

Internet Appendix for “Coming Early to the Party”

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This supplemental appendix presents further institutional details about the NYSE Euronext Paris market as well as additional analyses on the order flow and the behavior of the market participants.

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A. *The opening auction procedure and related institutional details*

The opening auction on NYSE Euronext Paris kicks off at 9.00 a.m. sharp during the period of our study.¹ During the accumulation period, orders not executed on the previous day populate the order book, and traders are also allowed to post new buy and sell orders. An order can be submitted with a validity of up to one year: these Good Till Cancelled orders remain active until the broker decides to cancel it or until the order is totally executed, up to one calendar year. This feature poses an additional issue in the rebuilding of the order book, i.e. keep track of the orders of the previous day, not or partially executed. These orders populate the order book at the beginning of the pre-opening phase, at 7.15 a.m., they do not usually cross and most of the time a midquote can be calculated, but not a theoretical opening price. The exchange disseminates the (predicted) opening price and the relative quantity available for trading every time there is a new order submission or cancellation that triggers a change in the auction price or quantity. The opening price is calculated by crossing the aggregate demand and supply curves, and selecting the prices that maximize the volume of shares traded at the call auction.

NYSE Euronext Paris disseminates two types of market data, throughout the NYSE Euronext Trading Platform. The first set of orders is called *Market by Orders*, and includes all buy and sell orders, the disclosed quantity and the displayed price. The second set of market data is called *Market by Limits*, and includes the ten best limits for buy and sell orders. For buy orders with prices higher than the theoretical price, and for sell order with prices lower than the theoretical price, the price limit displayed is the theoretical price, so that the most aggressive orders are not completely visible to subscribers.

Price priority is applied initially to market orders, buy orders with a limit price above the opening price and sell orders with a limit price below the open price - these orders are completely filled, including the hidden quantity. During both phases, the pre-opening phase and the main trading phase, traders are allowed to submit partially hidden (iceberg) orders. In fact, the theoretical opening price is calculated by also including the hidden quantity, but the hidden portion is not displayed to all market participants (orders can be partially but not completely hidden). In case of imbalances between demand and supply, orders with a limit price equal to the opening price are filled first, also following time priority. When an order is modified, it loses its time priority, except in cases where the volume of an existing order is decreased.²

During the main trading phase, the principle underlying order matching is, again, based on both price and time priority. Market participants can submit, modify and cancel different types of orders. Not all the order types contribute to the theoretical opening price, and

¹As of 19 August 2015, the opening time at NYSE Euronext Paris was randomized, but in the sample period considered, the auction occurred at exactly 9.00 a.m.

²For detailed rules of the opening call matching procedure and the order valid for the auction, please see the Euronext Trading Manual for the Universal Trading Platform, described in [Euronext \(2016\)](#)

some of them have a different behavior during the pre-opening phase and the main trading phase. In particular, the orders allowed are pure market and limit orders, stop-market, stop-limit and stop-on-quote orders, market-to-limit orders, and pegged orders. During the pre-opening phase, pegged orders are not allowed, market-to-limit orders are replaced by market-on-opening orders, and stop-orders are not taken into account in determining the opening price. To facilitate and incentivize HFT activity, NYSE Euronext Paris also offers co-location services and different connection speeds with the exchange's matching engine.

In order to enhance the liquidity of less liquid securities, NYSE Euronext Paris introduced a designated MM program in 1992, which was extended in 1994 to include more liquid stocks ([Venkataraman and Waisburd \(2007\)](#)). More recently, in 2011, NYSE Euronext Paris introduced the *Supplemental Liquidity Provision* (SLP) program dedicated only to the most liquid stocks, during the main trading phase.³ By signing an agreement, a trader (including a HFT) agrees to post two-way quotes that obey minimum capital and maximum spread restrictions for a given stock (see [Liquidity Providers and Market Makers on Euronext](#)). Any member of NYSE Euronext Paris is eligible to participate in the program, but only with their *own* resources, excluding all orders coming from customers. A new SLP program, which commenced in 2013, rewards members with a financial rebate, if they execute passive orders.

As for taxation, France introduced two new taxes in 2012: a financial transaction tax and a HFT tax.⁴ However, the latter tax is applicable only to HFTs registered in France, who are a minority of the HFTs operating on NYSE Euronext Paris. It is to be noted, that MMs are exempt from both these taxes. Therefore, when placing an order at NYSE Euronext Paris, market participants have to separate orders submitted as part of their MM activities from their proprietary activities. As a result of the financial transaction tax, the HFT tax, and MiFID II requirements, our data explicitly separates MM activities from OWN trading.

³Technical details and the list of the securities included can be found in [NYSE-Euronext \(2011\)](#).

⁴[Colliard and Hoffmann \(2016\)](#) provide a detailed analysis of the introduction of the financial transaction tax with BEDOFIH data.

B. Quoting and trading activity

The aim of this part is to verify if the quoting activity is stable through time and across stocks. A first aggregate comparison can be found in Figure IA.1 and Figure IA.2, which show the quoting and trading activity across dates and stocks, respectively, for the three trader categories (PURE-HFTs, MIXED-HFTs and NONHFTs). Figure IA.1 indicates that HFTs participate more selectively in the pre-opening phase, even if their trading activity is quite stable during the sample period. During the first 30-minutes of the main trading phase, HFTs' participation is very stable through time. The same picture across stocks is presented in Figure IA.2, which shows that the participation at the stock level can vary across trading phases. The figure indicates that, even though there is a low average level of participation in the pre-opening phase, the participation during the first 30-minutes of the main trading phase improves significantly. For instance, for the last stock in the column, the average quoting activity is less than 5% in the pre-opening phase, but the average quoting activity in the first 30-minutes of the main trading phase rises to 38%.

A formal assessment of HFT behavior is provided in Table IA.1. During the pre-opening phase, the median QAR for PURE-HFT-OWN is 25.17%, and ranges from 6.43% to 52.78%, indicating that HFTs participate intensively in the pre-opening phase, at least for some stocks, from their own account. This participation for the PURE-HFT-OWN category declines during the first 30-minutes of the main trading phase, given that HFTs switch most of their activity from their OWN account to the MM account. Similar conclusions can be drawn by looking at the distribution of trading activity, where the PURE-HFT-OWN group contributes to trading activity with a median TAR of 6.47% during the opening auction, ranging from zero to 44.25%, across stocks.

The proportions of quoting and trading activity, by account, are very different in the two phases analyzed. There is still good quoting participation by HFTs' proprietary trading in their OWN account in the pre-opening phase. In the first 30 minutes, almost all the activity switches to MM accounts, for both PURE-HFT and MIXED-HFT traders. The account identification provided by NYSE Euronext Paris reveals that, across stocks, there is a pronounced heterogeneity in the trader behavior. It is clear that traders from both the HFT and MIXED categories with the MM flag regularly post and trade orders only in the main trading phase, given the prevailing set of rules that does not offer them any advantage in terms of fee reduction in the pre-opening phase. A graphical representation of this behavior across stocks is provided in Figure IA.3.

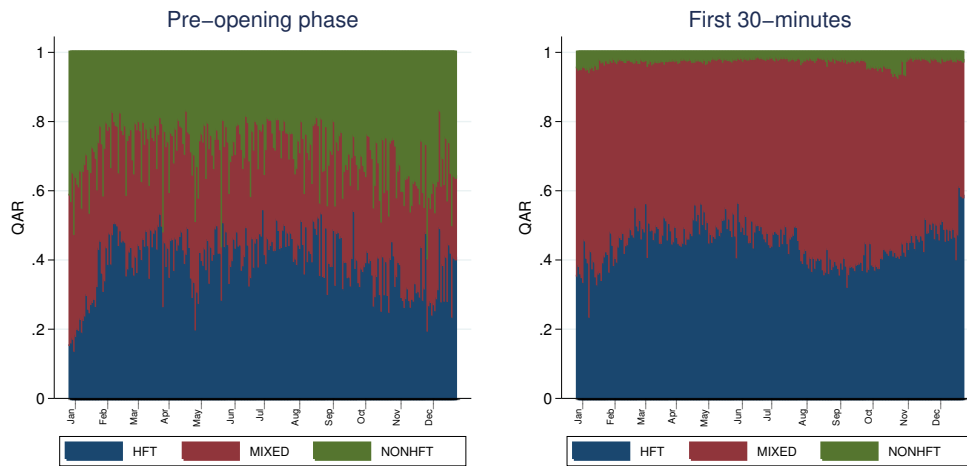
Table IA.1: Quoting and Trading activity distribution across stocks for HFTs and MIXED

This table shows the distribution of the quoting activity (Panel A) and trading activity (Panel B) across stocks for PURE-HFTs and MIXED-HFTs across four account types (CLIENT, OWN, MM, RLP), for the pre-opening phase, opening auction and the first 30-minutes of the main trading phase. The sample is composed of 37 stocks traded on NYSE Euronext Paris that belong to the CAC40 index, for the year 2013. Order flow data, with trader group and account flags are from BEDOFIH.

