Shifting Sands: High Frequency, Retail, and Institutional Trading Profits over Time[*]

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Abstract

We study the intra-day trading profits and losses of retail, institutional, and high frequency traders from 2006 to 2012, using granular trader-level data from the Toronto Stock Exchange and analyze the evolution in trading costs for traders who trade with both market and limit orders. Retail investors make persistent intra-day trading losses, institutional investors earn positive profits, and high frequency trading (HFT) profits decline over time. HFT activities are associated with a reduction in retail traders' liquidity costs and in the trading losses that are attributed to adverse future price movements. Institutional traders' profits are positively related to retail trading activities but unrelated to HFT activities. Retail losses add up to almost half a billion dollars over our six year sample, and only a small portion of these losses can be attributed to direct bid-ask spread costs – the remainder are due to adverse intra-day price movements.

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Over the last decade, advances in technology and new regulation caused seismic shifts in equity markets worldwide. New trading venues emerged, and a large fraction of trading that was formerly arranged through human interactions is now executed by automated computer programs. Algorithmic trading is particularly prevalent for market-making activities, and academic work to date indicates that the automation of trading has lowered the costs of intermediation and improved standard measures of market liquidity (see, e.g., Jones (2013)). In the process of automating trading a new type of trader has emerged, one that does not require direct human input to execute trading strategies and that can trade at extremely high frequencies. As Jones (2013) notes, the superior speed of this new type may lead to increased adverse selection and disadvantage other investors. Understanding the redistributive effects of recent market developments is thus key to evaluating changes in market quality. We conduct a longitudinal analysis of trading costs and profits for different groups of traders on the Toronto Stock Exchange from mid-2006 to mid-2012 for S&P/TSX 60 securities.

Over the six years of our study the quoted bid-ask spread, the most common measure of trading costs, has declined by 50%. A change in bid-ask spreads alone, however, is not sufficient to draw conclusions on changes in market quality. Modern equity markets are organized as limit order books, and traders use both market and limit orders in their strategies. A decline in the bid-ask spread reduces trading costs for marketable orders, but, on the flip side, it may yield lower benefits to limit order submitters. Furthermore, most large orders are now split into many smaller orders, and each small order may generate a price impact that moves prices in the direction of the trade. A lower bid-ask spread in combination with a higher price impact may, in fact, result in higher total trading costs. Since the transaction data that is typically available to researchers does not provide information about split orders, assessing the price impact is challenging.

Accounting for changes in the trading costs of both market and limit orders and for changes in the price impact is particularly important if there are changes in market structure, such as the entry of high frequency traders. First, the entry of a new class of traders likely caused the existing traders to change their trading strategies, both with respect to the choice

of the order type and with respect to order splitting. Second, as high frequency traders allegedly have an advantage at detecting large split orders, their entry likely affected the price impacts of large orders. To understand the redistributive effects, we must employ a measure that does not rely on traders being liquidity providers or demanders, that captures the price impact of possibly split orders, and that remains robust to changes in traders' order submission strategies.

The measure we use is a trader's intraday profits from buying and selling a security, with the end-of-day portfolio holdings evaluated at the closing price. This measure relates to Menkveld (2013)'s decomposition of trading revenues into positional and bid-ask-spread related components, and we believe that it is appropriate to evaluate the redistributive effects. A positive profit implies that a trader was able to "buy low or sell high" relative to the closing price. The day's closing price serves as a benchmark that, intuitively, captures the information about the stock's fundamental that has been revealed during the trading day. Arguably, for long-term investors, these profits/costs account for both the price impact of their possibly split orders and for the bid-ask spread. Furthermore, computed across all traders, these costs are zero-sum, which allows us to study the redistributive effects.

Equipped with trader-level data, we focus on three groups of traders: computerized traders that have very high activity levels, or "high-frequency traders" (HFT), the most sophisticated, non-high frequency traders, the least sophisticated traders, and everyone else. Our classification is based on simple trading characteristics: HFTs submit more than 100,000 messages (transactions, orders, and cancellations) across all securities on at least one day in a given week; unsophisticated traders trade with orders that were left in the order book overnight (we also refer to these traders as "retail"); and sophisticated traders accumulate, in a given stock and week, an absolute net position (buys minus sells) of more than $1 million (we also refer to these traders as "institutions"). All remaining traders are left unclassified.

Figure 1 plots the cumulative weekly intraday profits, taking the sum of all trading profits (in dollars) across groups of traders for our sample of S&P/TSX60 securities. The dashed

lines in Figure 1 are the transaction costs from (paying minus earning) the bid-ask spreads. Figure 1 thus illustrates that bid-ask spreads account for only a very small portion of the intraday profits/costs — the intraday price impact is a much more important component.

Moreover, as the figure illustrates, the group of unsophisticated traders loses persistently. This persistency is puzzling. Standard trading models employ unsophisticated traders that add noise and that trade in an unsystematic fashion. On average, these traders are on the wrong side of the market as often as they are on the right side and their losses should thus be bounded by transaction costs from the bid-ask spread. Yet there is a large portion that is not unaccounted for.

In a formal regression analysis we then try to understand the relationship between HFT activities and sophisticated and unsophisticated traders' profits and the effective spreads that these traders face. We measure HFT activity as the percentage of HFT in total message volume or total dollar volume of trading. We observe that on the daily level, unsophisticated traders' profits are, in fact, positively associated with increases in HFT activity and that sophisticated traders' profits are unrelated to HFT activities.

We further observe that unsophisticated traders' profits fall as unsophisticated traders trade more, i.e. they lose proportionally more as they increase their trading activity; this finding is consistent with Barber and Odean (2000). Sophisticated traders' profits are positively associated with unsophisticated traders' activities. We also find that as volatility increases, unsophisticated traders tend to lose more but sophisticated traders are able to increase their trading profits. Finally, we observe that unsophisticated traders face higher price impact when HFTs trade less passively suggesting that unsophisticated traders may receive unwanted flow that HFTs are able to detect and to avoid.

We further investigate whether the unsophisticated traders' losses stem from active, marketable or passive, limit orders. Arguably, when posting a marketable order, the best a trader can hope for in terms of transaction costs is that the spread only captures the trader's price impact (the liquidity provider rents captured by the realized spread would have been competed away). Likewise, when trading against a marketable order, the trader

receives the effective spread, but loses the price impact portion.

The left panel of Figure 2 plots the effective spread and price impact, as measured by the change in the midpoint five minutes after the trade, when an unsophisticated trader is on the active side, the right panel plots the same figures when this type of trader is on the passive side. Until mid-2008, unsophisticated traders pay more than their price impact whereas as of 2009, when computerized trading intensified, unsophisticated traders received a much better deal for their active orders. When unsophisticated traders are on the passive side, the picture is reversed: before 2008, the effective spread was, roughly, fair compensation compared to the price impact that a trader faces, but as of 2009, the price impact exceeds the spread-based compensation. Thus as spreads tighten, unsophisticated traders indeed benefit for market orders, but they obtain insufficient compensation for passive orders. Without claiming causality, Panel B in Figure 2 indicates that passively trading unsophisticated traders face higher adverse selection risk as HFT trading becomes more prevalent, consistently with the discussion in Jones (2013).

Our work indicates that one needs to be careful to differentiate the benefits from market evolution from the reduced bid-ask spreads. More importantly, our work also indicates that spreads, in fact, play only a minor role in trading costs, at least for unsophisticated traders, and that the price changes subsequent to a trade are more important for a trader's cost by an order of magnitude. We further believe that theoretical work is needed to understand the systematic nature of the unsophisticated traders' losses because these systematic losses may have important implications for long-run asset returns and illiquidity premia.

Related Literature. Our work is closely related to the literature on trader and investor performance and profitability. Hasbrouck and Sofianos (1993) study the profitability of market makers and break down their profits into liquidity and trading related. Barber and Odean (2000) show that active retail traders' portfolios perform poorly. Barber and Odean (2002) show that as investors switch to online brokerages, and trade more, their performance falls. Using a Taiwanese dataset, Barber, Lee, Liu, and Odean (2009) find that retail traders lose on their aggressive (liquidity demanding) trades. Hau (2002) finds that traders close to

corporate headquarters have higher trading profits than those located farther away, Dvořák (2005) finds that domestic traders are more profitable than foreign traders.

Baron, Brogaard, and Kirilenko (2012) analyze the profitability of HFTs in e-mini futures for August 2010 and find that during this time, HFTs are extremely profitable and that the fastest firms earn the highest profits. Menkveld (2013) shows how one HFT firm enabled a new market, Chi-X Europe, to gain market share and he documents this HFT's profitability.

Our work also relates to the expanding literature on high frequency trading. Biais and Woolley (2011) and Jones (2013) provide an overview of this literature. Brogaard, Hendershott, and Riordan (2012) use 2008-2009 data from NASDAQ that identifies HFT trades and show that aggressive HFT trades permanently impound information into prices, indicating that HFT trades predict future price movements. Hirschey (2011) uses data from NASDAQ that identifies trading by individual HFT firms and finds that aggressive HFT trades predict subsequent non-HFT liquidity demand. Kirilenko, Kyle, Samadi, and Tuzun (2011) study HFT in the E-mini S&P 500 futures market during the May 6th Flash Crash and suggest that HFT may have exacerbated volatility. Jovanovic and Menkveld (2011) model HFT as middlemen in limit order markets and examine welfare effects. Ye, Yao, and Gai (2013) study technological advances in message processing on NASDAQ and finds that a reduction in latency from milliseconds to microseconds led to no improvement in market quality, suggesting that there are diminishing returns from technological improvements.

I Trading on the TSX and Notable Events

The Canadian market is similar to the U.S. market, in terms of regulations and market participants. Trading on the TSX is organized in an electronic limit order book, according to price-time priority.[1] The Canadian market is closely connected to the United States, and most U.S. events have an impact on Canadian markets.

[1]Differently to U.S. markets, trades below 100 shares (odd-lot trades) are executed outside of the limit order book, by a registered trader. Canadian markets further employ so-called broker-preferencing, so orders that originate from the same brokerage may be matched with violations of time-priority.

Our data spans July 1st, 2006 to June 1st, 2012. During this time financial markets overall and Canadian markets, in particular, have experienced several major shocks and changes. We discuss changes that are most relevant to our analysis below.

2006-2007: Introduction of Maker-Taker Fees. In 2006, almost all Canadian trading in TSX-listed securities occurred on the TSX. High-frequency traders were few, with the most prominent known participant being Infinium Capital Corporation, which became a participating organization on the TSX on March 11, 2005.[2] On July 01, 2006, the TSX introduced maker-taker pricing, with rebates for liquidity provision, for all securities (a pilot started in 2005). According to the S.E.C., liquidity rebates facilitated the development of high frequency liquidity provision, and we thus chose to start our analysis in July 2006.[3]

2008-2009: Financial Crisis, Market Fragmentation, and Arrival of HFT. The year 2008 was pivotal for Canadian markets: with the 2008 financial crisis, the growth of alternative trading systems, and the arrival of major U.S. high frequency trading firms.

Pure Trading opened a cross-printing facility in October 2006 and launched continuous trading in September 2007; Omega ATS launched in December 2007; Chi-X Canada started in February 2008; Alpha Trading launched in November 2008. Continuous dark trading plays only a small role in Canada: the main dark pool, MATCH Now, launched in July 2007, and it has had an average market share of under 3%. Figure 3 illustrates the evolution of the TSX's market share from 2006 to 2012, using the data from IIROC's website. The graph shows that the TSX market share declined from 93% of dollar volume traded in January 2009 to 65% in January 2010, and that the TSX market share share has varied between 60 and 70% since January 2010. The two major competitors of the TSX are Alpha and Chi-X. Alpha's market share increased from 1.7% in January 2009 to 22.5% in January 2010, and has varied between 15 and 22% since then; Chi-X Canada's market share went from 2.7% in January 2009 to 8% in January 2010, and has been between 7 and 11% since then.

The arrival of alternative trading systems coincided with several major changes on the TSX. First, in 2007 the TSX introduced a new, faster trading engine. Second, in 2008, the

[2]See the TMX Group Notice 2005-010.

[3]See the S.E.C. 2010 Concept Release on Market Structure.

TSX offered co-location services, allowing traders to place their servers physically close to the main TSX trading engine.[4] Third, on October 29, 2008, the TSX started the "Electronic Liquidity Provider" (ELP) program that offered "fee incentives to experienced high-velocity traders that use proprietary capital and passive electronic strategies to aggressively tighten spreads on the TSX Central Limit Order Book."

