t$. The number of trading days with at least one trade 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 A: 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 $r^{CC}$ | 0.1% | 0.1% | 0.0% | 0.3% | 50 |
| $\sigma_{r^{CC}}$ | 1.6% | 0.5% | 1.0% | 3.2% | 50 |
| HILO | 0.023 | 0.014 | 0.01 | 0.081 | 50 |
| Nb trading days in Euronext | 415 | 0.904 | 412 | 416 | 50 |
| Nb trading days in BATS | 411 | 0.904 | 408 | 412 | 50 |
| Nb trading days in Chi-X | 411 | 0.904 | 408 | 412 | 50 |
| **Panel B: Non-index stocks** | | | | | |
| Market Capitalization (in mio €) | 2,230 | 1,561 | 358 | 6,298 | 49 |
| Close-to-close return $r^{CC}$ | 0.1% | 0.1% | -0.3% | 0.2% | 49 |
| $\sigma_{r^{CC}}$ | 1.7% | 0.4% | 1.1% | 2.8% | 49 |
| HILO | 0.024 | 0.012 | 0.009 | 0.064 | 49 |
| Nb trading days in Euronext | 411 | 24.31 | 245 | 416 | 49 |
| Nb trading days in BATS | 398 | 55.07 | 39 | 412 | 49 |
| Nb trading days in Chi-X | 404 | 43.00 | 110 | 412 | 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 platform $S$ 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 A: CAC40 or NextCAC20 stocks** | | | | | | | | | |
| # trades per day | 5,369 | 4,086 | 20,764 | 706 | 732 | 20,764 | 3,485 | 3,086 | 20,764 |
| Volume (mio €) | 44.07 | 49.07 | 20,764 | 2.748 | 3.651 | 20,764 | 14.586 | 16.525 | 20,764 |
| Market share | 72.5% | 7.4% | 20,764 | 4.1% | 2.2% | 20,764 | 23.4% | 6.4% | 20,764 |
| Trade size (€) | 7,078 | 3,082 | 20,764 | 3,946 | 2,171 | 20,764 | 4,075 | 1,945 | 20,764 |
| Price (€) | 47.19 | 42.18 | 20,764 | 46.66 | 41.16 | 20,263 | 46.97 | 41.65 | 20,490 |
| Relative Spread (in bp) | 6.8 | 2.6 | 20,764 | 19.2 | 15.7 | 20,564 | 7.7 | 4.6 | 20,539 |
| Depth in € | 37,661 | 24,758 | 20,764 | 10,767 | 9,166 | 20,564 | 13,942 | 11,898 | 20,539 |
| **Panel B: Non-index stocks** | | | | | | | | | |
| # trades per day | 1,008 | 866 | 20,147 | 97 | 133 | 20,147 | 474 | 524 | 20,147 |
| Volume (mio €) | 3.84 | 4.98 | 20,147 | 0.20 | 0.33 | 20,147 | 1.06 | 1.46 | 20,147 |
| Market share | 78.2% | 10.2% | 20,147 | 3.60% | 3.1% | 20,147 | 18.20% | 9.0% | 20,147 |
| Trade size (€) | 3,419 | 1,730 | 20,147 | 2,173 | 2,245 | 20,147 | 2,259 | 1,889 | 20,147 |
| Price (€) | 48.73 | 52.10 | 20,147 | 45.98 | 46.309 | 14,154 | 46.193 | 47.412 | 16,559 |
| Relative Spread (in bp) | 18.1 | 10.6 | 20,147 | 75.1 | 95.4 | 19,785 | 41.6 | 63.7 | 19,868 |
| Depth in € | 12,597 | 14,568 | 20,147 | 6,447 | 4,030 | 19,785 | 5,377 | 3,502 | 19,868 |