Panel A: quoting activity distribution for PURE-HFT and MIXED-HFT by account								
	Pre-opening period				First 30-minutes of continuous period			
	Median	SD	P5	P95	Median	SD	P5	P95
PURE-HFT CLIENT	0.13%	0.27%	0.00%	0.66%	0.04%	0.18%	0.01%	0.23%
PURE-HFT-OWN	41.05%	19.22%	0.73%	64.90%	3.92%	4.50%	0.39%	14.18%
PURE-HFT-RLP	0.00%	0.00%	0.00%	0.00%	10.83%	5.89%	4.27%	23.34%
PURE-HFT-MM	0.00%	0.98%	0.00%	0.30%	28.70%	7.62%	17.04%	41.52%
MIXED-HFT-CLIENT	6.39%	5.71%	2.43%	19.48%	2.12%	3.93%	0.56%	12.54%
MIXED-HFT-OWN	17.07%	9.26%	6.92%	36.67%	11.86%	7.25%	5.80%	29.06%
MIXED-HFT- RLP	0.00%	0.01%	0.00%	0.00%	4.95%	2.08%	2.78%	9.39%
MIXED-HFT- MM	0.56%	3.58%	0.00%	9.25%	27.41%	10.81%	7.57%	42.69%
MIXED-HFT-PARENT	1.47%	1.71%	0.29%	5.21%	3.84%	1.77%	1.29%	6.99%

Panel B: trading activity distribution for PURE-HFT and MIXED-HFT by account								
	Opening auction				First 30-minutes of continuous period			
	Median	SD	P5	P95	Median	SD	P5	P95
PURE-HFT CLIENT	0	1.47%	0	1.35%	0	0.88%	0	1.55%
PURE-HFT-OWN	3.16%	5.48%	0.06%	15.90%	1.30%	2.06%	0	5.76%
PURE-HFT-RLP	0	0	0	0	0	0.06%	0	0
PURE-HFT-MM	0	0.42%	0	0.83%	20.20%	7.25%	9.69%	33.47%
MIXED-HFT-CLIENT	13.14%	10.87%	0.60%	34.83%	7.74%	6.17%	0.96%	20.40%
MIXED-HFT-OWN	34.68%	13.04%	14.48%	57.60%	34.41%	10.17%	19.44%	52.61%
MIXED-HFT- RLP	0	0	0	0	0	0.07%	0	0
MIXED-HFT- MM	2.00%	3.25%	0	8.66%	7.37%	4.45%	1.29%	15.51%
MIXED-HFT-PARENT	5.21%	5.73%	0	17.67%	6.34%	3.72%	1.49%	13.75%

Panel A: Quoting Activity Ratio (QAR) by date



Panel B: Trading Activity Ratio (TAR) by date

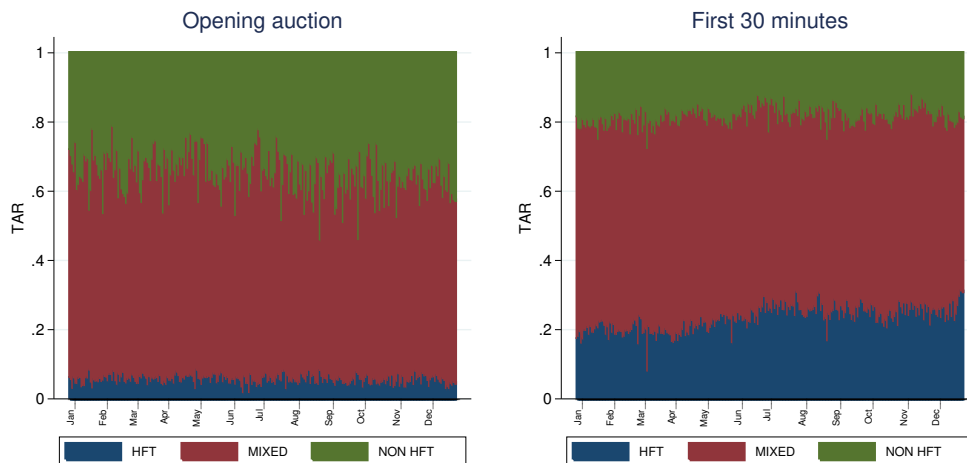
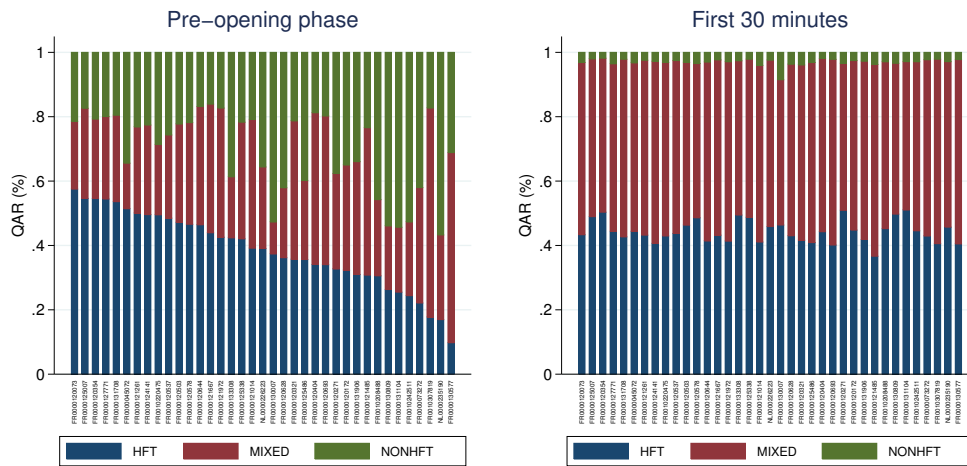


Figure IA.1: Quoting and Trading activity ratio for each date

This figure shows the total quoting (Panel A) and trading activity (Panel B), for each date, three trader groups (PURE-HFT, MIXED-HFT and NON-HFT) during the pre-opening phase, the opening auction, and the first 30 minutes of the main trading phase. The sample is composed of 37 stocks traded on NYSE Euronext Paris that belong to the CAC40 index, for the year 2013. Order flow data, with trader group and account flags are from BEDOFIH.

Panel A: Quoting Activity Ratio (QAR) by stock



Panel B: Trading Activity Ratio (TAR) by stock

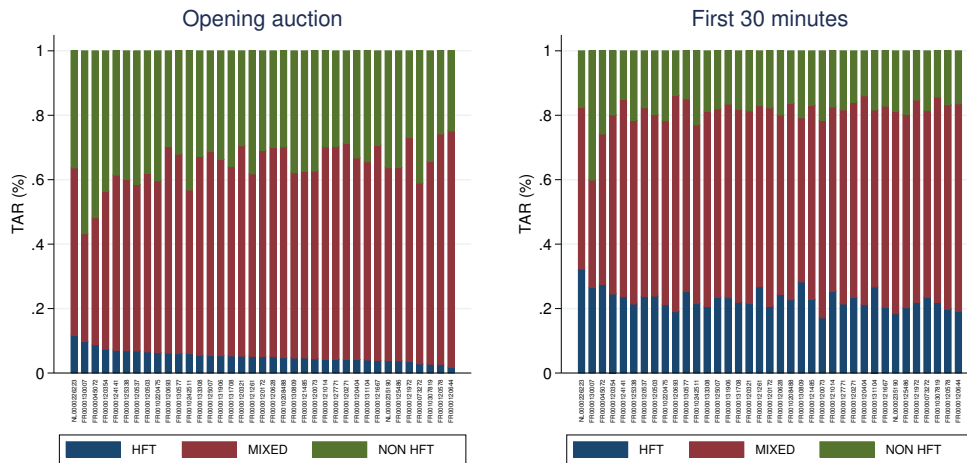
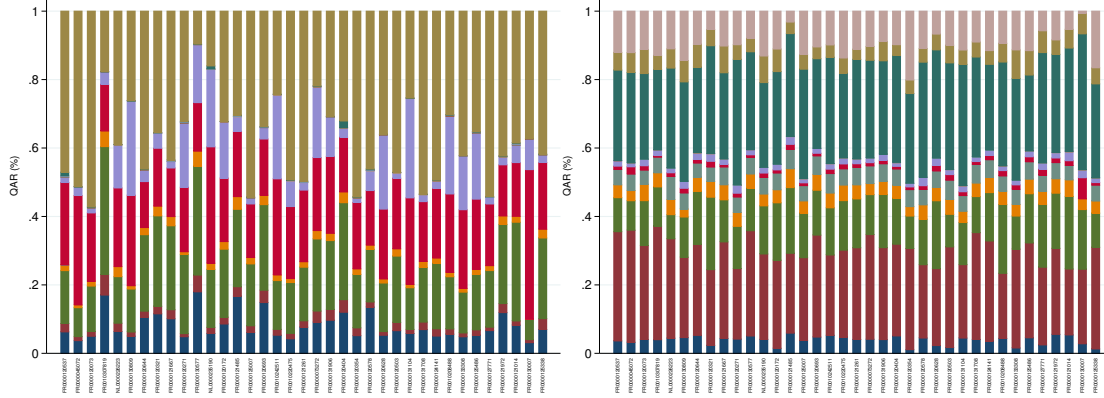


Figure IA.2: Quoting and Trading activity ratio for each stock

This figure shows the total quoting (Panel A) and trading activity (Panel B), for each stock, three trader groups (PURE-HFT, MIXED-HFT and NON-HFT) during the pre-opening phase, the opening auction, and the first 30-minutes of the main trading phase. The sample is composed of 37 stocks traded on NYSE Euronext Paris that belong to the CAC40 index, for the year 2013. Order flow data, with trader group and account flags are from BEDOFIH.