The above developments have arguably facilitated the arrival of major U.S. HFT firms. From public sources, we know that Getco LLC has participated in Canadian markets since 2008, and that Tradebot Systems expanded trading to Canada in October 2008.[5] Dave Cummings, Chairman of Tradebot Systems Inc. commented in particular, that "[t]he ELP program [...] was a major factor in [Tradebot's] decision to trade in the Canadian market."[6]

2010-2012: Flash Crash, Debt Crisis, and Per-Message-Fees. The years 2010-2012 were much calmer, with some notable exceptions. First, the May 6, 2010 "Flash Crash" drew public attention the presence of high-frequency trading. The flash crash was visible in Canadian data, albeit the price fluctuations were of smaller magnitude. Second, and more generally, May 2010 was the beginning of the European sovereign debt crisis, with high volatility levels. Volatility was also high from August to October 2011, fuelled by concerns over the U.S. debt ceiling and over the future of the European Monetary Union. Finally, on April 01, 2012 IIROC introduced a policy change that had a pronounced effect on high frequency trading. Namely, as of April 01, 2012, brokers incurred a fee per submitted message (such as a new order, trade, or a cancellation of an order). This fee is meant to recover the costs of surveillance and its exact magnitude varies with the total number of messages submitted by all participants.[7]

Fragmentation levels did not change much during this period, although, new venues did

[4]The TSX Quantum^{TM} engine migration was completed in May 2008; see TSX Group notice 2008-021. The TMX Group 2008 annual report describes the introduction of co-location services.

[5]See, e.g., Getco LLC regulatory comment to the CSA, available at `http://www.osc.gov.on.ca/documents/en/Securities-Category2-Comments/com_20110708_23-103_kinge.pdf` for Getco LLC arrival and "Tradebot Systems often accounts for 10 percent of U.S. stock market trading", Kansas City Business Journal, May 24, 2009, for Tradebot Systems Inc. arrival.

[6]http://www.newswire.ca/en/story/269659/tmx-group-targets-liquidity-with-reduced-equity-trading-fees, Canada Newswire, October 29, 2008.

[7]According to a research report by CIBC (2013), this fee is on the order of $0.00022 per message. Malinova, Park, and Riordan (2012) study the impact of this change on market quality.

come in. In June 2011, Alpha launched its IntraSpread™ dark pool, and almost concurrently, in July 2011, the TMX Group launched the alternative trading system TMX Select.[8]

II Data, Sample Selection, and Trader Classification

A Data

Our trade-based analysis is based on a proprietary dataset, provided to us by the TMX Group; we use additional proprietary methods to identify retail traders.[9] Index constituent status is obtained from the monthly TSX e-Review publications.

The TSX data is the output of the central trading engine, and it includes all messages from the (automated) message protocol between the brokers and the exchange. Messages include all orders, cancellations and modifications, all trade reports, and all details on dealer (upstairs) crosses. The data specifies the active (liquidity demanding) and passive (liquidity supplying) party in a trade, thus identifying each trade as buyer-initiated or seller-initiated. The "prevailing quote" identifies the best bid and ask quotes and is updated each time there is a change in the best quotes. The dataset used in our analysis is from July 1st, 2006, to June 1st, 2012.

Unique Identifiers. Our data has unique identifiers for the party that submitted an order to the exchange. A unique identifier links orders with a trading desk in charge of the order at a brokerage. Our unique identifiers are similar to those used by the Investment Industry Regulatory Organization of Canada (IIROC), and, according to them, are "the most granular means of identifying trading entities." For IIROC's data, a unique identifier may identify a single trader, a direct-market access (DMA) client, or a business flow (for example, orders originating from an online discount brokerage system). A DMA client may

[8] According to IIROC's published market shares statistics, TMX Select's 2012 market share of dollar volume was around 1.4%. IntraSpread is not listed separately in IIROC's market shares because IntraSpread is technically part of Alpha's main market. According to Alpha's April 2012 newsletter, the market share of IntraSpread™ was about 3.5-4%.

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have multiple unique identifiers if they trade through multiple TSX participating organizations (i.e., multiple brokers), or for business or administrative purposes.[10] To the best of our knowledge, most brokerages funnel specific types of order flow through separate unique identifiers, and they do not mix, for instance, retail and institutional order flow.

Our sample contains a total of 14,182 unique identifiers, but only around 2,000 unique identifiers are active in the market per month. It is our understanding that a unique identifier may be associated with a particular individual or with a particular algorithm, and that identifiers may be replaced when traders or algorithms change. Panel A in Figure 8 plots the number of unique identifiers in our sample across time.

B Sample Selection

Securities. Our main analysis focusses on the 48 equities that are continuously in the S&P/TSX60 index (Canada's Blue Chip index) for our sample period.

When classifying traders, we additionally consider their trading activities in those exchange traded funds (ETFs) that displayed more than 1,000 trades. We have chosen to expand the sample of securities for classification purposes, as common shares and ETFs are likely two most frequently used securities by high-frequency traders on the TSX.[11]

Dates. We study the period from July 1, 2006 to June 1, 2012.[12] For each security, we exclude the entire day if trading in that security was halted. We are interested in "normal" activity, and most of our trader classification is by week. We thus exclude weeks that saw either extraordinarily low or high activity. Specifically, we exclude the weeks that had 3 or fewer days of both U.S. and Canadian trading: the week of the 4$^{\text{th}}$ of July (the first of July is a national holiday in Canada) in 2006, 2007, and 2008; the weeks of US Thanksgiving;

[10] See the description of User IDs and account types in IIROC (2012). In IIROC's data, a User ID may use different account types, e.g. proprietary and client. In our data, different account types for the same user would correspond to separate unique identifiers.

[11] A recent study by a Canadian regulator IIROC finds in their sample that 68% of trading volume by unique identifiers with high-order-to-trade ratios trade is common shares and 28% of it is in ETFs; see Table 5 in their study.

[12] The TSX introduced so-called maker-taker pricing for all TSX listed securities on July 1$^{\text{st}}$, 2006. This fee schedule, which rewards the liquidity-providing side of a trade with a rebate while charging the liquidity taking side, is generally seen as a prerequisite for high-frequency trading.

the last week of all years, and the first week of the year in 2007, 2008, and 2009. We further exclude the week of the May 6th 2010 Flash Crash and the five weeks following the Lehman Brothers bankruptcy on September 15, 2008. Finally, we exclude the week of December 15, 2008 because the TSX experienced a technical glitch on December 17, 2008 and was closed for the entire day; trading activity on the following day (December 18, 2008) was also extremely low. Finally, our data files for January 2008 were corrupted and we have no data for this month.

C Classification of Traders

For each security, each day and each unique identifier we compute a number of trading characteristics: the buy and sell volume, transactions, and dollar volume (for the day, for intra-day trading in a limit order book, and for odd-lot trading); the number of messages sent and received (where a message is defined as a trade, a new or modified order, a cancellation of an order, or a fill-or-kill submission; an order modification in our data generates two messages). We generate almost 16 million per-day-per-stock-per-trader observations.

Our goal is to classify traders by simple, transparent criteria and to identify three distinct groups: high-frequency traders, as well as the least sophisticated and the most sophisticated non-high-frequency traders, who we would refer to as "retail" and "institutional", respectively. We aim to study the impact of HFT on the two non-HFT groups, arguably at the opposite ends of sophistication, and we do not study the impact on the remainder of the market.

We discuss the criteria in detail below; Table I summarizes these criteria; Panel B in Figure 4 illustrates the number of unique identifiers that we classify.

Non-sophisticated (Retail) Traders. In the past, researchers associated retail trades with small order sizes. In today's market, large institutional orders, referred to as "parent" orders, are commonly split into smaller "child" orders before being submitted to the exchange, thus retail orders may exceed the average order size. Since our data only allows us to see the orders sent to the exchange, an observed order size is a poor proxy for the level

Table I
Trader Classification Criteria in a Nutshell

Type of Trader	Criteria	Time Horizon	Securities	Median per day per stock	Total 2006-2012
Retail	uses "stale" orders or proprietary method	monthly	across all	42	1320
Institutional	$\geq \lvert\$1,000,000\rvert$ net position	weekly	by security	17	4818
HFT	$\geq$100,000 msgs on a day	weekly	across all	23	321

of trader sophistication.

For the later years of our sample, we are able to precisely classify some unique identifiers as retail, based on proprietary methods.[13] We are unable to restrict our sample of retail traders to these unique identifiers, however, because unique identifiers get replaced or newly introduced over the years.

We thus introduce a second qualifying criterion, and we use the time that a trader's passive order remained in the limit order book as a proxy for the trader's monitoring activities and the level of sophistication. Specifically, we classify a unique identifier as managing non-sophisticated ("retail") order flow if in a given month the unique identifier has at least one transaction with an order that was re-posted from a previous day (orders on the TSX do not automatically cancel at the end of the day). We refer to such overnight orders as "stale". While these unique identifiers do not necessarily represent retail clients, trading with stale orders indicates low market monitoring, which we believe to be correlated with traders' levels of sophistication.[14]

The practice of trading with "stale" orders is arguably endogenous to market conditions, and we indeed observe a decline over time in the number of traders that use them. How-

[13]Based on this method we capture some, but not necessarily all of unique identifiers that represent a retail flow and that trade on the TSX.

[14]We acknowledge, however, that some sophisticated trader may occasionally trade with "stale" orders because they post so-called "stub" orders at extreme prices.

ever, the total number of traders that either use "stale" orders or that we identify using proprietary methods remained relatively stable over time, with an average of 42 traders per day per stock (see Table II) and a total of 1320 (over the 6-year time span).

High Frequency Traders. We classify unique identifiers as high frequency traders based on their technical capability to submit orders at high frequency. Specifically, we classify a unique identifier as an HFT if in a given week on at least one day this unique identifier generated more than 100,000 messages, in total across the securities.[15] Of the 14,182 unique identifiers in our 6-year sample, 321 classify as HFTs.

We acknowledge that our classification is biased towards message-intensive strategies such as market making. It is imaginable that we do not capture traders that have the capacity to react quickly to changes in trading environment but do not otherwise trade at the highest frequencies. Linking trigger and reaction events is, however, too complex, particularly, given that participants may have reacted to information that is outside the TSX dataset.

While there is little precedent for a methodology on the long-run classification of HFTs, several classifications have been used in the literature, albeit for shorter horizons. Several authors focus on inventory criteria such as inventory mean-reversion and zero overnight inventory to identify HFTs. Kirilenko, Kyle, Samadi, and Tuzun (2011) study trading in E-mini S&P 500 futures and classify HFTs based on high volume and low inventory. Menkveld (2013) identified a single large HFT as a broker ID that participated in 70-80% of all Chi-X trades; he confirmed that this unique identifier is an HFT by pairing this broker ID with a broker ID on Euronext and observing that the aggregate inventory was mean-reverting. We are unable to use inventory as a criterium, for two reasons. First, we do not have data from all marketplaces, and some of the securities that we study are also cross-listed with U.S. exchanges and trade in the U.S. Second, high frequency traders are likely to utilize direct market access, and, according to IIROC (2012), direct market access clients may choose to

[15] A loose justification of this number is as follows: according to Hasbrouck and Saar (2011), minimal human reaction time to visual stimulus is 200 milliseconds, and thus a person, in principle, should be able to perform 4-5 message submissions per second. The trading day has 23,400 seconds, so that theoretically a person could generate roughly 100,000 messages on any given day.

have more than one unique identifier.[16]

Another criterium that has been used in the literature is the ratio of the number of orders submitted by a trader to the number of trades executed by the same trader. For instance, IIROC (2012) studies unique identifiers that have a high order-to-trade ratio, and Malinova, Park, and Riordan (2012) classify traders based on their message-to-trade ratios and numbers of transactions. The ratio of messages to trades is, however, endogenous to prevailing market conditions, and it is difficult to find the appropriate message-to-trade threshold that would classify traders as HFTs over a long time horizon. Over our sample period the number of messages more than quadrupled, yet the trading volume did not see the same dramatic increase.

Institutional (Sophisticated) Traders. We are interested in traders who build (or possibly trade out of) a significant position in a given week, who are reasonably sophisticated and who do not employ high-frequency strategies to execute their trades. Specifically, we classify an unique identifier as an institutional trader if its net position (the absolute dollar volume of buys minus sells) in a given stock exceeds $1,000,000. We exclude traders that we classify as HFTs or retail, and we further exclude unique identifiers with account identifiers that correspond to option market makers, equity specialists, and traders who trade on a broker's inventory. The classification is performed per stock per week; being an institutional trader in one stock has no bearing on this trader's classification in another stock.

Figure 4 plots both the total number of traders and the average number of traders of a given type per stock.

[16]In their study, IIROC further splits activities of higher-order-to-trade (HOT) unique identifiers into activities by direct market access (DMA) customers, brokerages proprietary trading activities, and orders and trades that brokerages execute on behalf of their customers. IIROC knows the User IDs of DMA clients — our data does not identify DMA clients, and our analysis does not distinguish between HFT firms (clients/customers) that have DMA relationships with brokerages and the brokerages' own trading desks that have superior technological capabilities.