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. #trades is the number of trades resulting from the opening call auction(flagged with a special variable on our dataset). Volume in €is the volume cleared at the opening call auction. 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. Euronext opening price is the clearing price resulting from the Euronext 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. 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 A: CAC40 or NextCAC20 stocks** | | | | |
| $V_{open}$ in # trades | 73 | (1.6%) | 68 | 20,764 |
| $V_{open}$ in $1,000$ € | 636.72 | (1.3%) | 1,085.48 | 20,764 |
| Correlation ($V_{Open}$, $V^E_{day}$) | 0.479*** | | 0.122 | 20,764 |
| Correlation ($V_{Open}$, $V^E_{day^E\_w/o\_open}$) | 0.477*** | | 0.126 | 20,746 |
| Correlation ($V_{Open}$, $V^B_{day}$) | 0.302*** | | 0.141 | 20,764 |
| Correlation ($V_{Open}$, $V^C_{day}$) | 0.405*** | | 0.115 | 20,764 |
| Euronext Opening price | 47.19 | | 42.22 | 20,764 |
| Close-to-open return $r^{CO}$ | 0.033% | (0.33%) | 0.80% | 20,764 |
| Correlation ($r^{CC}, r^{CO}$) | 0.404 | | 0.083 | 20,764 |
| **Panel B: Non index stocks** | | | | |
| $V_{open}$ in # trades | 18 | (2.5%) | 18 | 20,147 |
| $V_{open}$ in $1,000$ €) | 50.91 | (1.8%) | 113.38 | 20,147 |
| Correlation ($V_{Open}$, $V^E_{day}$) | 0.455*** | | 0.169 | 20,147 |
| Correlation ($V_{Open}$, $V^E_{day^E\_w/o\_open}$) | 0.457*** | | 0.164 | 20,147 |
| Correlation ($V_{Open}$, $V^B_{day}$) | 0.287*** | | 0.151 | 20,147 |
| Correlation ($V_{Open}$, $V^C_{day}$) | 0.380*** | | 0.149 | 20,147 |
| Euronext Opening price | 48.73 | | 52.08 | 20,147 |
| Close-to-open return $r^{CO}$ | 0.043% | (0.43%) | 0.78% | 20,146 |
| Correlation ($r^{CC}, r^{CO}$) | 0.365 | | 0.096 | 20,146 |

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), MIXED financial institutions which trade at high- or low-frequency depending on their activities, and slow traders (NON-HFT). 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 | MIXED | NON HFT | SUM |
|---|---|---|---|---|
| **Panel *Index*: CAC40 or Next CAC 20 stocks** | | | | |
| Clients | 0.16% | 13.74% | 30.30% | 44.20% |
| Prop traders | 5.05% | 36.54% | 7.49% | 49.08% |
| Liquidity providers | 0.04% | 2.28% | 0.31% | 2.63% |
| Retail traders | 0.00% | 0.00% | 0.09% | 0.09% |
| Others | 0.00% | 3.84% | 0.16% | 4.00% |
| **SUM** | 5.25% | 56.40% | 38.35% | 100% |
| **Panel *Non Index*: Non index stocks** | | | | |
| Clients | 0.11% | 10.44% | 45.03% | 55.58% |
| Prop traders | 5.95% | 27.91% | 6.20% | 40.06% |
| Liquidity providers | 0.00% | 0.20% | 3.93% | 4.13% |
| Retail traders | 0.00% | 0.00% | 0.04% | 0.04% |
| Others | 0.00% | 0.04% | 0.15% | 0.19% |
| **SUM** | 6.06% | 38.59% | 55.35% | 100% |

**(b) Euronext continuous trading session**

| Type | HFT | MIXED | NON HFT | SUM |
|---|---|---|---|---|
| **Panel *Index*: CAC40 or Next CAC 20 stocks** | | | | |
| Clients | 0.12% | 9.02% | 13.35% | 22.49% |
| Prop traders | 4.13% | 35.29% | 5.23% | 44.65% |
| Liquidity providers | 21.13% | 7.59% | 0.21% | 28.93% |
| Retail traders | 0.00% | 0% | 0.03% | 0.03% |
| Others | 0.00% | 3.87% | 0.03% | 3.90% |
| **SUM** | 25.38% | 55.77% | 18.85% | 100% |
| **Panel *Non Index*: Non index stocks** | | | | |
| Clients | 0.09% | 10.46% | 29.39% | 39.94% |
| Prop traders | 11.93% | 35.34% | 5.41% | 52.68% |
| Liquidity providers | 2.27% | 0.58% | 2.23% | 5.08% |
| Retail traders | 0.00% | 0.00% | 0.01% | 0.01% |
| Others | 0.00% | 2.22% | 0.07% | 2.29% |
| **SUM** | 14.29% | 48.60% | 37.11% | 100% |