Panel A: Quoting Activity Ratio (QAR) by stock and account
Pre-opening phase First 30 minutes



Panel B: Trading Activity Ratio (TAR) by stock and account
Opening Auction First 30 minutes

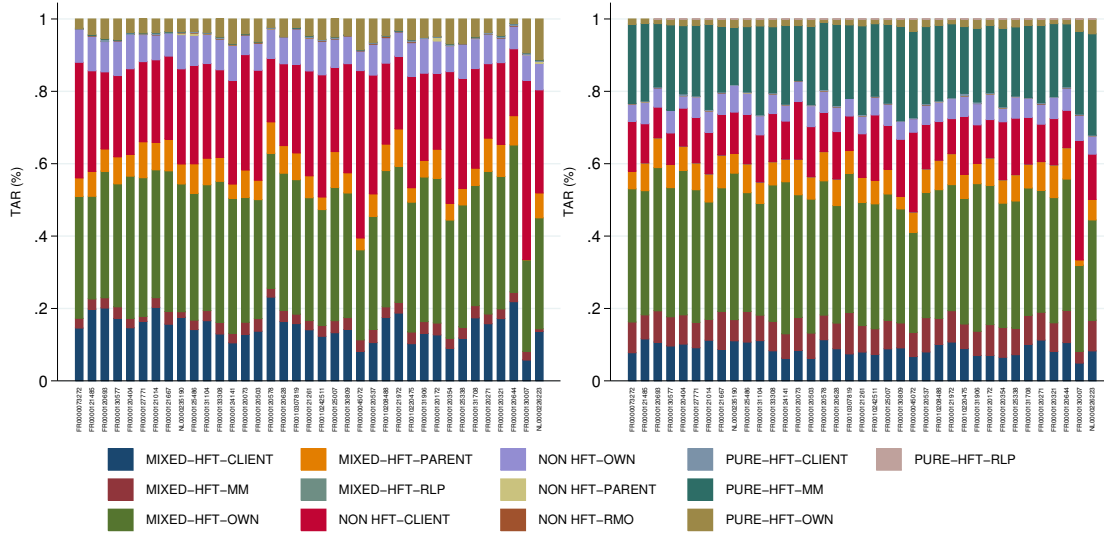


Figure IA.3: Quoting and Trading activity ratio by stock and accounts

This figure shows the average quoting (Panel A) and trading (Panel B) activity ratios for each stock in our sample, for three trader groups (PURE-HFT, MIXED-HFT and NON-HFT), six account types (CLIENT, OWN, RLP, RMO, MM, PARENT), for the pre-opening phase, opening auction and the first 30-minutes of main trading phase. The sample is composed of 37 stocks traded on NYSE Euronext Paris that belong to the CAC40 index, for the year 2013. Order flow data, with trader group and account flags are from BEDOFIH.

C. Participation statistics for the pre-opening phase and opening auction

Table IA.2 provides descriptive statistics for the participation of the various groups of traders in the pre-opening phase and opening auction. Most of the traders participate during the pre-opening with their OWN account, in all 37 stocks. The median number of days ranges from 237 to 248. On average, 98 trades for every stock-day are executed on behalf of their clients from the NON-HFT group. In our sample, MIXED-HFT-OWN traders represent the second largest trader group in the auction. Despite the intense quoting activity of PURE-HFT-OWN traders, the quantity traded is quite small, compared to the other categories.

Table IA.2: Participation

This table shows the summary statistics for the pre-opening and auction participation by trader/account type. Data are presented for three trader groups (PURE-HFT, MIXED-HFT, NON-HFT) and six account types. The orders/account can be flagged as own proprietary trading orders (OWN), orders on behalf of the client (CLIENT), submitted due to their market making affiliation (MM), parent company order (PARENT) or related to retail market organization (RMO) and retail liquidity provision (RLP) activities. The sample is composed of 37 stocks traded on NYSE Euronext Paris that belong to the CAC40 index, for the year 2013. Order flow data, with trader group and account flags are from BEDOFIH.

Panel C: traders' participation in the auction by account						
		Median # of stocks per day	Median # days per stock	Average # of shares traded	Average gross capital for the auction (euro)	Average # of trades
PURE-HFT	Client	4	29	6'610.39	46'495.10	3.8
	Own	36	244	5'004.88	47'906.19	7.4
	MM	35	27	412.51	14'894.41	1.7
MIXED-HFT	Client	36	245	10'251.64	284'998.70	19.1
	Own	37	248	28'176.47	653'902.17	46.7
	MM	29	164	2'655.93	66'631.77	4.8
	Parent	35	220	3'230.69	102'289.09	7.0
NON-HFT	Client	37	248	34'413.05	455'046.93	98.1
	Own	35	237	7'755.94	154'910.48	11.2
	RMO	5	27	664.39	6'131.44	1.9
	Parent	1	2	32'833.33	141'488.33	4.3

D. Speed of the traders

We aim to investigate whether HFTs *always* use their speed capability equally, regardless of the period of the day and the account they are trading for, especially when the speed is more important, i.e. just before the opening auction. In order to address the speed capacity usage by different trader groups and account types, we first estimate the median of the speed distribution per stock-day-trader-account to use as a benchmark. Speed is defined as the time elapsed between order entry/modification and modification/cancellation of the same order. We test whether the speed capacity usage is the same for different trader/account types, and for different time intervals, by running the following panel regression separately for the pre-opening and first 30-minutes of the continuous trading phases:

$$Speed_{i,j,k,l} = a_{0,l} + \sum a_{k,l} * I_k + e_{i,j,k,l} \quad (\text{IA.1})$$

where $Speed_{i,j,k,l}$ is our measure of median speed for stock i , day j , trader/account k for the period l . The periods considered are the last minute, the last 15 seconds, the last 5 seconds and the very last second of the pre-opening phase. I_k is a dummy variable that equals 1 for trader/account k . We use the NONHFT-CLIENT accounts as a base category. Table III of the paper presents the summary statistics of the speed distribution of the different trader groups and account types, where we find that the 5th percentile of speed is extremely high (the time elapsed is less than 5 milliseconds) even for NONHFT account types.

We investigate whether one group of traders is faster compared to the others, by regressing the median (stock-day) realized speed over a set of dummies that identify each group as described in Equation IA.1. We use, again as a base case, the NONHFT-CLIENT category. Table IA.3 shows that during the pre-opening phase and in all intervals considered, PURE-HFT-OWN traders are the fastest market participants (the lower the coefficient, the lower is the elapsed time and the higher is the speed). The MIXED-HFT traders are, in general, very close to the PURE-HFTs, due to the fact that the investment banks and the big brokers are using the same technology and comparable strategies. In the first 30 minutes, the field is more leveled and almost all the HFTs and the MIXED-HFTs use a comparable speed. The analysis suggests that HFTs engage in strategies that essentially require high speed. This is consistent with the notion that HFTs use their superior speed capability for risk management, when they act as MMs (as in Ait-Sahalia and Saglam (2014)).

Table IA.3: Speed of the Traders Regression

This table shows the regression coefficients of the speed capacity by three trader groups (PURE-HFT, MIXED-HFT, NON-HFT) and six account types (CLIENT, OWN, RLP, RMO, MM, PARENT) for different segments of the pre-opening phase and first 30-minutes of main trading phase. We refer to speed as the time elapsed between order entry/modification and modification/cancellation of the same order. We present the coefficients of the regressions described in Section D, by group, where ***, **, * correspond to 1%, 5%, and 10% significance levels. Statistics and regression estimates are presented for 37 stocks traded on NYSE Euronext Paris that belong to the CAC40 index, for the year 2013. Order flow data, with trader group and account flags are from BEDOFIH.