III Methodology and Trader Profits

Trader Profits. The main focus of this analysis is on the relation of intra-day trader profits and HFT activities. The per stock s, per day t, per trader-group i (retail, HFT, and institutional) profit is

$$\text{profit}_{its} = (\text{sell \$ vol}_{its} - \text{buy \$ vol}_{its}) + (\text{buy vol}_{its} - \text{sell vol}_{its}) \times \text{closing price}_{ts}, \quad (1)$$

where sell \$ vol_{its} and buy \$ vol_{its} are the total sell and buy volumes, measured in dollars, respectively, for the trader-group i, and buy vol_{its} and sell vol_{its} are trading volumes measured in shares for this group. The underlying idea is that (sell \$ vol_{its} − buy \$ vol_{its}) signifies the profit from intra-day trading; (buy vol_{its} − sell vol_{its}) is the end-of-day net position (assuming a zero inventory position at the beginning of each day), which we evaluate at the closing price, $\text{closing price}_{ts}$. Another way to think about the components of the profits is that (sell \$ vol_{its} − buy \$ vol_{its}) signifies the cost of the position and (buy vol_{its} − sell vol_{its}) × $\text{closing price}_{ts}$ signifies what the trader should have paid had he been able to trade at the (presumably) efficient benchmark price.

For most of our analysis, we use per share profits, where we divide the gross profit by the total number of shares traded (the measure is expressed in cents) and per dollar profits, where we divide our gross profit by the total dollar volume traded (the measure is expressed in basis points).

We acknowledge that our analysis is based on TSX trading only — traders may well trade on other Canadian venues or in the U.S. as part of a cross-venue or cross-country arbitrage strategy, and thus their actual trading profits may be different from the ones that we record. This issue is partly mitigated, as we focus on trading profits of groups of participants (rather than individual traders) and study daily profits that are aggregated over 67 securities — for our profit measure to exhibit a systematic bias, the entire group of interest must persistently choose, for instance, to buy all the securities on the TSX and to sell them on a different exchange.

Maker-Taker Fee Adjustments. Throughout our sample, the TSX applied maker-taker trading fees. The main focus of our analysis is on profits by retail and institutional investors, and it is debatable whether maker-taker fees should be included in their profit computation. One complicating factor is that it is not clear whether a broker passes on the fees to its customers — this practice differs by brokerage and by the type of client. For instance, brokerages frequently charge their retail clients a fixed fee per trade, but pass through both taker fees and maker rebates to their direct market access clients.

We have conducted the analysis both, accounting for and excluding the maker-taker fees, and we present the corresponding summary statistics. We present regression results for profits for these two groups, excluding maker-taker fees; results on profits accounting for the fees are qualitatively similar and we omit them. We compute maker-taker payments that a trader group incurs per share as[17]

$$\text{maker rebate}\times\%\text{passive}-\text{taker fee}\times\%\text{active}, \text{ where } \%\text{ passive} = \frac{\text{passive intra-day volume}}{\text{total intra-day volume}}.$$

Intra-day volume is the volume that is traded during the continuous trading session, via the limit order book plus odd-lot volume, and it excludes market-on-open trades, market-on-close trades, after hours trades, and dealer crosses. Odd-lot trades, i.e., trades (or portions of trades) for less than 100 shares are executed with a registered trader and are always liquidity-taking trades.[18]

Bid-Ask-Spread Adjustments. If prices in a stock are always efficient in the sense that the midpoint reflects the true value of a stock, then a trade with a market order will result in a negative profit — which is half the bid-ask-spread. A trade with a limit order, conversely,

[17]The maker-taker fees that the TSX levies on brokers depend on a broker's overall TSX-based trading volume; furthermore, equity specialists and so-called electronic liquidity providers (typically, high-frequency traders that are more than 65% passive in at least 25 securities with an average share volume in excess of 500,000 shares)) face fee schedules that are different from the rest of the market. Additionally, market-on-open trades, market-on-close trades, dealer crosses, and, as of mid-2011, dark trades all involve different fees. For our present analysis, we use the maker-taker fees for the highest available rebate and the lowest available taker fee. Prior to Nov 01, 2007, the best maker/taker fees were \$0.0032 taker/\$0.0031 maker; after April 01, 2010, the best maker/taker fees were \$0.0033 taker/\$0.0032. We ignore exchange fees for the market-on-open trades, market-on-close trades, after hours trades, and dealer crosses.

[18]See Malinova and Park (2011) for further details on odd-lot trading on the TSX.

would result in trading profit of a half-spread. Put differently, trading profits, relative to an efficient benchmark, have a mechanical profit-loss relation due to bid-ask spreads. To adjust for this mechanical portion, we compute[19,20]

$$\text{transaction costs}_{its} = \frac{1}{2} \times \frac{\text{espread}_{its}^{\text{active}} \times \text{vol}_{its}^{\text{active}} - \text{espread}_{its}^{\text{passive}} \times \text{vol}_{its}^{\text{passive}}}{\text{vol}_{its}^{\text{active}} + \text{vol}_{its}^{\text{passive}}}, \qquad (3)$$

where $\text{espread}_{its}^{\text{active}}$ and $\text{espread}_{its}^{\text{passive}}$ are the average volume-weighted effective spreads incurred (or received) by trader-group i when they are on the active (market order) and passive (limit order) sides of the transaction, respectively, and $\text{vol}_{its}^{\text{active}}$ and $\text{vol}_{its}^{\text{passive}}$ are trader-group i active and passive trading volumes.

We then compute per share profits, net of the average transaction costs, as a sum of the per share (per dollar) profit and the above per share (per dollar) transaction cost, normalized by the trader-group i's intra-day fraction of share (dollar) volume (since no spread costs are incurred on market-on-open and market-on-close trades, or on dealer crosses).

Our methodology for computing profits net of the actual per-group transaction costs in (3) is similar to Menkveld (2013); he focuses on profit computations for a single high frequency trader, profits net of the actual transaction costs then become this trader's "positional revenue."

[19]We also performed an adjustment by "average" transaction costs. Namely, we compute "average" per share and per dollar transaction costs for a trader group i (retail, institutional, and HFT), per day t, per stock s, as follows:

$$\text{transaction costs av}_{its} = \frac{1}{2} \times \text{effective spread}_{ts} \times (\%\ \text{active}_{its} - \%\text{passive}_{its}), \qquad (2)$$

where $\text{effective spread}_{ts}$ is the average, volume-weighted effective spread (in cents for the per share computations and in basis points for the per dollar computations); and $\%\ \text{active}_{its}$ and $\%\ \text{passive}_{its}$ are fractions of passive and active intra-day trading volumes for trader-group i. This adjustment for the average transaction cost accounts for the profits/losses from trading passive/active, assuming that a trader is able to trade at the average prevailing cost. The actual trading costs that are incurred by each trader group thus account potential differences in timing abilities of institutional, retail, and high frequency traders.

[20]When estimating the average transaction costs, we only consider costs incurred when trading in the limit order book and we use limit order book trading volumes. We further exclude the first 10 minutes of the trading day, to exclude any effects of the opening trades and the last 20 minutes of the trading day, to exclude market-on-close effects on the spread, since market-on-close imbalances are first published at 15:40.

Regression Methodology. In our regression analysis we seek to understand the relation between retail and institutional trader profits and HFT activities. We are further interested to understand the relation between retail trader activities (which are arguably the most random of the three trader groups), such as trading volume and the fraction of trading volume that stems from "stale" orders, and their own and other participants' trading profits. Finally, we want to understand to what extent market quality variables, such as bid-ask spreads and price impacts, can explain variations in trader profits.

We employ standard OLS regression, using stock fixed effects and stock and date double clustered errors to account for autocorrelation and heteroscedasticity. To ensure that our results are not driven by outliers, we winsorize profits and per-trader spreads and price impacts at the 1% level.[21]

Specifically, we are interested in % HFT of all messages, %HFT of all dollar volume, per share/per dollar HFT maker-taker fees as measures for HFT activities; log-dollar volume of retail trading and % retail passive or all retail volume for retail activities; and quoted bid-ask spreads (in cents and bps), intra-day price fluctuations and 5-minute price impact as market quality measures. The definitions for market quality measures are standard in the literature, and we outline them in the appendix. The dependent variables of interest are retail trader profits both per share and per dollar traded, with and without an adjustment for transaction costs, and the institutional trader cost per share and per dollar traded.

Many of the possible explanatory variables (for instance, market quality measures) are strongly correlated with HFT activities. We thus present our results for simple regressions in which the respective variable is the only explanatory variable that was used. Specifically, we estimate the following type of equation

$$\text{profit group } j = \alpha_{(i)} + \beta \text{HFT/retail activity/market quality measure}_{st} + \epsilon_{it}, \qquad (4)$$

where $\alpha_{(i)}$ are the stock fixed effects and β is the coefficient of interest. To further understand the evolution of effects across time, we further provide results for a specification in which

[21] Results without winsorization are qualitatively similar.

we split the covariates by year:

$$\text{profit group } j = \alpha_{(i)} + \sum_{k=1}^{7} \beta_k \text{year}_k \times \text{HFT/retail activity/market quality measure}_{st} + \epsilon_{it}, \quad (5)$$

where year dummy$_k$ is a dummy that is 1 in year $2005 + k$ and 0 otherwise. Coefficients β_k capture the effects by year.

IV Results

Table I presents summary statistics by year from July 2006 to July 2012. We report statistics on the average midpoint and average (arithmetic) daily return based on daily midpoints of the bid and ask prices, market liquidity, measured by bid-ask spreads, and market-wide activity. The effects of the 2008 financial crisis can be seen in the average market prices as average prices drop from 2008 to 2009. Moreover, from 2011 to 2012 we note a further drop in prices, triggered by the debt crisis in the PIGS countries in Europe and the political stand-off on the debt ceiling in the U.S. We further report averages for quoted spreads in cents and basis points (bps). Over time, bid-ask spreads fall by almost 50%, both in terms of cents and in terms of basis points. This effect is illustrated graphically in Panels C and D in Figure 6. The panels further exhibit a spike in spreads at the height of the 2008 financial crisis, following the collapse of Lehman Brothers. Finally, Table I reports average daily per-stock dollar- and share-volumes of trading, the number of transactions and the number of total messages on the TSX. In dollar terms, average daily trading volume on the TSX has remained stable between 2007 and 2012 (albeit, the TSX market share has declined), but there have been substantial daily fluctuations during the financial crisis. Over time, the number of transactions has more than doubled. As Panel B in Figure 6 highlights, this increase goes hand-in-hand with a substantial drop in the average order size. Furthermore, between 2007 and 2009, the total number of messages has quadrupled.

A Trader Activities

Table II reports summary statistics on trading activity, broken down by individual trader type; HFT, retail, and institutional. The average number of HFTs per stock per day increases from 5 in 2006 to 26 in 2012. The number of retail and institutional accounts remains relatively stable over the sample period. From 2009 onwards, HFTs trade more than 63% of their volume passive; prior to 2009 this ratio is lower. This shift goes along with the entry of major HFT firms into Canada (see our references to the public record above) and with the introduction of the TSX's Electronic Liquidity Provider (ELP) program. We further observe that on average retail traders trade more passively in later years. Consequently, even though HFTs enter the market for liquidity provision, retail traders frequently get their passive orders filled. Institutional traders, on the other hand, reduce their liquidity supplying activities over time and trade actively more frequently.

The table further confirms Panel B from Figure 6 in that average transaction sizes fall overall and for all traders types. Both HFTs and institutions as groups increase the total number of messages over time, although HFTs submit considerably more messages overall and the number quadrupled between 2006 and 2012. The percentage of messages by HFTs increases from 45% to 76% highlighting the increase in their activities during this period. Dollar volume and the percentage of dollar volume show similar trends until 2009, after which volumes are stable. After 2008, on average, HFTs submit more than 90 messages for each transaction; retail traders and institutional traders submit about 4-5 messages per transaction and their message-to-trade ratios are stable across time.[22]

B Trader Costs: Spreads and Price Impacts

Table III lists the trading costs that different groups of traders chose to trade at. When trading actively with marketable orders, HFTs pay smaller effective spreads compared to retail traders and institutions; notably, even in 2012, when spreads by groups are closest,

[22] Messages include order submissions, cancellations, and transactions; an order modification is represented in our data as two messages, an order submission and a cancellation.

retail traders still trade at spreads that are on average 25% wider relative to the spreads that HFTs trade at. Retail traders also trade at substantially lower and on average negative realized spreads, implying that when a retail trader gets a limit order executed, the price will likely move against the trader subsequent to the trade. This point is confirmed by the price impact that traders face when they are on the passive side. While all trader groups face a positive price impact when trading with limit orders, indicating that they are adversely selected, retail traders face a larger than average price impact and thus face higher than average adverse selection costs. Finally, retail traders cause lower than average price impact when trading aggressively, with market orders, confirming the intuition that, on average, their trades are the least informed. In summary, retail traders face highest effective spreads, receive lowest compensation for providing liquidity, and generally see prices move against them. These findings are consistent with the notion that retail traders constitute the least sophisticated group in the market.