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

**(c) Closing call session**

| Type | HFT | MIXED | NON HFT | SUM |
|---|---|---|---|---|
| **Panel *Index*: CAC40 or Next CAC 20 stocks** | | | | |
| Clients | 0.09% | 12.80% | 9.08% | 21.97% |
| Prop traders | 0.99% | 53.54% | 12.24% | 66.77% |
| Liquidity providers | 0.20% | 3.26% | 0.04% | 3.50% |
| Retail traders | 0.00% | 0.00% | 0.01% | 0.01% |
| Others | 0.00% | 7.12% | 0.63% | 7.75% |
| **SUM** | 1.28% | 76.72% | 22.00% | 100% |
| **Panel *Non Index*: Non index stocks** | | | | |
| Clients | 0.05% | 13.18% | 15.29% | 28.52% |
| Prop traders | 3.53% | 49.52% | 12.64% | 65.69% |
| Liquidity providers | 0.02% | 0.26% | 1.47% | 1.75% |
| Retail traders | 0.00% | 0.00% | 0.00% | 0.00% |
| Others | 0.00% | 3.17% | 0.87% | 4.04% |
| **SUM** | 3.60% | 66.13% | 30.27% | 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. $r^{CTOP_\tau}$ is the return from the close to the tentative opening price $TOP^\tau$ calculated when supply and demand functions cross. $r^{CTMQ_\tau}$ is the return from the close to the preopening midquote $TMQ^\tau$ at time $\tau$ 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.

| Variable | 7:30 | 7:45 | 8:00 | 8:15 | 8:30 | 8:45 |
|---|---|---|---|---|---|---|
| **When there is a crossing of supply and demand: tentative opening prices** | | | | | | |
| # crosses | 24,178 | 32,704 | 33,696 | 34,806 | 35,543 | 36,801 |
| $r^{CTOP_\tau}$ | -0.2% | -0.2% | -0.2% | -0.2% | -0.2% | -0.1% |
| Corr($r^{CTOP_\tau}$, $r^{CO}$) | 0.215 | 0.258 | 0.281 | 0.309 | 0.349 | 0.446 |
| Corr($r^{CTOP_\tau}$, $r^{CC}$) | 0.041 | 0.053 | 0.061 | 0.067 | 0.089 | 0.133 |
| Corr($r^{CTOP_\tau}$, $r^{O,MQ15^E}$) | -0.059 | -0.089 | -0.102 | -0.106 | -0.115 | -0.124 |
| Corr($r^{CTOP_\tau}$, $r^{O,MQ15^B}$) | -0.053 | -0.075 | -0.084 | -0.087 | -0.097 | -0.107 |
| Corr($r^{CTOP_\tau}$, $r^{O,MQ15^C}$) | -0.056 | -0.083 | -0.094 | -0.097 | -0.106 | -0.113 |
| **When there is no crossing of supply and demand: theoretical midquotes** | | | | | | |
| # no cross | 16,732 | 8,206 | 7,214 | 6,105 | 5,368 | 4,110 |
| # no cross s.t. a midquote exists | 14,554 | 6,546 | 5,651 | 4,678 | 3,999 | 2,927 |
| $r^{CTMQ_\tau}$ | 0.0% | 0.1% | 0.1% | 0.1% | 0.1% | 0.1% |
| Corr($r^{CTMQ_\tau}$, $r^{CO}$) | 0.183 | 0.183 | 0.182 | 0.218 | 0.231 | 0.299 |
| Corr($r^{CTMQ_\tau}$, $r^{CC}$) | 0.032 | 0.038 | 0.037 | 0.048 | 0.050 | 0.077 |
| Corr($r^{CTMQ_\tau}$, $r^{O,MQ15^E}$) | -0.013 | -0.016 | -0.005 | -0.001 | -0.006 | -0.024 |
| Corr($r^{CTMQ_\tau}$, $r^{O,MQ15^B}$) | -0.025 | -0.053 | -0.047 | -0.039 | -0.045 | -0.042 |
| Corr($r^{CTMQ_\tau}$, $r^{O,MQ15^C}$) | -0.030 | -0.034 | -0.025 | -0.019 | -0.027 | -0.040 |
| **Tentative opening volume** | | | | | | |
| Tentative volume (in $1,000$ €) when cross | 8.57 | 21.77 | 27.69 | 36.93 | 44.71 | 67.92 |
| Corr(Tentative volume including no cross, Daily volume) | 0.087 | 0.110 | 0.117 | 0.141 | 0.167 | 0.211 |
| Corr(Tentative volume including no cross, Daily volume Bats) | 0.024 | 0.055 | 0.052 | 0.065 | 0.079 | 0.112 |
| Corr(Tentative volume including no cross, Daily volume Chi-x) | 0.090 | 0.104 | 0.101 | 0.121 | 0.138 | 0.174 |

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 platform $S$, 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). 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. 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 |