Speed regression by stock-date						
		Pre-Opening Phase				First 30 minutes
		Last minute	Last 15 seconds	Last 5 seconds	Last second	Median Speed
PURE-HFT	Client					671.5***
	MM					-180.6***
	Own	-21.13***	-4.003***	-0.596***	-0.244***	-173.9***
	RLP					-182.6***
MIXED-HFT	Client	-11.82***	-0.833**	0.657***	0.0751***	-158.3***
	MM	-17.89***	-1.791***	0.335***	0.0620***	-177.3***
	Own	-18.58***	-1.533***	0.563***	-0.0126	-176.8***
	Parent	1.877*	0.758**	1.482***		-169.4***
	RLP					-175.2***
NON HFT	Own	-19.15***	-2.704***	0.348***	0.0492*	-164.6***
	Parent					
	Client	base	base	base	base	base
	Constant	23.08***	4.686***	1.148***	0.475***	183.8***
	# obs	36,902	30,170	24,582	8,402	95,037
	Adj R ²	0.341	0.131	0.105	0.164	0.225
	Clustered St. Err	by stock	by stock	by stock	by stock	by stock
Test of equality of coefficients - Fstat (Pvalue)						
	$\beta_{PURE-HFT-OWN} = \beta_{MIXED-HFT-MM}$	107.09 (0.00)	641.5 (0.00)	344.8 (0.00)	720.5 (0.00)	5.29 (0.027)
	$\beta_{PURE-HFT-OWN} = \beta_{MIXED-HFT-OWN}$	63.51 (0.00)	778.3 (0.00)	758.4 (0.00)	356.2 (0.00)	3.52(0.068)
	$\beta_{MIXED-HFT-OWN} = \beta_{MIXED-HFT-MM}$	8.75 (0.01)	6.9 (0.01)	29.9 (0.00)	47.3 (0.00)	0.83 (0.3670)

E. Order submission in the last second of the pre-opening phase

Figure IA.4 and IA.5 show the total number of new orders and cancellations in the last second of the pre-opening phase, for the most relevant traders and for each stock. Each column represents the total number of new order (or cancellations) submitted during the ten-millisecond window interval. Both MIXED-HFT-OWNs and NON-HFT-OWNs submit a relevant number of new orders within the last 100 milliseconds of the pre-opening phase. However, almost all trader groups are able to submit and cancel orders few milliseconds before the opening auction. This opportunity can easily be exploited, since the auction time is fixed and every trader can measure the latency between their device and the exchange matching engine in normal times. The speed and the capacity (number of messages sent) can be fully exploited only in case of co-location of the servers, a typical setup for HFTs.

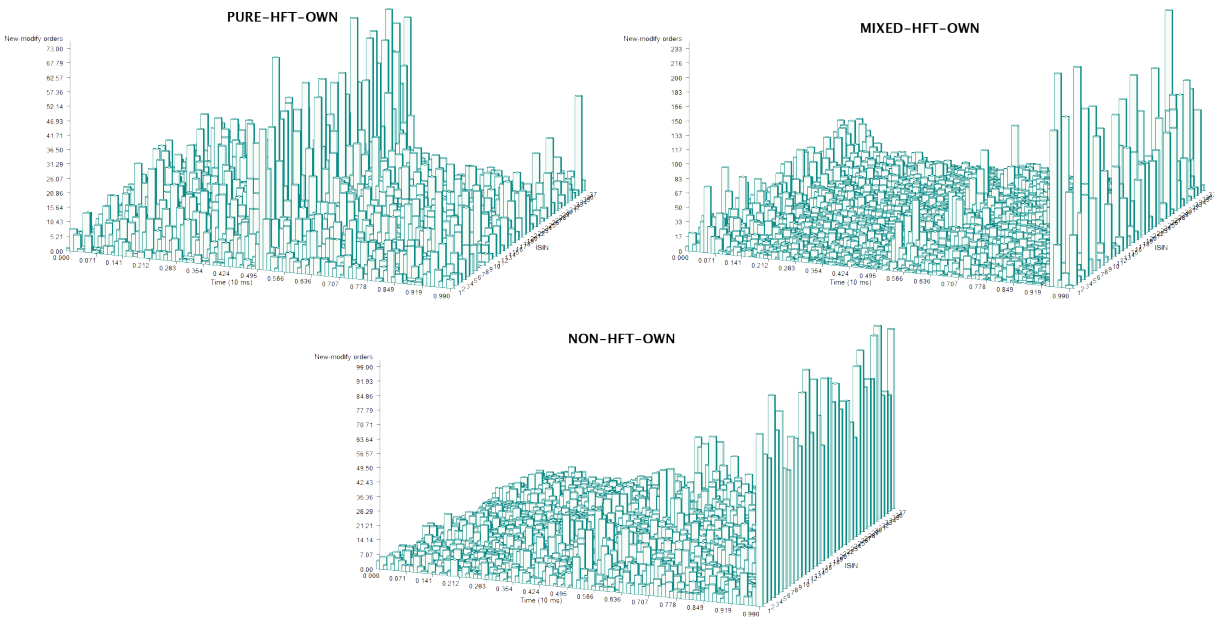


Figure IA.4: New Order and modification submission across stocks during the last second of the Pre-Opening Phase

This figure shows the total number of new order submissions for the most relevant trader/account categories. Each column represents the total number of new orders submitted during the last second, for each stock, summed across days. The sample is composed of 37 stocks traded on NYSE Euronext Paris that belong to the CAC40 index, for the year 2013. Order flow data, with trader group and account flags are from BEDOFIH.

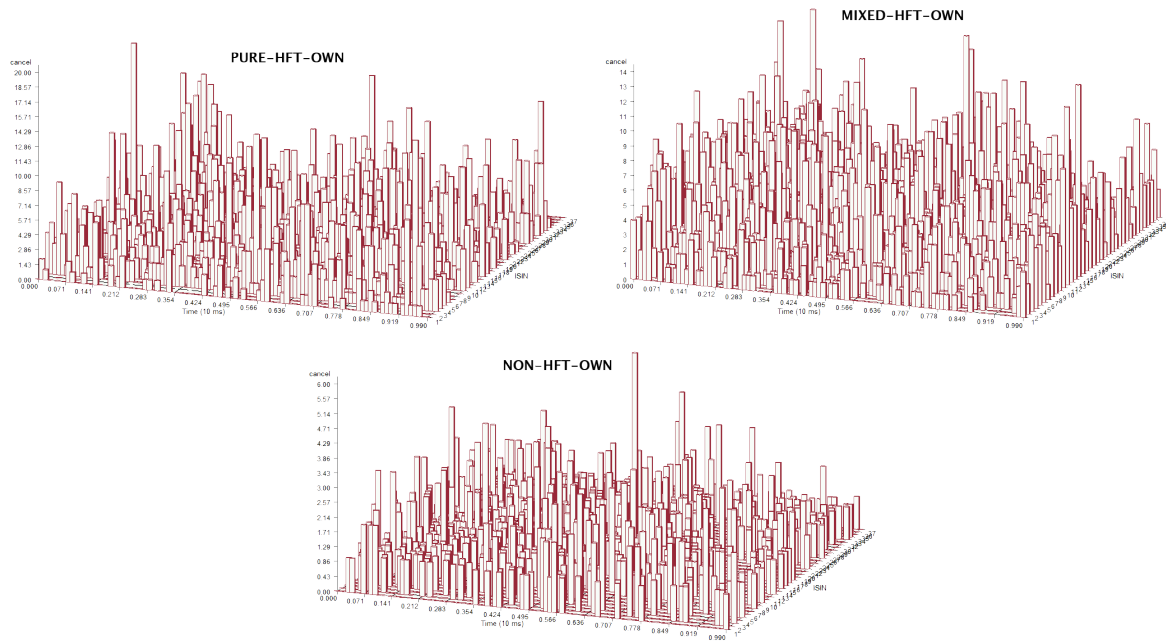


Figure IA.5: Cancellations across stocks during the last second of the Pre-Opening Phase

This figure shows the total number of cancellations for the most relevant trader/account categories. Each column represents the total number of cancellations submitted during the last second, for each stock, summed across days. The sample is composed of 37 stocks traded on NYSE Euronext Paris that belong to the CAC40 index, for the year 2013. Order flow data, with trader group and account flags are from BEDOFIH.

F. *Weighted Price Discovery order by order*

The contribution to price discovery, as described in the Section IV.C of the paper, is measured using the Weighted Price Discovery Contribution (WPDC). We define the WPDC order by order: this estimation helps us to exploit the overall contribution of each group of traders by different order type. We can also gain some insights about the different submission strategies that the traders follow during the pre-opening phase, using limit orders, limit orders with iceberg quantities, market orders or very aggressive orders.