Panel D in Figure 6 is in line with these observations. Realized spreads in particular display a marked drop between 2008 and 2009 when high frequency trading picked up substantially. The average realized spread, as suggested by the figure, is negative. The summary statistics suggest, however, that HFTs are able to at least partially avoid being adversely selected when trading passively — their realized spread, while negative in later years of our sample, is the highest among the three trader groups that we study.[23]

C Trader Profits — Summary Statistics

The summary statistics provide us with insights into the market structure in Canada and the breakdown of trading across different trader types. We are particularly interested in analyzing how each group of traders has fared as the Canadian market has modernized. Our focus here is on the intra-day profits, not on holding period returns.

Panel A in Figure 8 plots the per day profits, aggregated across securities, for the three

[23] We compute a 5-minute realized spread. The adverse selection may be lower for HFTs, if they are able to trade out of the position faster.

trader groups. Panel B in Figure 8 displays the cumulative aggregate intra-day trading profits. This latter figure allows for a cleaner visual inspection across time. As can be seen, retail traders lose on average, institutional traders and HFTs make positive profits.[24] Since the dollar volumes of the three groups that we study add up to only 60% of volume and since profits across all traders are zero-sum, the remaining group of traders, on average, will make negative profits.

Table IV reports per stock per day trading profits broken down by trader groups. We first observe that HFTs become increasingly competitive in the later part of our sample since their combined, per group, profits fall from $6,381 per day per stock in 2009 to $1,196 in 2012. At the same time retail profits increase, albeit they remain negative, from -$11,561 in 2009 to $-3,016 in 2012, suggesting that the competition among HFTs may have benefited the least sophisticated traders. Institutional trading profits remain relatively stable, except for a large dip in 2008.

Per share traded, HFTs earn less than 0.1 cent per share traded from 2010 onwards. Over time, retail traders' losses decrease per share from 1.7 in 2006 to 0.2 cents in 2012. Institutions also see a mild decrease in per share profits. Per dollar profits exhibit similar characteristics. HFTs trading profits decline from 1.1 basis point per dollar traded in 2009 to 0.1 basis points; retail traders have been able to reduce their trading losses over time, from -3.3 bps in 2006 to -0.9 in 2012.

Table IV further illustrates the importance of maker-taker fees for HFT trading profits. In the later years of our sample, as competition intensifies, HFT per dollar profits stem primarily from liquidity rebates.

As we argued above, bid-ask-spreads have a mechanical impact on traders in that those who trade with market orders should, on average, lose on the intra-day level due to the bid-ask spread. At the same time, reductions in the bid-ask spread benefit only those who trade with market orders — those who trade against market orders will obtain a lower spread.

[24] Our finding that retail traders make negative trading profits is consistent with the previous literature, see, e.g., Barber and Odean (2000). Our focus is on the evolution of profits and losses over time, with the changes in market structure.

We account for both effects simultaneously and net out the effect of transaction costs by adding average transaction costs to profits.

Figure 9 illustrates losses from transaction costs vis a vis losses from trading: only a small share of retail trader losses can actually be attributed to bid-ask spreads. Our summary statistics confirm this visual observation. Retail losses remain negative, even after netting-out transaction costs. Figure 9 additionally illustrates that retail traders incur higher than average transaction costs.

D Trader Profits — Regression Analysis

The summary statistics suggest that retail and institutional trader profits increase across time, as HFT activity intensifies. We now attempt to formally establish the link using a regression analysis. As outlined above, we follow a simple approach in which we regress retail trader profits and institutional trader profits on individual explanatory variables. The variables that we choose fall, loosely, into two categories: first, HFT activity (the fraction of messages submitted by HFTs, the fraction of dollar-volume traded by HFTs, the the fraction of their volume that HFTs trade passively); second, retail activity (the logarithm of retail dollar volume, the fraction of their volume that retail traders trade with passive limit orders, and the fraction of their volume that is traded with overnight orders). For each explanatory variable, we run regressions for the whole sample and split by year. Since the explanatory variables are correlated, we employ only one at a time.

Retail Profits and HFT Activity. Table V shows that retail profits are generally positively associated with HFT activities, both in terms of per share and per dollar profits. That is, as HFT increase their activity level (e.g., by increasing their share of volume or messages), retail profits increase. The estimated coefficients on the share of volume and the share of messages are highly significant. The benefit of HFT activities for retail extends beyond bid-ask spread, because even true for positional profits, after we net out transaction costs, HFT activities are beneficial. The first two columns in Panels A and B of Table VII

and of Table VIII further highlight that HFT activities benefit retail trader profits across time, and that the benefit is most pronounced in later years when competition among HFTs has intensified.

The HFTs passive ratio can be understood as the extent of HFT intermediation; moreover, since passive trades earn HFTs a maker rebate, and since the rebate is, arguably a redistribution of rents from takers of liquidity to makers of liquidity, the passive ratio can be thought of as an HFT tax on trading.[25] However, we do not find a negative effect either for the full sample or the the by-year specifications.

Retail Profits and Retail Activity. Table V shows that retail activities are generally negatively associated with retail profits. The more retail traders trade and the more they trade with stale orders, the more they lose per share (and per dollar) that they trade. This insight is not immediately obvious: ceteris paribus, higher activity by retail traders could create more noise and may lead to, on average, lower spreads and thus lower losses per share (or per dollar). Our data does not lend support for the above intuition. We observe that trading volumes are positively correlated across groups, and thus retail traders trade more when everyone else also trades more. Consequently, increased retail trader activities do not lower the spreads, and instead the more retail traders trade, the more likely they are to be on the wrong side of the market. Column three in Panels A and B of Table VII and of Table VIII shows that this relation persists across time.

Table V and column four in Panels A and B of Table VII and of Table VIII all indicate that trading a larger fraction of one's shares with passive limit orders isn't good news for retail traders either: the higher the fraction of passive trades, the more retail traders lose.

Institutional Profits and HFT Activity. Table VI shows that institutional profits are generally not related to HFT message activities or HFT volume, negatively or positively, neither in terms of per share or per dollar profits. When splitting the effects by year in

[25]Table IV confirms the industry perception that HFTs, on average, earn a positive fee; see also the aforementioned article in the Globe and Mail from Jan. 31 2011.

Table IX we observe that there are a number years when there is a negative association between institutional profits and the HFT share of volume. This effect, however, is not persistent, and it does not appear in trading profits per dollar traded.

Maker-taker fees earned by HFTs generally have a positive impact on institutional profits, both across the sample, Table VI, and when splitting across years (column five in Table IX). In the latter case, the effect appears in later years. Our findings suggest that institutional traders are able to use the liquidity that HFT provide to their advantage.

Institutional Profits and Retail Activity. Tables VI and Table IX show that the more retail traders trade, the more institutional traders profit. It appears institutions are able to from the total retail volume, and that they also benefit as retail traders trade a larger fraction of their volume with passive limit orders. Arguably, institutional traders that build up a position speculate on a price movement and, assuming they are, in fact, good at predicting future movements, retail traders trading against institutions provide cheap liquidity.

E By-Trader Spreads and Price Impacts: Regression Analysis

We focus on retail traders and we compute effective spreads and 5-minute price impacts when the trader is on the active and passive side. If on the active side, a trader pays the effective spread and causes the price impact. If on the passive side, the trader gains the effective spread but suffers the price impact. We study the relation of per-trader spreads and price impacts and HFT activity.

Per-trader effective spreads. We observe that effective spreads per trader are generally negatively associated with HFT activity. The estimated relation is larger for the passive side, implying that the gains from lower active costs are offset by lower spreads when providing liquidity. Across the years, we observe that until 2009, the relation of HFT activity and per-trader spreads is positive but that it reverses as of 2010.

Per-trader price impacts. There is no relation between per-trader price impacts when on the active side and HFT activity. When on the passive side, the fraction that HFTs trade passively is negatively related to the price impact that a liquidity providing retail trader faces. As with effective spreads, we notice that the latter effect flips from being positive to negative after 2010.

V Price Discovery and Trader Activities

The literature has developed a number of measures to capture the speed and extent to which prices incorporate new information; generally speaking, the faster the price discovery process, the more informationally efficient are the prices. Efficient prices benefit uninformed traders as they can then trade at the "fair", fundamental value.

Autocorrelation of Returns. Similar to Hendershott and Jones (2005) we compute the autocorrelation of mid-quote returns, for 30 seconds, 1 minute, 5 minutes, 15 minutes and 30 minutes. A lower absolute value of the autocorrelation is associated with higher market efficiency because prices mimic a random walk. We observe that as of 2009, when HFT trading became more prevalent in Canadian markets, autocorrelation of 30 second and 1 minute returns declined, while longer-horizon return autocorrelations remain unaffected. Although the decline suggests an improvement in price efficiency, one could also argue that the quoting activities and the interplay between different HFTs itself may create noise that just looks like improved price discovery. In our regression, we observe that 30-second autocorrelation and HFT activities, including passive trading, are negatively related.

Variance Ratios. If prices are efficient and follow a random walk then the variance of mid-quotes is linear in the time horizon. Consequently, the closer the scaled ratio of variances over two time horizons, following Campbell, Andrew, and Mackinlay (1997) defined formally as $|\sigma_{tk}/(k\sigma_t)-1|$, is to 0, the more efficient is the market. We computed the ratio for a variety of time-length variations. In the aggregate, as for autocorrelation, as of 2009 short-horizon

variance ratios (30-seconds to 1 min, 1 minute to 5 minutes) drop visibly whereas longer-horizon variance ratios remain unaffected. In our regression, we observe that 1-minute/30-second variance ratio HFT activities, including passive trading, are negatively related.

Intra-Day Volatility. We computed two range measures. The first is the difference of the highest mid-quote per day minus the lowest mid-quote scaled by the average mid-quote. The second is the average of the high-low range for 10-minute intervals, scaled by the average daily mid-quote. The first two measures are strongly correlated with overall market volatility as measured by the volatility index VIX. Both measures are positively associated with HFT volume and message activities and negatively with higher fractions of HFT passive trading. These findings are persistent over the years. The positive relation of HFT activities and volatility do not imply causality — instead, HFTs may merely find it beneficial to trade when volatility is high. There is also a positive relation between volatility and retail dollar volume.

Price Impact from Spread Decomposition. The price impact of a trade is the signed difference of the mid-quote x minutes into the future minus the mid-quote at the time of the transaction. We observe that price impact is negative related to HFT activities, the relation is statistically weal, however, and in particular when price impact is measured in basis points of the prevailing mid-quote. Price impact and retail activities are positively related. Since retail traders have lower price impact, this latter finding suggests that retail traders are more active when price impacts are higher. Much of the positive relation is driven by the first years in our data.

Volume-synchronized Probability of Informed Trading. We follow the description in Easley, de Prado, and O'Hara (2012) and compute the Volume-synchronized Probability of Informed Trading (VPIN) based on 50 dollar-volume based trading buckets as

$$\text{VPIN}_t = \sum_{i=1}^{50} \frac{\text{buy volume}_{it} - \text{sell volume}_{it}}{50 \times \text{average volume}}.$$

The average volume is computed over the entire sample for intra-day trading from 9:35 to 15:55. The identification of volume as buyer and seller-initiated is part of our data. For the 50-observation moving average, we compute the cdf over the sample and we use the average daily cdf value in our regressions. Aggregated over the entire sample, we observe that VPIN shifts down at the beginning of 2009. There are a number of possible explanations for this shift. First, after 2009 there were multiple marketplaces in Canada and traders may thus be able to split their volume across different venues. Second, with the advent of high-activity HFTs, traders may have started to trade more cautiously, splitting large orders over time. As a consequence, large orders may get spread over multiple buckets, thus watering down the VPIN measure. We observe that VPIN in negatively associated with HFT activities, in particular for later years in our sample. Retail volume is positively related with VPIN, suggesting that retail traders are active when flow is more toxic whereas HFTs are able to avoid toxic flow.

VI Discussion and Conclusion

Government agencies across the world are discussing how to regulate high frequency trading. In March 2013, the U.S. "FBI decided to join the S.E.C. to investigate the potential threat of market manipulation via computerized trading."[26] In a recent comment letter to IIROC, the Canadian RCMP asserted that "HFTs are making vast sums of money [...] It would appear that genuine investors are systematically disadvantaged and are experiencing losses as a result of the early intervention of HFTs."

Equipped with highly granular data, we perform a detailed analysis of traders' profits. Specifically, we study the evolution and the determinants of profits for trader groups that we believe to be the most and the least sophisticated non-high frequency traders in the market. While our results are preliminary, we find no evidence that HFT activities systematically disadvantage investors at either end of the sophistication spectrum.

[26]Financial Times, March 05, 2013 "FBI joins S.E.C. in computer trading probe" by Kara Scannell.

Over time, retail traders' trading losses have decreased overall and on a per share and per dollar trading basis. While some portion of this improvement is due to tightened bid-ask spreads, overall, direct transaction costs account only for a small portion of profits and losses and much work remains to be done to understand why, on the aggregate level, unsophisticated traders seem to lose persistently. Our preliminary results do not point in the direction of high frequency traders as the culprit in retail trading losses. If anything their activities appear to benefit the least sophisticated traders.

Our focus is on intra-day trading profits, and we do not account for cost factors other than direct trading costs in the form of bid-ask spreads or exchange trading fees. Industry participants and academics have argued that the development of high frequency trading may impose externalities on other market participants, for instance, by compelling them to upgrade trading technologies and to invest in infrastructure to process the information from the dramatically increased number of order submissions and cancellations.[27] Ye, Yao, and Gai (2012) find evidence that fast market participants may engage in so-called quote stuffing, or submitting an extraordinarily large number of messages to generate data congestion, potentially imposing additional data processing costs on market participants. We recognize the possibility that brokerages may be facing increased infrastructure costs as high frequency trading becomes more prevalent. As we have no information on these costs, we cannot account for them.

Finally, we also note that the profits and losses that we compute are for intra-day trading only. Over longer holding periods, it is possible that even retail traders, who have negative intra-day profits, earn a positive return on their long-term investment. As these long-term returns are only weakly related to changes in market structure and increases in HFT we do not study them here.

[27]For instance, during the 2012 IIROC/OSC Market Structure conference, Stephen Bain, of RBC Capital Markets, asserted that HFTs have triggered a constant arms race of technology that forces market participants such as exchanges and brokers, to invest millions into new equipment (Toronto Star "High-frequency traders growing in influence" June 27 2012 and the audio record at http://www.osc.gov.on.ca/static/_/OSC-IIROC-2012/msc_20120626_osc-iiroc_pd-study-hft.mp3).

Appendix: Liquidity and Trading Cost Measures

A Quoted Visible Liquidity

We measure quoted liquidity using time weighted quoted spreads and depth. The *quoted spread* is the difference between the lowest price at which someone is willing to sell, or the best offer price, and the highest price at which someone is willing to buy, or the best bid price. We use spread measures expressed in cents and in basis points of the prevailing midpoint of the bid-ask spread.

B Effective Liquidity

Quoted liquidity only measures posted conditions, whereas effective liquidity captures the conditions that traders decided to act upon. The costs of a transaction to the liquidity demander are measured by the *effective spread*, which is is the difference between the transaction price and the midpoint of the bid and ask quotes at the time of the transaction. This measure also captures the costs that arise when the volume of an incoming order exceeds the posted size at the best prices. For the t-th trade in stock i, the proportional effective spread is defined as

$$espread_{ti} = 2q_{ti}(p_{ti} - m_{ti})/m_{ti}, \tag{6}$$

where p_{ti} is the transaction price, m_{ti} is the midpoint of the quote prevailing at the time of the trade, and q_{ti} is an indicator variable, which equals 1 if the trade is buyer-initiated and -1 if the trade is seller-initiated. Our data includes identifiers for the active and passive side of each transaction, precisely signing the trades. Our data is message by message, and it includes quote changes. This allows us to identify the prevailing quote at the time of each transaction. All trade based measures are computed as volume-weighted daily averages.

The change in liquidity provider profits is measured by decomposing the effective spread

into its permanent and transitory components, the *price impact* and the *realized spread*,

$$espread_{ti} = 2 \times priceimpact_{ti} + rspread_{ti}. \tag{7}$$

The price impact reflects the portion of the transaction costs that is due to the presence of informed liquidity demanders; a decline in the price impact would indicate a decline in adverse selection. It is also the amount by which the midpoint moves between time t and some time $t+x$ in the future. Since we use full spreads, i.e. twice the difference between the bid and ask price, we multiply the price impact with factor 2. The realized spread reflects the portion of the transaction costs that is attributed to liquidity provider revenues. In our analysis we use the five-minute realized spread, which assumes that liquidity providers are able to close their positions at the midpoint five minutes after the trade. The five-minute proportional realized spread is defined as

$$rspread_{ti} = 2q_{ti}(p_{ti} - m_{t+5\ \mathrm{min},i})/m_{ti}, \tag{8}$$

where p_{ti} is the transaction price, $m_{t+5\ \mathrm{min},i}$ is the midpoint of the quote 5 minutes after the t-th trade, and q_{ti} is an indicator variable that equals 1 if the trade is buyer-initiated and -1 if the trade is seller-initiated.

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Table I
Basic Market Variables

This table presents summary statistics for major trading variables by year. Each number is per day per security for the 48 stocks in our sample. The sample is from July 1st 2006 to June 1st 2012, but omits a number of weeks as described in the Section II. Daily returns refer to the simple, non-compounded average. The minimum price increment/tick size in our sample is 1 cent.

	Units	2006	2007	2008	2009	2010	2011	2012
daily midpoint	dollars	50.9	54.3	47.2	39.0	44.4	42.9	39.2
daily return	percent	0.14	0.01	-0.14	0.15	0.06	-0.06	-0.04
quoted spread	cent	4.0	3.9	3.7	2.5	1.9	2.2	1.6
effective spread	cent	3.6	3.7	3.4	2.3	1.7	1.8	1.4
realized spread	cent	-0.9	-0.5	-0.8	-0.7	-0.8	-0.8	-0.7
price impact	cent	4.5	4.2	4.2	3.0	2.6	2.6	2.1
quoted spread	bps	8.5	7.7	8.9	7.2	4.7	5.3	5.0
effective spread	bps	7.9	7.4	8.4	6.8	4.5	4.7	4.6
realized spread	bps	-1.4	-0.7	-2.0	-2.2	-2.2	-2.2	-2.3
price impact	bps	9.3	8.0	10.3	9.0	6.7	6.9	6.9
dollar-volume	dollar (million)	126	159	213.3	150.3	135.8	133.1	113.2
share-volume	dollar (million)	3.1	3.8	5.6	4.9	3.7	3.8	3.6
transactions	(thousands)	4.8	7.0	14.1	13.6	11.3	11.6	10.5
total messages	(thousands)	74	127	351	502	470	369	218

Table II
Trading Statistics by Trader Types

This table presents summary statistics for the three groups of traders (HFT, retail, and institutional), by year. Each number is per day per security for the 48 stocks in our sample. The sample is from July 1st 2006 to June 1st 2012, but omits a number of weeks as highlighted in the main texts. A message is an order, a trade, or a cancellation; note that an order in our model creates two messages. Volume is double counted; e.g., if two traders engage in a transaction of 100 shares, we record a volume of 200 shares. % passive volume refers to the percentage that a group of traders traders with limit orders (as opposed to with marketable orders).

	Units	2006	2007	2008	2009	2010	2011	2012
average number of traders per stock								
HFT		5	10	19	23	29	30	26
Retail		36	38	51	47	44	38	45
institution		17	20	29	20	17	17	15
% passive of own volume								
HFT		50	48	45	63	67	65	67
retail		40	42	41	45	43	47	46
institution		55	57	57	50	45	48	47
average transaction size								
all		382	332	255	239	208	195	197
HFT		227	198	180	194	163	156	160
retail		351	335	286	296	264	256	263
institution		475	415	297	277	254	233	225
total messages submitted								
HFT	(thousands)	48	97	303	428	430	322	178
retail	(thousands)	3	3	5	6	4	3	3
institution	(thousands)	5	6	14	30	8	12	8
% total messages								
HFT		45	56	68	73	82	81	76
retail		7	5	3	3	2	1	2
institution		11	10	8	7	3	4	4
dollar volume								
HFT	dollar (millions)	9.3	19.4	43.3	36.6	35.7	35.2	25.4
retail	dollar (millions)	15.2	18.7	23.4	20.2	15.8	12.8	9.7
institution	dollar (millions)	45.1	55.3	72.5	40.2	36.8	36.6	31.3
% dollar volume								
HFT		7	11	18	21	24	25	23
retail		13	12	10	13	11	10	9
institution		33	32	32	25	25	24	24

Table III
Spreads and Price Impacts by Trader Types

This table presents summary statistics for standard bid-ask spread measures by three groups (traders, HFT, retail, and institutional), by year. Each number is per day per security for the 48 stocks in our sample, all figures are in basis points of the prevailing mid-quote. We measure the effective spreads, the 5-minute realized spread and the 5-minute price impact per trader and then compute the volume-weighted average across the group. The measure *price impact when active* is the 5-minute price impact that results from the traders trade. The measure *price impact when passive* is the 5-minute price impact that results when the trader is on the passive side where the direction of the trade is derived by the active order. Consequently, a positive number indicates that the price moved against the passive-side trader.

	2006	2007	2008	2009	2010	2011	2012
effective spread when active							
HFT	5.6	6.0	7.0	5.6	4.0	4.1	4.4
retail	10.2	9.8	12.2	8.9	5.2	4.8	5.5
institution	8.1	7.8	8.9	7.0	4.5	4.8	4.8
effective spread when passive							
HFT	15.3	14.2	13.4	4.6	2.1	2.5	1.9
retail	12.2	10.6	12.7	8.9	5.6	3.7	5.2
institution	7.0	5.4	5.7	8.3	6.8	19.0	10.3
realized spread							
HFT	0.4	2.2	1.1	0.0	-1.1	-1.1	-1.4
retail	-3.6	-3.1	-5.8	-5.6	-5.0	-2.6	-5.2
institution	-2.1	-1.3	-2.0	-2.0	-1.8	-0.4	-2.1
price impact when active							
HFT	6.6	7.2	9.5	8.2	5.9	6.6	6.4
retail	5.0	4.3	5.8	5.4	3.9	6.2	4.3
institution	9.5	8.3	11.0	10.2	7.7	8.6	7.7
price impact when passive							
HFT	9.1	7.8	9.8	8.1	6.0	6.2	6.7
retail	12.2	10.9	14.8	13.0	9.6	7.3	10.2
institution	8.9	7.6	8.8	7.9	5.8	4.2	6.3

Table IV
Profits by Trader Types

This table presents summary statistics for standard bid-ask spread measures by three groups (traders, HFT, retail, and institutional), by year. Each number is per day per security for the 48 stocks in our sample, all figures are in basis points of the prevailing mid-quote. Per day profits for a trader are computed as

$$\text{profit}_{its} = (\text{sell \$ vol}_{its} - \text{buy \$ vol}_{its}) + (\text{buy vol}_{its} - \text{sell vol}_{its}) \times \text{closing price}_{ts}.$$

The aggregate number in the table sums the profits of across all traders of a particular type. The per share profits are the aggregate profits of the group divided by the aggregate volume of the respective group. The per dollar profits are the aggregate profits of the group divided by the aggregate dollar volume of the respective group. Adjusted profits for retail signify profits for retail plus average transaction costs, where we compute per share transaction costs as

$$\text{transaction costs}_{its} = \frac{1}{2} \times \text{effective spread}_{ts} \times (\%\text{active}_{its} - \%\text{passive}_{its}).$$

Maker-taker fees per share are

$$\text{maker-taker fees}_{its} = \$0.0031 \times \%\text{passive}_{its} - \$0.0033 \times \%\text{active}_{its}.$$

A positive maker-taker fee indicates that the group of HFTs received a payment.