The distinct feature of our measure of price discovery is that it sums up to -100%, in a way that a negative value reduces the deviation and moves the price close to the opening price. A positive WPDC is viewed as a deterioration of price discovery (the theoretical opening price is pushed away from the future opening price), while a negative WPDC represents an improvements in price discovery. Each panel of Table IA.4 and IA.5 represents the price discovery that occurs during the specific time period until the end of the pre-opening phase (Panel B of Table IA.4, the WPDC is calculated from 8.10 a.m. until the auction, thus excluding the period from 7.15 a.m. to 8.09 a.m.). The *Total* columns represent the total WPDC as reported in Table VII of the paper. In the top-left corner of the intermediate tables, the WPDC for each interval is reported. If the value is below -100%, it means that the price has moved away from the direction of the final auction price. The value of -48.77%, reported in Panel A of Table IA.5, indicates that 48.77% of the price discovery will occur in the last minute of the pre-opening phase.

The overall assessment of the total price discovery is provided in Panel A of Table IA.4. New limit orders and cancellations of market orders drive the price discovery process, while the submission of new market orders, especially from NON HFT-Client, deteriorate the WPDC. In general, the cancellation of limit orders deteriorate the price discovery, most likely because there is no intention to execute the order at the theoretical opening price. However, if the trader is not willing to participate at the auction, the cancellation of the order will occur before the very last moments of the pre-opening phase. In fact, Panel B and C of Table IA.5 show that the cancellation of both limit and market orders do provide price discovery, with the exception of MIXED-HFT-Client and NON HFT. Further, in the very last second and last 100 milliseconds, cancellation does not move the price significantly, which indicates that the orders accumulated are large enough to absorb the impact of a cancellation, making it difficult to manipulate the opening price.

The behavior of the PURE-HFT traders is mainly driven by the fact that most of them start submitting their orders after 8.30. The speed advantage is exploited in the last part of the pre-opening phase. During the last minute (Table IA.5, Panel A), the price discovery of PURE-HFT-OWN traders is provided by modification of existing limit orders, since the WPDC of new orders and deleted limit orders cancel out. In the last second and last 100 milliseconds, their intention to execute is signaled by the submission of new limit orders that contribute to the price discovery. The majority of price discovery, in all intervals considered, is provided by the MIXED-HFT-OWN.

Since the theoretical opening price includes also the iceberg quantities, we analyze if the submission of orders with hidden quantities do contribute or deteriorate price discovery.

In general, new limit orders with iceberg quantity do not harm price discovery and follow the regular limit orders and the market orders in the price discovery process. Finally, we also document the usage of very aggressive limit orders (orders that are over the 6% change from the yesterday closing price), and flash-crash orders. Aggressive limit orders marginally provide price discovery, especially in the last portion of the pre-opening phase. Flash crash orders have a very small impact on the determination of the opening price, since their purpose is to exploit temporary and unexpected price movements.

Table IA.4: Weighted Price Discovery Contribution (WPDC) by type of order

This table shows the Weighted Price Discovery Contribution, defined in Section IV.C of the paper, for three trader groups (PURE-HFT, MIXED-HFT, NON-HFT) and six account types (CLIENT, OWN, RLP, RMO, MM, PARENT) during the pre-opening phase. All numbers in each panel sum to 100%. Data are for 37 stocks traded on NYSE Euronext Paris that belong to the CAC40 index, for the year 2013. Order flow data, with trader group and account flags are from BEDOFIH.

Panel A: WPDC by type of order during the entire pre-opening phase																								
		Limit Orders			Market Orders			Limit w. Iceberg			Flash Crash Limit			Flash Crash Limit w. Iceberg			Aggressive Limit			Aggressive Limit w. Iceberg				
		TOTAL	New	Modify	Cancel	New	Modify	Cancel	New	Modify	Cancel	New	Modify	Cancel	New	Modify	Cancel	New	Modify	Cancel	New	Modify	Cancel	
PURE-HFT	Client	0.32%	-0.49%		0.03%	0.87%		-0.05%	-0.07%		0.04%							0.02%		-0.03%				
	Own	-11.75%	-16.79%	-2.22%	6.20%	1.01%		0.04%	0.00%		0.00%		0.00%		0.00%			0.02%		-0.02%				
	MM	-0.03%	0.00%			0.00%													-0.02%					
MIXED-HFT	Client	-8.75%	-32.09%	-3.12%	16.71%	12.00%	-0.44%	-0.79%	-4.60%	1.30%	0.68%	-0.04%	0.00%	0.00%	-0.03%	-0.01%	0.01%	1.62%	0.01%	0.04%	-0.03%	0.01%	0.02%	
	Own	-47.47%	-56.27%	-4.57%	4.13%	35.23%	-3.05%	-20.23%	-2.87%	-0.03%	0.16%	-0.06%	0.00%	0.00%				0.02%	-0.05%	0.12%	0.03%		-0.04%	
	MM	-6.03%	-6.21%	-0.16%	0.33%							0.00%	0.00%					0.00%						
	Parent	-12.71%	-7.94%	0.04%	-0.47%	-3.50%		-0.81%	-0.02%	0.01%	0.00%				0.00%				-0.01%					
NON HFT	Client	3.09%	-69.57%	-0.34%	6.82%	119.66%	0.06%	-46.45%	-8.48%	-0.30%	0.48%	0.07%	0.01%	0.02%	0.00%	0.00%		1.07%	0.01%	-0.05%	0.10%		-0.01%	
	Own	-16.96%	-18.32%	-0.61%	2.27%	0.52%	-0.10%	0.15%	-1.38%	0.46%	0.14%	-0.07%	-0.05%	0.00%		0.03%		0.07%	0.01%	-0.06%	-0.01%	0.02%	-0.01%	
	RMO	0.05%	-0.18%	-0.01%	0.01%	0.22%		0.01%										0.01%						
	Parent	0.24%	-0.14%	0.09%	0.03%	0.25%													-0.02%	0.00%				
WPDC LEFT: -122.83%		Panel B: WPDC by type of order in the pre-opening phase: from 8:10 AM																						
PURE-HFT	Client	-0.09%	-0.36%		0.03%	0.29%		-0.03%	-0.05%		0.03%							0.00%		0.00%				
	Own	-9.07%	-12.76%	-1.85%	5.26%	0.26%		0.03%	0.00%		0.00%		-0.01%		0.00%			0.00%		-0.01%				
	MM	-0.02%	0.00%			0.00%													-0.02%					
MIXED-HFT	Client	-7.86%	-25.55%	-2.47%	13.81%	8.21%	-0.25%	-0.56%	-3.58%	1.09%	0.61%	-0.03%	0.00%	0.00%	-0.04%	0.00%	0.01%	0.84%	0.01%	0.05%	-0.02%	0.01%	0.01%	
	Own	-37.35%	-46.63%	-3.77%	3.60%	32.78%	-2.63%	-18.52%	-2.30%	-0.03%	0.14%	-0.06%	0.00%	0.00%				0.00%	-0.02%	0.09%	-0.01%			
	MM	-5.07%	-5.09%	-0.29%	0.31%							0.00%	0.00%					0.00%						
	Parent	-10.47%	-6.48%	0.05%	-0.55%	-2.26%		-1.19%	-0.02%	0.01%	0.00%				0.00%				-0.02%					
NON HFT	Client	-16.48%	-21.70%	-0.29%	4.14%	11.16%	-0.08%	-3.56%	-6.75%	-0.24%	0.42%	0.00%		0.00%	-0.01%	0.00%		0.35%	0.01%	-0.05%	0.16%		-0.04%	
	Own	-13.74%	-14.73%	-0.51%	1.82%	1.02%	-0.09%	-0.51%	-1.07%	0.36%	0.07%	-0.06%	-0.04%	0.00%		0.03%		0.05%	0.00%	-0.05%	0.01%	-0.01%	0.00%	
	RMO	-0.08%	-0.04%	-0.01%	0.00%	-0.04%		0.01%																
	Parent	0.24%	-0.09%	0.07%	0.02%	0.21%													-0.02%	0.00%				
WPDC LEFT: -121.78%		Panel C: WPDC by type of order in the pre-opening phase: from 8:30 AM																						
PURE-HFT	Client	-0.12%	-0.33%		0.05%	0.23%		-0.04%	-0.06%		0.04%							0.00%		0.00%				
	Own	-8.86%	-12.31%	-1.89%	5.20%	0.14%		0.00%	0.00%		0.00%		-0.01%		0.00%			0.00%		-0.01%				
	MM	-0.02%	0.00%			0.00%													-0.02%					
MIXED-HFT	Client	-8.90%	-24.81%	-2.41%	13.98%	4.76%	-0.20%	-0.01%	-2.68%	1.11%	0.52%	-0.03%	0.00%		-0.04%	-0.01%	0.01%	0.78%	0.01%	0.10%	-0.01%	0.01%	0.01%	
	Own	-40.74%	-46.00%	-3.85%	3.41%	28.10%	-2.68%	-17.97%	-1.94%	-0.03%	0.15%	-0.05%	0.00%	0.00%				0.06%	-0.04%	0.10%	-0.01%			
	MM	-5.06%	-5.16%	-0.24%	0.34%							0.00%	0.00%					0.00%						
	Parent	-10.03%	-6.77%	0.05%	-0.32%	-1.85%		-1.12%	-0.02%	0.01%	0.00%				0.00%				-0.02%					
NON HFT	Client	-13.27%	-17.95%	-0.29%	3.67%	9.55%	-0.13%	-2.49%	-6.04%	-0.20%	0.39%	-0.02%		0.00%	-0.01%	0.00%		0.24%	0.01%	-0.02%	0.03%		-0.03%	
	Own	-13.16%	-14.26%	-0.49%	1.76%	1.46%	-0.08%	-0.90%	-1.02%	0.38%	0.04%	-0.06%	-0.04%	0.00%		0.03%		0.04%	0.01%	-0.02%		-0.01%	0.01%	
	RMO	-0.07%	-0.04%	-0.01%	0.00%	-0.04%		0.01%																
	Parent	0.25%	-0.08%	0.07%	0.02%	0.27%		-0.01%											-0.02%	0.00%				

Table IA.5: Weighted Price Discovery Contribution (WPDC) by type of order from 8:59 AM

This table shows the Weighted Price Discovery Contribution, defined in Section IV.C, for three trader groups (PURE-HFT, MIXED-HFT, NON-HFT) and six account types (CLIENT, OWN, RLP, RMO, MM, PARENT) during the last second of the pre-opening phase. Compared to Table 8, we exclude the order type that does not contribute to the price discovery in the very last second. Data are for 37 stocks traded on NYSE Euronext Paris that belong to the CAC40 index, for the year 2013. Order flow data, with trader group and account flags are from BEDOFIH.

WPDC LEFT: -48.77%			Panel A: WPDC by type of order during the last minute of the pre-opening phase																				
TOTAL			Limit Orders			Market Orders			Limit w. Iceberg			Flash Crash Limit			Flash Crash Limit w. Iceberg			Aggressive Limit			Aggressive Limit w. Iceberg		
			New	Modify	Cancel	New	Modify	Cancel	New	Modify	Cancel	New	Modify	Cancel	New	Modify	Cancel	New	Modify	Cancel	New	Modify	Cancel
PURE-HFT	Client	-0.14%	-0.07%	-2.75%	-0.01%	-0.06%		0.01%		-0.02%										0.01%			
	Own	-1.97%	-5.47%		5.92%															-0.05%			
	MM	-0.06%	0.00%																				
MIXED-HFT	Client	-2.89%	-9.84%	-1.60%	7.51%	-0.26%	0.14%	-0.02%	-0.53%	1.70%	0.09%	0.00%			0.00%				-0.04%	0.00%	-0.04%	0.01%	
	Own	-51.92%	-49.26%	-2.05%	1.62%	1.99%	-1.21%	-2.57%	-0.33%	0.00%	0.00%	-0.04%	0.00%						0.01%	-0.05%	-0.01%		
	MM	-10.54%	-10.75%	-0.21%	0.41%							-0.01%	0.00%						0.01%				
	Parent	-14.49%	-13.64%	-0.01%	-0.60%	0.23%		-0.44%	-0.02%	0.00%	0.00%				0.00%				-0.01%				
NON HFT	Client	-4.31%	-6.11%	-0.11%	3.01%	0.00%	0.02%	-0.46%	-0.56%	-0.10%	0.08%			0.00%					-0.02%	0.00%	-0.05%		
	Own	-13.78%	-15.12%	-1.39%	3.28%	-0.44%	-0.03%	-0.05%	-0.20%	0.14%	-0.01%	0.01%	0.01%	0.00%					0.04%		-0.01%	0.00%	
	RMO	0.00%	0.00%																				
	Parent	0.11%	-0.05%	0.15%	0.05%	0.01%													-0.05%	0.00%			

WPDC LEFT: -10.60%			Panel B: WPDC by type of order during the last second of the pre-opening phase																				
TOTAL			Limit Orders			Market Orders			Limit w. Iceberg			Flash Crash Limit			Flash Crash Limit w. Iceberg			Aggressive Limit			Aggressive Limit w. Iceberg		
			New	Modify	Cancel	New	Modify	Cancel	New	Modify	Cancel	New	Modify	Cancel	New	Modify	Cancel	New	Modify	Cancel	New	Modify	Cancel
PURE-HFT	Client	-0.03%	-0.03%																				
	Own	-13.61%	-13.15%	-0.47%	0.01%	0.00%														-0.49%			
	MM	-0.49%																					
MIXED-HFT	Client	-2.30%	-1.64%	-0.49%	0.57%	-0.21%	-0.02%	0.18%	-0.02%	-0.58%									-0.11%	0.00%			
	Own	-54.61%	-49.84%	-1.15%	-0.60%	-2.03%	-0.03%	-0.83%	-0.01%										-0.09%		-0.03%		
	MM	-2.79%	-2.45%	-0.26%	-0.08%																		
	Parent	-0.91%	-0.23%		-0.57%	-0.06%		-0.04%															
NON HFT	Client	-0.82%	-0.24%	-0.04%	0.03%	-0.18%	-0.04%	-0.25%	-0.05%	-0.05%										0.00%			
	Own	-24.39%	-23.16%	-1.64%	0.47%	0.00%		0.00%		-0.04%	-0.01%												
	RMO	0.00%	0.00%																				
	Parent	-0.04%	0.01%	-0.04%	-0.01%																		

WPDC LEFT: -1.71%			Panel C: WPDC by type of order during the last 100 milliseconds of the pre-opening phase																				
TOTAL			Limit Orders			Market Orders			Limit w. Iceberg			Flash Crash Limit			Flash Crash Limit w. Iceberg			Aggressive Limit			Aggressive Limit w. Iceberg		
			New	Modify	Cancel	New	Modify	Cancel	New	Modify	Cancel	New	Modify	Cancel	New	Modify	Cancel	New	Modify	Cancel	New	Modify	Cancel
PURE-HFT	Client																						
	Own	-8.75%	-8.08%	-0.18%	-0.49%																		
	MM																						
MIXED-HFT	Client	-1.66%	-0.49%	-1.15%	-0.22%	-0.11%	-0.01%	0.37%		-0.04%													
	Own	-81.83%	-76.66%	-0.37%	-1.63%	-2.31%	-0.03%	-0.82%															
	MM	-0.75%	-0.67%	-0.08%																			
	Parent	-0.52%	-0.37%			-0.15%																	
NON HFT	Client	-1.42%	-0.96%	-0.11%	-0.07%	-0.18%	-0.06%			-0.04%													
	Own	-4.27%	-2.66%	-1.18%	-0.36%						-0.08%												
	RMO																						
	Parent	0.01%		0.01%																			

G. Iceberg orders usage

According to the Euronext Trading Manual for the Universal Trading Platform ([Euronext \(2016\)](#)), when an order is entered, the trader has to specify the total volume and the peak volume. The latter will be disclosed to the central order book, while the total quantity will be hidden to the other market participants. In our database, we can observe both quantities. An iceberg order can be submitted both during the pre-opening phase and the main trading phase. There are several papers that investigate the presence and the usage of the iceberg orders, especially on the Euronext market. Remarkable examples are [De Winne and D'hondt \(2007\)](#) and [Bessembinder et al. \(2009\)](#), who also provide the rationale behind the usage of the iceberg orders. We only document empirically what happens to the visible (and invisible) part of the order book during the pre-opening phase.

Figure [IA.6](#) shows the average hidden quantity for the entire pre-opening phase. For most of the time, the hidden quantity is around 10% of the total depth (visible plus hidden), and mainly driven by flash-crash and very aggressive orders. An interesting pattern arises in the last three minutes of the pre-opening phase: the hidden quantities skyrocket up to 50% on average. As we documented before, this increase in the hidden quantity does not have a remarkable impact on the price discovery process.