	Units	2006	2007	2008	2009	2010	2011	2012
aggregate								
HFT	dollar	3226	2912	5551	6381	3411	2064	1196
retail	dollar	-5023	-6264	-17931	-11561	-6692	-3939	-3016
institution	dollar	6375	3296	4702	10901	7295	8527	4678
per share								
HFT	cents	0.9	0.5	0.3	0.5	0.1	0.1	0.1
retail	cents	-1.7	-1.3	-1.6	-0.9	-0.6	-0.6	-0.2
institution	cents	0.8	0.3	0.3	0.6	0.5	0.6	0.4
per dollar								
HFT	bps	1.6	0.9	0.7	1.1	0.2	0.3	0.1
retail	bps	-3.3	-2.4	-4.1	-2.3	-1.3	-1.8	-0.9
institution	bps	1.8	0.9	1.5	1.8	1.8	2.0	2.2
per share incl. maker-taker								
HFT	cents	0.9	0.5	0.2	0.5	0.2	0.2	0.1
retail	cents	-1.7	-1.4	-1.7	-0.9	-0.6	-0.6	-0.2
institution	cents	0.8	0.3	0.4	0.6	0.5	0.6	0.4
per dollar incl. maker-taker								
HFT	bps	1.5	0.8	0.7	1.4	0.5	0.7	0.5
retail	bps	-3.4	-2.6	-4.2	-2.4	-1.4	-1.8	-1.0
institution	bps	1.8	0.9	1.5	1.7	1.7	1.9	2.1
retail profits net of spreads								
profits net of spread	dollar	-4190	-5207	-16084	-10814	-6470	-4697	-2958
costs from spreads	bps	1.2	1.1	1.7	0.8	0.4	-0.1	0.2
net per share	cents	-1.2	-0.8	-1.1	-0.7	-0.5	-0.6	-0.1
net per dollar	bps	-2.3	-1.5	-2.7	-1.6	-0.9	-1.8	-0.7
HFT								
Maker-taker fees	dollar	-38	-92	-157	902	839	671	756

Table V
Regressions for Trader Profits: Part I (Retail)

This table presents the results from the regression of profits for retail traders on a number of market quality and HFT and retail activity variables. Retail trader profits are either per dollar traded or per share traded, and they are adjusted or not adjusted for average transaction costs, as indicated in Section III. To save space, the table compresses a large number of regressions. Namely, each entry represents the results from an individual regression with a profit measures as the dependent variable and the row variable as the single regressor; the corresponding equation is

$$\text{profit group } j = \alpha_{(i)} + \beta \text{HFT/retail activity/market quality measure}_{st} + \epsilon_{it}.$$

$\alpha_{(i)}$ are the stock fixed effects and β is the coefficient of interest. Standard errors are double-clustered by firm and time. * indicates significance of non-zero correlation at the 10% level, *+ at the 6% level, ** at the 5% level, **+ at the 2% level, and *** at the 1% level.

	retail profits net of transaction costs		retail profits	
	per dollar	per share	per dollar	per share
% HFT messages	0.03**+	0.01**+	0.04***	0.02***
	(0.01)	(0.01)	(0.01)	(0.01)
% HFT dollar volume	0.08***	0.03***	0.09***	0.04***
	(0.02)	(0.01)	(0.02)	(0.01)
% passive for HFT	0.01	0.01	0.02**	0.01**+
	(0.01)	(0.00)	(0.01)	(0.00)
log retail dollar volume	-4.89***	-2.08***	-4.88***	-2.09***
	(0.53)	(0.25)	(0.54)	(0.26)
% passive for retail	-0.26***	-0.10***	-0.20***	-0.08***
	(0.03)	(0.01)	(0.03)	(0.01)
% stale volume retail	-1.09***	-0.46***	-1.01***	-0.43***
	(0.13)	(0.07)	(0.13)	(0.07)
Observations	59,051	59,051	58,491	59,051

Table VI
Regressions for Trader Profits: Part II (Institutions)

This table is similar to Table V except that, in contrast to retail profits, we do not present the results when institutional profits are adjusted by transaction costs (these results are similar).

	institutional profits net of transaction costs		institutional profits	
	per dollar	per share	per dollar	per share
%HFT messages	0.02*+	0.00	0.02	0.00
	(0.01)	(0.00)	(0.01)	(0.00)
% HFT dollar volume	-0.01	-0.01	-0.03	-0.02*
	(0.02)	(0.01)	(0.02)	(0.01)
% passive for HFT	0.04***	0.01***	0.03***	0.01***
	(0.01)	(0.00)	(0.01)	(0.00)
log retail dollar volume	1.36***	0.58***	1.30***	0.54***
	(0.36)	(0.14)	(0.37)	(0.14)
% passive for retail	0.16***	0.06***	0.15***	0.06***
	(0.02)	(0.01)	(0.02)	(0.01)
% stale volume retail	0.64***	0.25***	0.61***	0.23***
	(0.08)	(0.03)	(0.08)	(0.03)
Observations	55,103	55,103	55,103	55,103

Table VII
Regressions for Trader Profits on HFT activities: Part I (Retail per dollar)

This table presents the results from the regression of profits for retail traders on a number of market quality and HFT- and retail-related activity variables. Retail trader profits are per dollar traded and they are adjusted or not adjusted for transaction costs, as indicated in Section III. This table relates to Table V, expect that we split the regression by year by estimating the following equation

$$\text{profit group } j = \alpha_{(i)} + \sum_{k=1}^{7} \beta_k \text{year}_k \times \text{HFT activity or retail activity}_{st} + \epsilon_{it},$$

where year dummy$_k$ is a dummy that is 1 in year $2005+k$ and 0 otherwise. Coefficient β_k thus captures the effects that we are interested in by year. Standard errors are double-clustered by firm and time. * indicates significance of non-zero correlation at the 10% level, *+ at the 6% level, ** at the 5% level, **+ at the 2% level, and *** at the 1% level.

Panel A. Dependent Variable: Retail profits per dollar – not adjusted by transaction costs

	% HFT messages	% HFT dollar volume	% passive for HFT	Log retail dollar volume	% passive for retail	% retail stale orders
2006	0.01	0.01	-0.01	-2.32***	-0.13***	-0.67***
	(0.01)	(0.04)	(0.01)	(0.26)	(0.02)	(0.13)
2007	0.02*	0.05	0.00	-2.19***	-0.11***	-0.66***
	(0.01)	(0.04)	(0.01)	(0.26)	(0.02)	(0.11)
2008	0.01	0.02	-0.01	-2.20***	-0.12***	-0.62***
	(0.01)	(0.02)	(0.01)	(0.27)	(0.02)	(0.16)
2009	0.01*	0.03**	0.00	-2.20***	-0.11***	-0.63***
	(0.01)	(0.02)	(0.00)	(0.26)	(0.01)	(0.12)
2010	0.01**	0.04***	0.00	-2.23***	-0.10***	-0.38***
	(0.01)	(0.01)	(0.00)	(0.26)	(0.01)	(0.07)
2011	0.01*+	0.03**	0.00	-2.30***	-0.10***	-0.40***
	(0.01)	(0.01)	(0.00)	(0.27)	(0.01)	(0.08)
2012	0.02***	0.05***	0.01	-2.30***	-0.09***	-0.24***
	(0.01)	(0.01)	(0.01)	(0.29)	(0.01)	(0.08)
Observations	59,051	58,491	59,051	59,051	59,051	59,051
R-squared	0.006	0.005	0.015	0.012	0.017	0.006

Panel B. Dependent Variable: Retail profits per dollar – adjusted by transaction costs

	% HFT messages	% HFT dollar volume	% passive for HFT	Log retail dollar volume	% passive for retail	% retail stale orders
2006	0.03*	0.11*	-0.01	-5.44***	-0.31***	-1.40***
	(0.02)	(0.06)	(0.01)	(0.56)	(0.03)	(0.24)
2007	0.04**	0.15***	0.00	-5.16***	-0.27***	-1.25***
	(0.02)	(0.05)	(0.01)	(0.56)	(0.03)	(0.19)
2008	0.01	0.06	-0.02	-5.24***	-0.31***	-1.34***
	(0.02)	(0.05)	(0.02)	(0.59)	(0.04)	(0.32)
2009	0.03*+	0.09**	0.00	-5.21***	-0.26***	-1.57***
	(0.02)	(0.04)	(0.01)	(0.58)	(0.04)	(0.27)
2010	0.03***	0.11***	0.01	-5.27***	-0.25***	-0.86***
	(0.01)	(0.03)	(0.01)	(0.59)	(0.03)	(0.15)
2011	0.02*+	0.07**+	0.00	-5.49***	-0.26***	-1.05***
	(0.01)	(0.03)	(0.01)	(0.60)	(0.03)	(0.17)
2012	0.04***	0.12***	0.01	-5.53***	-0.23***	-0.66***
	(0.01)	(0.03)	(0.01)	(0.64)	(0.03)	(0.19)
Observations	59,051	59,051	58,491	59,051	59,051	59,051
R-squared	0.004	0.005	0.004	0.017	0.012	0.017

Table VIII
Regressions for Trader Profits on HFT activities: Part II (Retail per share)

This table is constructed similarly to Table VII, except that the dependent variables are retail profits per share.

Panel A. Dependent Variable: Retail profits per share – not adjusted by transaction costs

	% HFT messages	% HFT dollar volume	% passive for HFT	Log retail dollar volume	% passive for retail	% retail stale orders
2006	0.01	0.00	-0.01	-2.26***	-0.11***	-0.66***
	(0.01)	(0.04)	(0.01)	(0.26)	(0.01)	(0.13)
2007	0.02*	0.04	0.00	-2.13***	-0.10***	-0.67***
	(0.01)	(0.04)	(0.01)	(0.26)	(0.01)	(0.11)
2008	0.01	0.01	-0.01	-2.16***	-0.11***	-0.63***
	(0.01)	(0.02)	(0.01)	(0.27)	(0.02)	(0.16)
2009	0.02**+	0.04**	0.00	-2.11***	-0.08***	-0.59***
	(0.01)	(0.02)	(0.00)	(0.27)	(0.01)	(0.12)
2010	0.02***	0.04***	0.00	-2.13***	-0.08***	-0.34***
	(0.01)	(0.01)	(0.00)	(0.27)	(0.01)	(0.07)
2011	0.02***	0.04***	0.01	-2.18***	-0.08***	-0.35***
	(0.01)	(0.01)	(0.00)	(0.27)	(0.01)	(0.08)
2012	0.03***	0.06***	0.01**	-2.19***	-0.06***	-0.20**+
	(0.01)	(0.01)	(0.01)	(0.29)	(0.01)	(0.09)
Observations	59,051	59,051	58,491	59,051	59,051	59,051
R-squared	0.007	0.007	0.006	0.016	0.01	0.016

Panel B. Dependent Variable: Retail profits per share – adjusted by transaction costs

	% HFT messages	% HFT dollar volume	% passive for HFT	Log retail dollar volume	% passive for retail	% retail stale orders
2006	0.01	0.01	-0.01	-2.32***	-0.13***	-0.67***
	(0.01)	(0.04)	(0.01)	(0.26)	(0.02)	(0.13)
2007	0.02*	0.05	0.00	-2.19***	-0.11***	-0.66***
	(0.01)	(0.04)	(0.01)	(0.26)	(0.02)	(0.11)
2008	0.01	0.02	-0.01	-2.20***	-0.12***	-0.62***
	(0.01)	(0.02)	(0.01)	(0.27)	(0.02)	(0.16)
2009	0.01*	0.03**	0.00	-2.20***	-0.11***	-0.63***
	(0.01)	(0.02)	(0.00)	(0.26)	(0.01)	(0.12)
2010	0.01**	0.04***	0.00	-2.23***	-0.10***	-0.38***
	(0.01)	(0.01)	(0.00)	(0.26)	(0.01)	(0.07)
2011	0.01*+	0.03**	0.00	-2.30***	-0.10***	-0.40***
	(0.01)	(0.01)	(0.00)	(0.27)	(0.01)	(0.08)
2012	0.02***	0.05***	0.01	-2.30***	-0.09***	-0.24***
	(0.01)	(0.01)	(0.01)	(0.29)	(0.01)	(0.08)
Observations	59,051	58,491	59,051	59,051	59,051	59,051
R-squared	0.006	0.005	0.015	0.012	0.017	0.006

Table IX
Regressions for Trader Profits on HFT activities: Part III (Institutions)

This table is constructed similarly to Table VII, except that the dependent variables are institutional profits per share and per dollar.