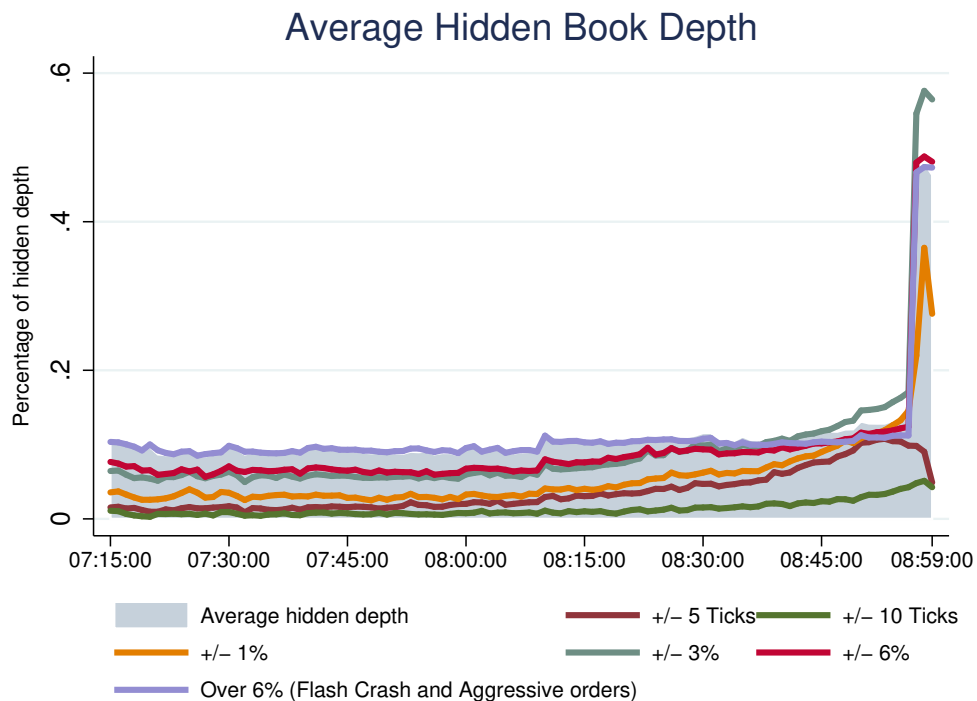


Figure IA.6: Iceberg orders during the Pre-Opening Phase

This figure shows the average hidden quantity per minute, across stock-days, for different positions of the limit order book with respect to the calculated theoretical opening price. The sample is composed of 37 stocks traded on NYSE Euronext Paris that belong to the CAC40 index, for the year 2013. Order flow data, with trader group and account flags are from BEDOFIH.

H. Profit by order

Figure IA.7 plots the potential profits by order across all stock-days made on orders submitted during the last second of the pre-opening phase, assuming that the position taken in the auction is reverted one-minute after the auction at the market price, i.e., it is evaluated at the mark-to-market price one minute after the opening auction. We observe that PURE-HFT-OWN traders are the only ones for whom most of the executed orders were submitted in the last 500 milliseconds, while executed orders of all other trader/account types are spread evenly throughout the last second.

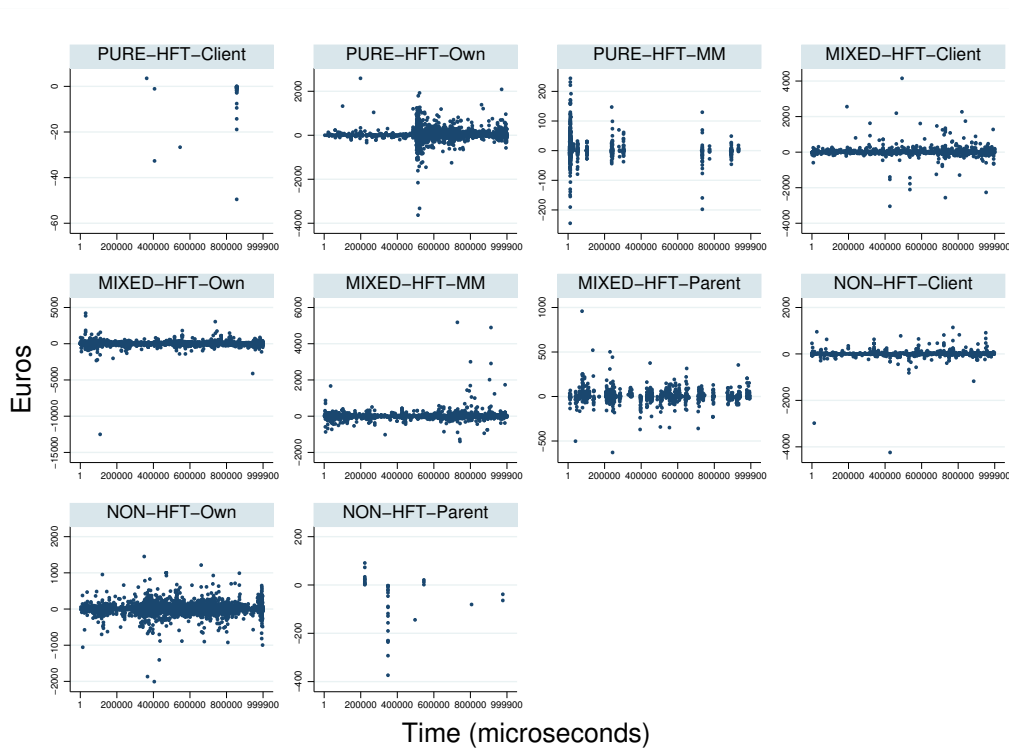


Figure IA.7: Time of submission and return in the last second

The figure shows, for each trader/account, the return on individual orders executed at the auction and the time where the executed order has been submitted for the last second of the pre-opening phase. We assume that position taken in the auction is liquidated one minute after the auction at the market price. The sample is composed of 37 stocks traded on NYSE Euronext Paris that belongs to the CAC40 index, for the year 2013. Order flow data, with trader group and account flags are from BEDOFIH.

I. Shape of the order book during the Pre-Opening Phase

As explained in Section A of this Appendix, the order book during the pre-opening phase looks quite different compared to the book during the main trading phase. This section describes the main differences and provides some insights about the shape of the order book, and how the traders behave during the pre-opening phase. First of all, in order to calculate the theoretical opening price order by order, it is necessary to rebuild the entire order book, which also includes the “left-over” orders from the previous days. A best-bid and best-ask price, at the top of the book, is not available given that the book is crossed. Further, the presence of the market orders (which are usually executed immediately in the main trading phase) requires a different set of metrics to establish if an order is executable or not. We define three price intervals: plus/minus 5 ticks, plus/minus 10 ticks (interval between 5 ticks and 10 ticks) and up to plus/minus 1% of the theoretical opening price. Orders inside the 10 tick interval are very likely to be executed at the opening auction. The tick size depends on the level of the stock price and varies between 0.001 euro (when the stock price is between 0 and 10 euro) and 0.05 euro (when the stock price is larger than 100 euro). Going down on the price grid, the probability of execution of an order decreases. We sample the presence of these three parts of the order book for every minute, and for every second, in the last minute of the pre-opening phase, and then draw a box plot that indicates the presence (in minutes or seconds) for the most relevant group of traders. As shown in Figure IA.8, for entire pre-opening phase, PURE-HFT-OWN (MIXED-HFT-OWN) traders are present in the limit order book within +/- 5 ticks around the theoretical opening price for a median time of 15 (5) minutes, while NON-HFT-CLIENT traders are there for almost 90 minutes out of 105 minutes in total. If we focus on the period after 08:30 a.m. (Figure IA.9), then PURE-HFT-OWN (MIXED-HFT-OWN) are present in the limit order book within +/- 5 ticks around the theoretical opening price for a median time of 15 (10) minutes out of 30 minutes remaining from the pre-opening phase. In the last one minute (Figure IA.10), PURE-HFT-OWN (MIXED-HFT-OWN) are present in the top of the book for a median time of 45 (55) seconds, while MIXED-HFT-MM are there for only around 5 seconds.

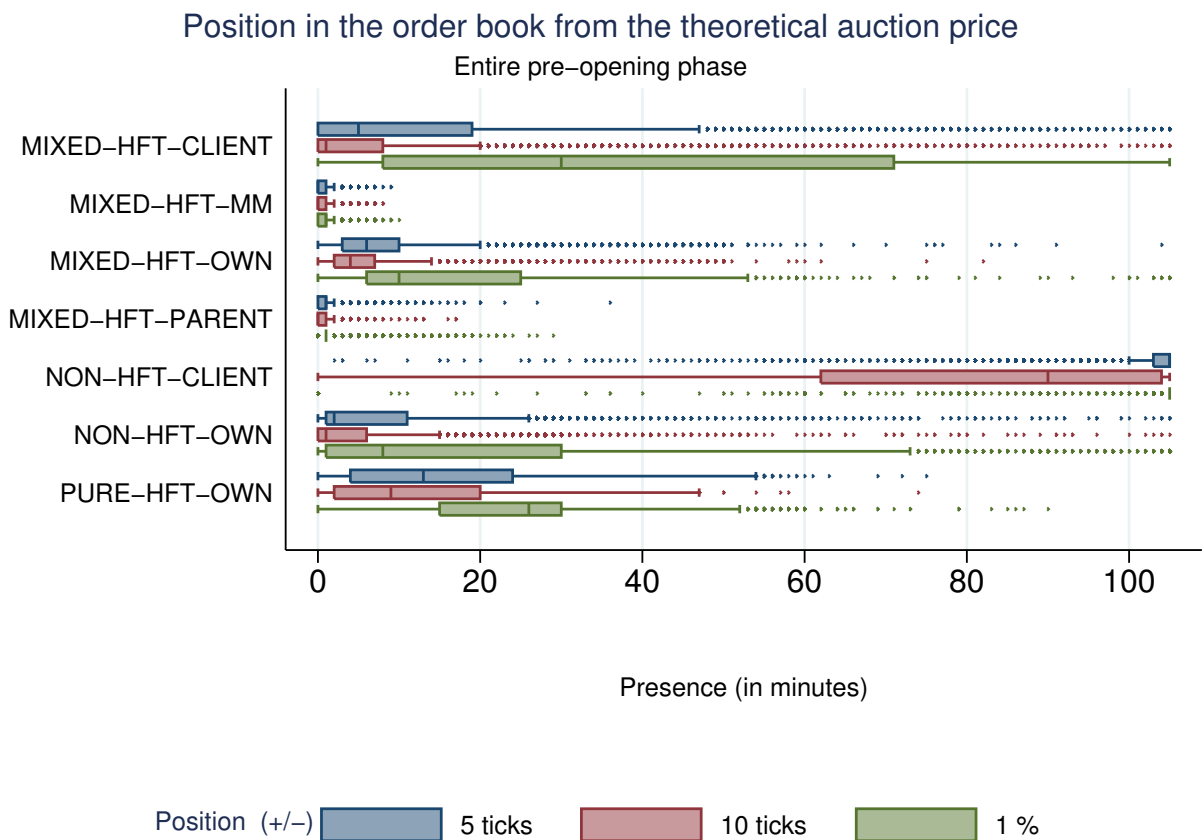


Figure IA.8: Shape of the order book during the Pre-Opening Phase

The box plots show the average presence time (in minutes) during the entire pre-opening phase. The presence is sampled at the end of every minutes from the rebuilt order book. The sample is composed of 37 stocks traded on NYSE Euronext Paris that belong to the CAC40 index, for the year 2013. Order flow data, with trader group and account flags are from BEDOFIH.

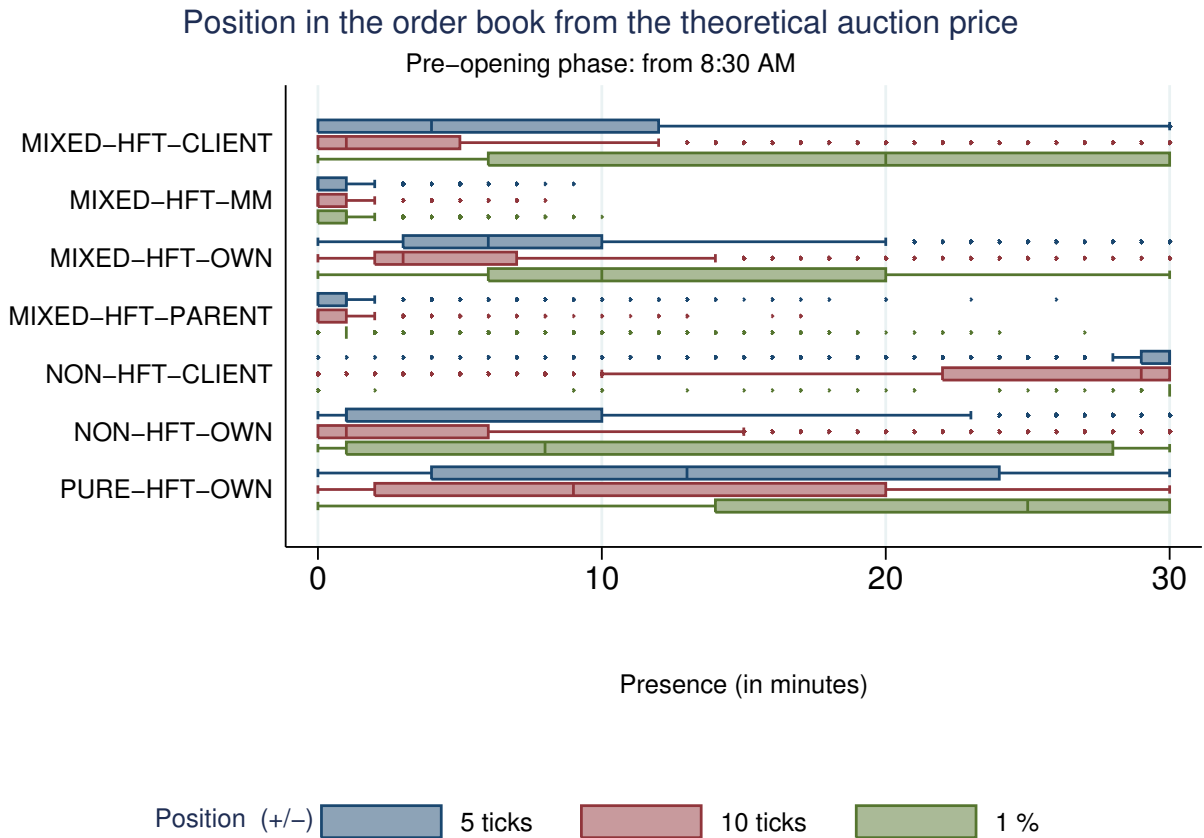


Figure IA.9: Shape of the order book during the Pre-Opening Phase: from 8:30 AM
The box plots show the average presence time (in minutes) during the last 30 minutes of the pre-opening phase. The presence is sampled at the end of every minutes from the rebuilt order book, after 8:30 AM. The sample is composed of 37 stocks traded on NYSE Euronext Paris that belong to the CAC40 index, for the year 2013. Order flow data, with trader group and account flags are from BEDOFIH.

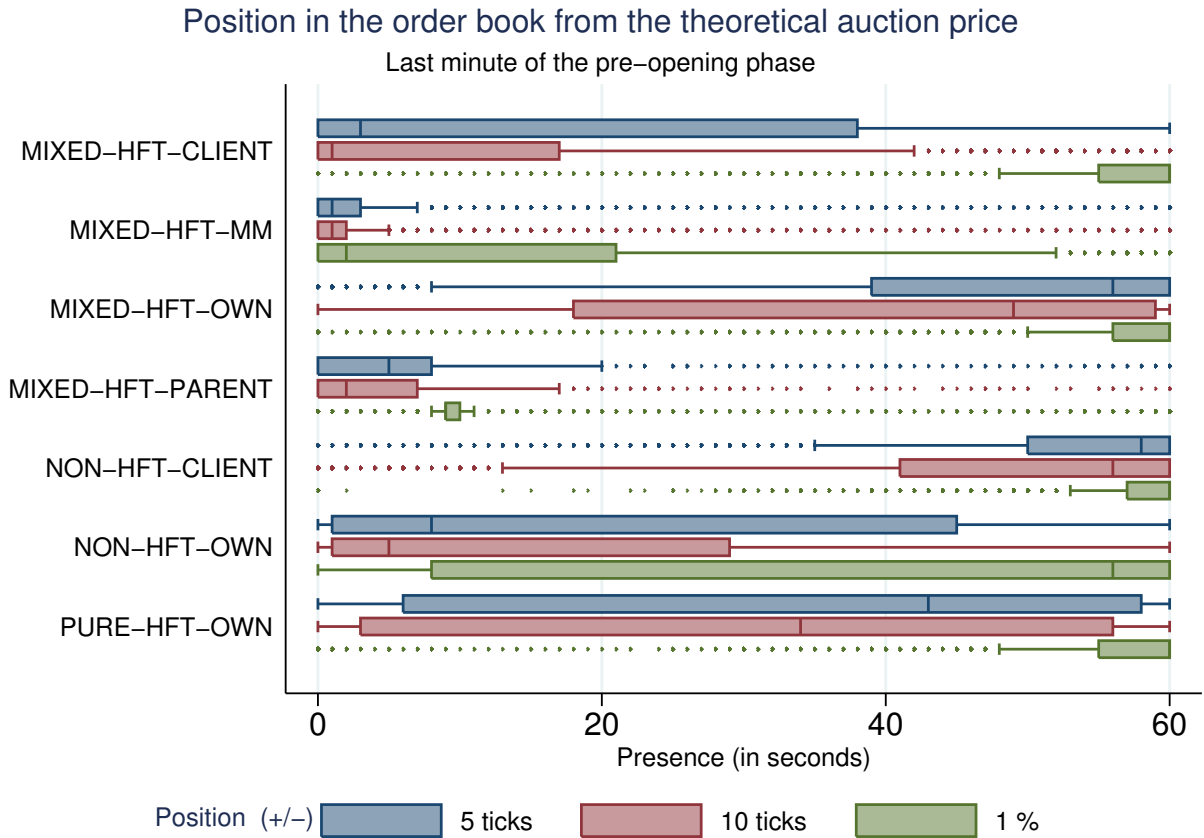


Figure IA.10: Shape of the order book during the Pre-Opening Phase: last minute
 The box plots show the average presence time (in seconds) during the last minute of the pre-opening phase. The presence is sampled at the end of every second from the rebuilt order book, after 8:59:00 AM. The sample is composed of 37 stocks traded on NYSE Euronext Paris that belong to the CAC40 index, for the year 2013. Order flow data, with trader group and account flags are from BEDOFIH.

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