Panel A. Dependent Variable: Institutional profits per dollar

	% HFT messages	% HFT dollar volume	% passive for HFT	Log retail dollar volume	% passive for retail	% retail stale orders
2006	0.03	-0.07	0.04***	1.68***	0.16***	0.65***
	(0.02)	(0.07)	(0.01)	(0.41)	(0.02)	(0.15)
2007	0.01	-0.10**	0.02	1.50***	0.13***	0.52***
	(0.02)	(0.05)	(0.01)	(0.41)	(0.02)	(0.14)
2008	0.01	-0.05	0.02	1.54***	0.14***	0.55**+
	(0.02)	(0.05)	(0.02)	(0.42)	(0.03)	(0.23)
2009	0.02	-0.05	0.03***	1.65***	0.16***	0.91***
	(0.01)	(0.03)	(0.01)	(0.42)	(0.02)	(0.19)
2010	0.02	-0.04	0.03**+	1.69***	0.15***	0.53***
	(0.01)	(0.03)	(0.01)	(0.43)	(0.02)	(0.11)
2011	0.02	-0.03	0.03***	1.77***	0.15***	0.62***
	(0.01)	(0.02)	(0.01)	(0.44)	(0.02)	(0.11)
2012	0.02	-0.02	0.03***	1.84***	0.16***	0.51***
	(0.02)	(0.03)	(0.01)	(0.47)	(0.03)	(0.15)
Observations	58,765	58,765	58,208	58,765	58,765	58,765
R-squared	0.004	0.004	0.004	0.005	0.006	0.007

Panel B. Dependent Variable: Institutional profits per share

	% HFT messages	% HFT dollar volume	% passive for HFT	Log retail dollar volume	% passive for retail	% retail stale orders
2006	0.01	-0.03	0.01**+	0.70***	0.07***	0.27***
	(0.01)	(0.03)	(0.01)	(0.14)	(0.01)	(0.06)
2007	0.00	-0.05**	0.00	0.62***	0.05***	0.26***
	(0.01)	(0.02)	(0.00)	(0.14)	(0.01)	(0.07)
2008	0.00	-0.03	0.00	0.60***	0.05***	0.19**
	(0.01)	(0.02)	(0.01)	(0.15)	(0.01)	(0.10)
2009	0.00	-0.02	0.01**	0.67***	0.06***	0.35***
	(0.01)	(0.01)	(0.00)	(0.15)	(0.01)	(0.07)
2010	0.00	-0.02*	0.01*	0.68***	0.06***	0.21***
	(0.00)	(0.01)	(0.00)	(0.15)	(0.01)	(0.04)
2011	0.00	-0.02*	0.01**	0.70***	0.06***	0.23***
	(0.01)	(0.01)	(0.00)	(0.15)	(0.01)	(0.04)
2012	0.00	-0.02*	0.01*	0.69***	0.05***	0.13***
	(0.01)	(0.01)	(0.00)	(0.16)	(0.01)	(0.04)
Observations	58,765	58,765	58,208	58,765	58,765	58,765
R-squared	0.001	0.002	0.002	0.003	0.004	0.004

Table X
Regressions for Retail Trader Spreads

This table report the regression of per-trader effective spreads on HFT and retail activity variables.

	effective spread		5-minute price impact	
	active	passive	active	passive
% HFT messages	-0.06***	-0.10***	-0.00	0.02*
	(0.01)	(0.01)	(0.01)	(0.01)
% HFT dollar volume	-0.05***	-0.12***	0.03	0.02
	(0.01)	(0.02)	(0.02)	(0.02)
% passive for HFT	-0.08***	-0.08***	-0.01	-0.04***
	(0.01)	(0.02)	(0.01)	(0.01)
log retail dollar volume	0.54*	0.52	0.11	2.09***
	(0.29)	(0.37)	(0.17)	(0.36)
% passive for retail	-0.02***	-0.34***	-0.01	0.11***
	(0.01)	(0.03)	(0.01)	(0.01)
% stale volume retail	-0.12***	-0.41***	-0.07***	0.65***
	(0.01)	(0.04)	(0.01)	(0.04)
Observations	59,051			

Table XI
Regressions for Retail Trader Spreads – by year

This table report the regression of by-trader effective spreads on HFT and retail activity.

Panel A: Effective spread per retail trader when active

	% HFT messages	% HFT dollar volume	% passive for HFT	Log retail dollar volume	% passive for retail	% retail stale orders
2006	0.02*	0.25***	0.01	-0.31*	0.06***	0.32***
	(0.01)	(0.05)	(0.01)	(0.17)	(0.01)	(0.06)
2007	0.02	0.19***	0.01*	-0.33*	0.05***	0.31***
	(0.01)	(0.03)	(0.01)	(0.18)	(0.01)	(0.05)
2008	0.05***	0.24***	0.07***	-0.03	0.11***	0.70***
	(0.01)	(0.03)	(0.01)	(0.21)	(0.02)	(0.08)
2009	0.00	0.08***	-0.01	-0.47***	0.02**+	0.09*
	(0.01)	(0.02)	(0.01)	(0.18)	(0.01)	(0.05)
2010	-0.04***	-0.05***	-0.06***	-0.98***	-0.07***	-0.42***
	(0.01)	(0.01)	(0.01)	(0.19)	(0.01)	(0.03)
2011	-0.04***	-0.03***	-0.05***	-0.93***	-0.05***	-0.35***
	(0.01)	(0.01)	(0.01)	(0.20)	(0.01)	(0.03)
2012	-0.05***	-0.06***	-0.06***	-1.03***	-0.07***	-0.36***
	(0.01)	(0.02)	(0.01)	(0.21)	(0.01)	(0.04)
Observations	59,051	59,051	58,491	59,051	59,051	59,051
R-squared	0.583	0.567	0.579	0.576	0.566	0.450

Panel B: Effective spread per retail trader when passive

	% HFT messages	% HFT dollar volume	% passive for HFT	Log retail dollar volume	% passive for retail	% retail stale orders
2006	-0.01	0.12*	0.06***	-0.21	-0.25***	0.28***
	(0.02)	(0.07)	(0.02)	(0.24)	(0.03)	(0.06)
2007	-0.03	0.05	0.04***	-0.39*	-0.28***	0.13
	(0.02)	(0.04)	(0.01)	(0.24)	(0.03)	(0.09)
2008	0.00	0.11***	0.08***	-0.18	-0.24***	0.31***
	(0.02)	(0.04)	(0.02)	(0.27)	(0.03)	(0.10)
2009	-0.05***	-0.01	0.00	-0.66***	-0.30***	-0.32***
	(0.02)	(0.03)	(0.02)	(0.23)	(0.03)	(0.05)
2010	-0.08***	-0.11***	-0.05***	-1.09***	-0.38***	-0.66***
	(0.01)	(0.02)	(0.01)	(0.26)	(0.03)	(0.06)
2011	-0.09***	-0.12***	-0.06***	-1.20***	-0.37***	-0.73***
	(0.01)	(0.02)	(0.01)	(0.26)	(0.03)	(0.05)
2012	-0.09***	-0.15***	-0.06***	-1.27***	-0.38***	-0.65***
	(0.02)	(0.03)	(0.02)	(0.27)	(0.03)	(0.06)
Observations	59,051	59,051	58,491	59,051	59,051	59,051
R-squared	0.159	0.163	0.160	0.159	0.159	0.155

Table XII
Regressions for Retail Trader Price Impacts – by year

This table report the regression of by-trader effective spreads on HFT and retail activity.

Panel A: 5-minute price impact per retail trader when active

	% HFT messages	% HFT dollar volume	% passive for HFT	Log retail dollar volume	% passive for retail	% retail stale orders
2006	0.03	0.17***	0.01	-0.03	0.00	0.01
	(0.02)	(0.05)	(0.01)	(0.17)	(0.01)	(0.07)
2007	0.01	0.10***	0.00	-0.12	-0.02	-0.16**+
	(0.02)	(0.03)	(0.01)	(0.17)	(0.02)	(0.06)
2008	0.03	0.11***	0.03**	0.04	0.01	0.09
	(0.02)	(0.03)	(0.01)	(0.18)	(0.02)	(0.06)
2009	0.02	0.08***	0.01	0.00	0.01	0.07
	(0.02)	(0.03)	(0.01)	(0.18)	(0.01)	(0.05)
2010	0.00	0.03	-0.01	-0.19	-0.03***	-0.12***
	(0.01)	(0.02)	(0.01)	(0.19)	(0.01)	(0.03)
2011	0.00	0.03	0.00	-0.16	-0.02***	-0.12***
	(0.02)	(0.02)	(0.01)	(0.19)	(0.01)	(0.03)
2012	0.01	0.05**	0.00	-0.12	-0.02*	-0.08***
	(0.02)	(0.02)	(0.01)	(0.20)	(0.01)	(0.03)
Observations	59,048	59,048	58,488	59,048	59,048	59,048
R-squared	0.422	0.385	0.428	0.424	0.521	0.367

Panel B: 5-minute price impact per retail trader when passive

	% HFT messages	% HFT dollar volume	% passive for HFT	Log retail dollar volume	% passive for retail	% retail stale orders
2006	0.01	0.24***	0.00	1.67***	0.15***	0.85***
	(0.02)	(0.06)	(0.01)	(0.37)	(0.02)	(0.11)
2007	-0.01	0.11***	-0.02	1.47***	0.11***	0.85***
	(0.02)	(0.04)	(0.01)	(0.36)	(0.01)	(0.11)
2008	0.04**+	0.21***	0.06***	1.96***	0.22***	1.64***
	(0.02)	(0.05)	(0.02)	(0.39)	(0.02)	(0.14)
2009	0.02	0.13***	0.01	1.75***	0.16***	1.15***
	(0.02)	(0.03)	(0.01)	(0.40)	(0.01)	(0.12)
2010	-0.02	0.00	-0.03***	1.33***	0.08***	0.38***
	(0.01)	(0.02)	(0.01)	(0.41)	(0.01)	(0.06)
2011	-0.02	0.02	-0.03**+	1.44***	0.08***	0.39***
	(0.01)	(0.02)	(0.01)	(0.42)	(0.01)	(0.06)
2012	-0.02	0.00	-0.03**	1.44***	0.07***	0.28***
	(0.02)	(0.03)	(0.02)	(0.46)	(0.02)	(0.09)
Observations	59,048	59,048	58,488	59,048	59,048	59,048
R-squared	0.127	0.126	0.124	0.132	0.135	0.144

Table XIII
Regressions for Price Efficiency/Discovery vs. Activity

This table report the regression of several price efficiency and price discovery measures on HFT and retail activity.

	Price Impact in cent	Price Impact in bps	autocorrelation 30 sec	variance ratio 1min/30sec	VPIN av. daily cdf	range vol. 10-min	range vol. daily
% HFT messages	-0.03***	-0.02	-0.00***	-0.00***	-0.01***	0.45***	0.56***
	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)	(0.13)	(0.17)
% HFT dollar volume	-0.02	0.05	-0.00***	-0.00***	-0.01***	2.24***	2.87***
	(0.02)	(0.06)	(0.00)	(0.00)	(0.00)	(0.29)	(0.40)
% passive for HFT	-0.03***	-0.03**	-0.00***	-0.00***	-0.00***	-1.02***	-1.42***
	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.18)	(0.24)
log retail dollar volume	0.50***	0.38*	0.00	0.00	0.13***	50.12***	70.80***
	(0.10)	(0.21)	(0.00)	(0.00)	(0.01)	(4.34)	(5.78)
% passive for retail	0.02***	0.03***	-0.00***	-0.00***	0.00	1.00***	1.79***
	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.14)	(0.17)
% stale volume retail	0.06***	0.14***	-0.00**	-0.00***	0.00***	3.50***	6.47***
	(0.01)	(0.02)	(0.00)	(0.00)	(0.00)	(0.34)	(0.53)
Observations	59,051						

Table XIV
Regressions for Price Efficiency/Discovery vs. Activity by year (Part I)

This table report the regression of several price efficiency and price discovery measures on HFT and retail activity.

Panel A: 5-minute price impact in cents

	% HFT messages	% HFT dollar volume	% passive for HFT	Log retail dollar volume	% passive for retail	% retail stale orders
2006	0.00	0.14***	0.01***	0.36***	0.07***	0.27***
	(0.01)	(0.05)	(0.01)	(0.11)	(0.01)	(0.05)
2007	0.00	0.10***	0.01**	0.31***	0.06***	0.32***
	(0.01)	(0.03)	(0.01)	(0.10)	(0.01)	(0.05)
2008	0.00	0.09**	0.01**	0.33***	0.06***	0.28***
	(0.01)	(0.04)	(0.01)	(0.10)	(0.01)	(0.03)
2009	-0.02**	0.01	-0.01***	0.15	0.02***	0.05***
	(0.01)	(0.02)	(0.00)	(0.11)	(0.00)	(0.02)
2010	-0.02***	-0.01	-0.01***	0.09	0.01**	-0.02
	(0.01)	(0.02)	(0.00)	(0.12)	(0.00)	(0.03)
2011	-0.02***	-0.01	-0.01***	0.10	0.01**+	-0.01
	(0.01)	(0.02)	(0.00)	(0.13)	(0.00)	(0.02)
2012	-0.03***	-0.02	-0.02***	0.03	0.00	-0.09***
	(0.01)	(0.02)	(0.00)	(0.13)	(0.00)	(0.02)
Observations	59051	59051	58491	59051	59051	59051
R-squared	0.28	0.29	0.26	0.28	0.29	0.25

Panel B: 5-minute price impact in bps

	% HFT messages	% HFT dollar volume	% passive for HFT	Log retail dollar volume	% passive for retail	% retail stale orders
2006	0.03	0.34***	0.02*	0.04	0.08***	0.40***
	(0.02)	(0.13)	(0.01)	(0.21)	(0.01)	(0.06)
2007	0.01	0.19**	0.01	-0.13	0.04***	0.25***
	(0.02)	(0.09)	(0.01)	(0.22)	(0.01)	(0.08)
2008	0.04*	0.28**	0.06***	0.17	0.11***	0.63***
	(0.02)	(0.14)	(0.02)	(0.20)	(0.03)	(0.06)
2009	0.02	0.14**+	0.02	-0.01	0.06***	0.38***
	(0.02)	(0.06)	(0.01)	(0.23)	(0.01)	(0.07)
2010	-0.01	0.05	-0.02	-0.32	0.00	-0.02
	(0.02)	(0.05)	(0.01)	(0.25)	(0.01)	(0.04)
2011	-0.01	0.05	-0.01	-0.31	0.01	-0.02
	(0.02)	(0.05)	(0.01)	(0.25)	(0.01)	(0.03)
2012	-0.01	0.06	-0.01	-0.30	0.01	-0.03
	(0.02)	(0.06)	(0.01)	(0.27)	(0.01)	(0.05)
Observations	59051	59051	58491	59051	59051	59051
R-squared	0.20	0.22	0.19	0.20	0.20	0.19

Table XV
Regressions for Price Efficiency/Discovery vs. Activity by year (Part II)

This table report the regression of several price efficiency and price discovery measures on HFT and retail activity.

Panel A: 30-second autocorrelation

	% HFT messages	% HFT dollar volume	% passive for HFT	Log retail dollar volume	% passive for retail	% retail stale orders
2006	0.00***	0.00**+	0.00**+	0.00**	0.00***	0.00***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
2007	0.00	0.00	-0.00*	0.00	0.00	0.00***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
2008	0.00	0.00	-0.00**+	0.00	0.00	0.00***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
2009	-0.00***	-0.00***	-0.00***	0.00	-0.00***	-0.00***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
2010	-0.00***	-0.00***	-0.00***	0.00	-0.00***	-0.00***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
2011	-0.00***	-0.00***	-0.00***	0.00	-0.00***	-0.00***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
2012	-0.00***	-0.00***	-0.00***	0.00	-0.00**	-0.00**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Observations	59051	59051	58491	59051	59051	59051
R-squared	0.03	0.03	0.03	0.03	0.03	0.02

Panel B: 1 minute/ 30 seconds variance ratio

	% HFT messages	% HFT dollar volume	% passive for HFT	Log retail dollar volume	% passive for retail	% retail stale orders
2006	0.00***	0.00**	0.00**+	0.00*+	0.00***	0.00***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
2007	0.00	-0.00*	0.00	0.00	0.00	0.00***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
2008	-0.00*+	-0.00*+	0.00	0.00	0.00	0.00***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
2009	-0.00***	-0.00***	-0.00***	0.00	-0.00***	-0.00***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
2010	-0.00***	-0.00***	-0.00***	0.00	-0.00***	-0.00***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
2011	-0.00***	-0.00***	-0.00***	0.00	-0.00***	-0.00***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
2012	-0.00***	-0.00***	-0.00***	0.00	-0.00***	-0.00**+
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Observations	59051	59051	58491	59051	59051	59051
R-squared	0.03	0.02	0.02	0.02	0.02	0.02

Table XVI
Regressions for Price Efficiency/Discovery vs. Activity by year (Part III)

This table report the regression of several price efficiency and price discovery measures on HFT and retail activity.

Panel A: 10-minute range volatility

	% HFT messages	% HFT dollar volume	% passive for HFT	Log retail dollar volume	% passive for retail	% retail stale orders
2006	0.80***	4.74***	-0.71***	33.87***	0.61***	0.13
	(0.17)	(0.80)	(0.16)	(3.59)	(0.19)	(0.88)
2007	0.63***	3.65***	-0.79***	32.44***	0.53***	0.28
	(0.14)	(0.43)	(0.17)	(3.36)	(0.20)	(1.07)
2008	2.17***	8.18***	1.63***	48.02***	3.83***	23.42***
	(0.21)	(0.60)	(0.30)	(3.61)	(0.29)	(2.64)
2009	1.45***	5.27***	0.37**	42.99***	2.37***	13.80***
	(0.16)	(0.41)	(0.18)	(3.75)	(0.19)	(1.53)
2010	0.21**	0.98***	-0.86***	30.98***	0.02	-1.96***
	(0.10)	(0.21)	(0.14)	(3.68)	(0.16)	(0.64)
2011	0.48***	1.87***	-0.63***	34.98***	0.58***	0.59
	(0.11)	(0.24)	(0.14)	(3.76)	(0.15)	(0.66)
2012	0.30**+	1.37***	-0.79***	33.61***	0.18	-0.86
	(0.12)	(0.28)	(0.14)	(3.92)	(0.16)	(0.60)
Observations	59051	59051	58491	59051	59051	59051
R-squared	0.34	0.39	0.32	0.36	0.33	0.24

Panel B: Daily range volatility

	% HFT messages	% HFT dollar volume	% passive for HFT	Log retail dollar volume	% passive for retail	% retail stale orders
2006	1.11***	6.53***	-0.93***	49.91***	1.42***	2.74**
	(0.22)	(1.08)	(0.21)	(5.02)	(0.24)	(1.36)
2007	0.89***	5.09***	-1.03***	47.90***	1.31***	4.20***
	(0.19)	(0.56)	(0.22)	(4.66)	(0.24)	(1.50)
2008	2.90***	10.96***	2.15***	68.31***	5.68***	35.12***
	(0.28)	(0.80)	(0.38)	(5.03)	(0.39)	(3.88)
2009	1.87***	6.82***	0.39*	60.85***	3.52***	19.67***
	(0.21)	(0.55)	(0.23)	(5.19)	(0.26)	(2.12)
2010	0.28**	1.27***	-1.18***	45.58***	0.52***	-1.54**
	(0.14)	(0.29)	(0.18)	(5.10)	(0.19)	(0.78)
2011	0.64***	2.47***	-0.87***	51.06***	1.23***	2.29***
	(0.15)	(0.32)	(0.18)	(5.25)	(0.19)	(0.87)
2012	0.37**	1.75***	-1.11***	49.15***	0.67***	0.05
	(0.16)	(0.38)	(0.18)	(5.55)	(0.21)	(0.89)
Observations	59051	59051	58491	59051	59051	59051
R-squared	0.32	0.37	0.30	0.34	0.31	0.23

Table XVII
Regressions for Price Efficiency/Discovery vs. Activity by year (Part IV)

This table report the regression of several price efficiency and price discovery measures on HFT and retail activity.

Panel A: Volume-Syncronized Probability of Informated Trading

	% HFT messages	% HFT dollar volume	% passive for HFT	Log retail dollar volume	% passive for retail	% retail stale orders
2006	0.00	-0.01***	0.00***	0.13***	0.01***	0.04***
	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.01)
2007	0.00	-0.01***	0.00***	0.13***	0.01***	0.04***
	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)
2008	-0.00***	-0.01***	0.00	0.11***	0.00***	0.02***
	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)
2009	-0.00***	-0.01***	-0.00***	0.09***	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)
2010	-0.00***	-0.01***	-0.00***	0.09***	0.00	-0.00**
	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)
2011	-0.00***	-0.01***	-0.00***	0.09***	-0.00***	-0.01***
	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)
2012	-0.00***	-0.02***	-0.00***	0.09***	-0.00***	-0.01***
	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)
Observations	59051	59051	58491	59051	59051	59051
R-squared	0.23	0.26	0.20	0.28	0.20	0.07

Figure 1
Cumulative Losses and Transaction Costs for Retail and Institutional Traders

The blue solid line plots cumulative profits of the group of institutional traders, the black solid line plots the profits/losses for the group of retail traders. We aggregate over all 67 stocks in our sample and all retail traders per week; the scale is in 10,000s of dollars, i.e. by 2012, cumulative losses by retail traders amounted to half a billion dollars. The dashed line display the total transaction costs/benefits from bid-ask-spreads.

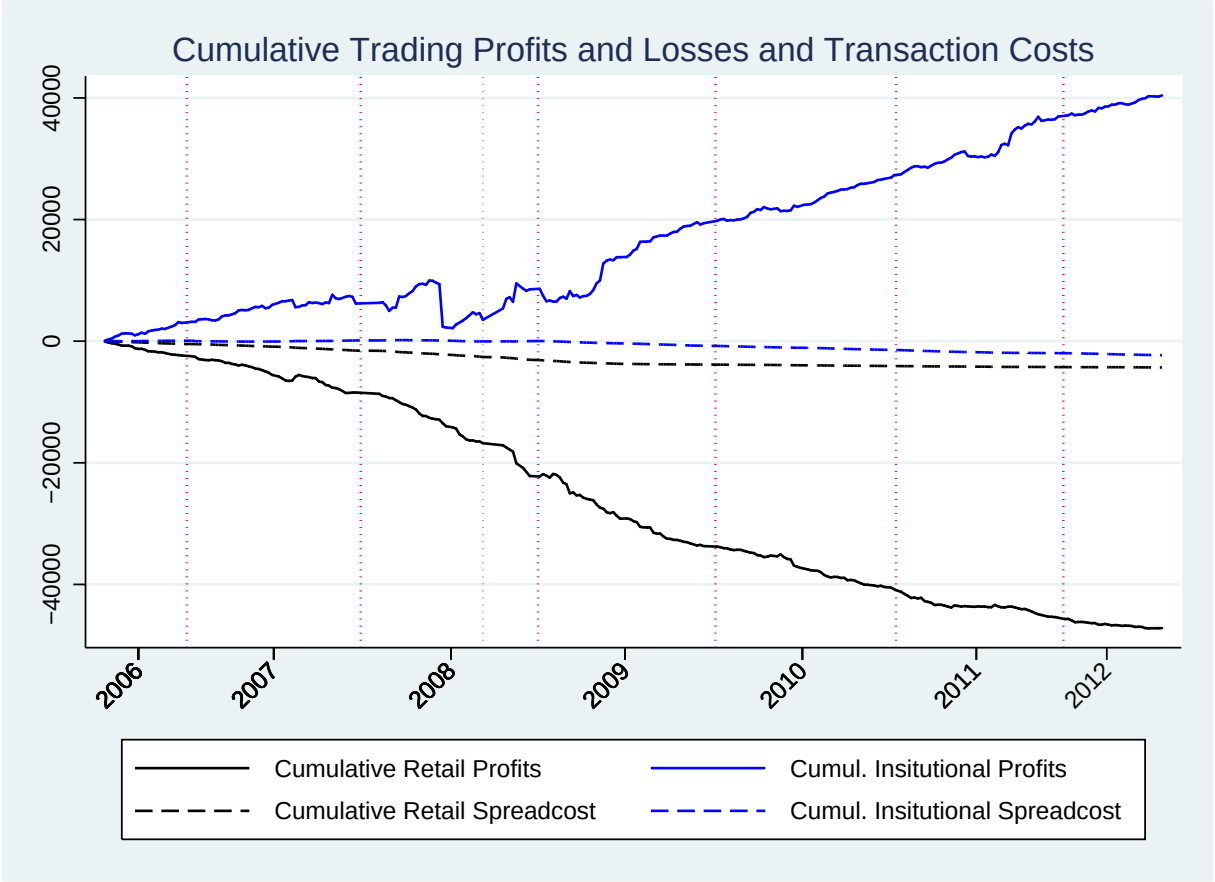
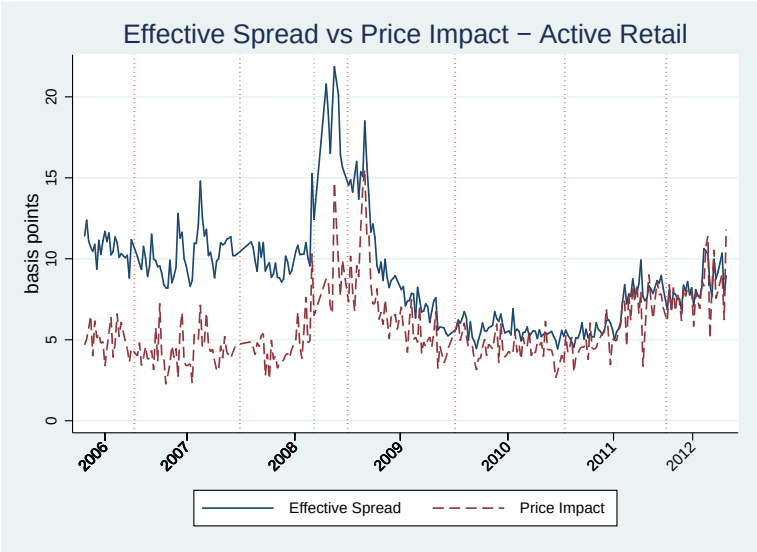
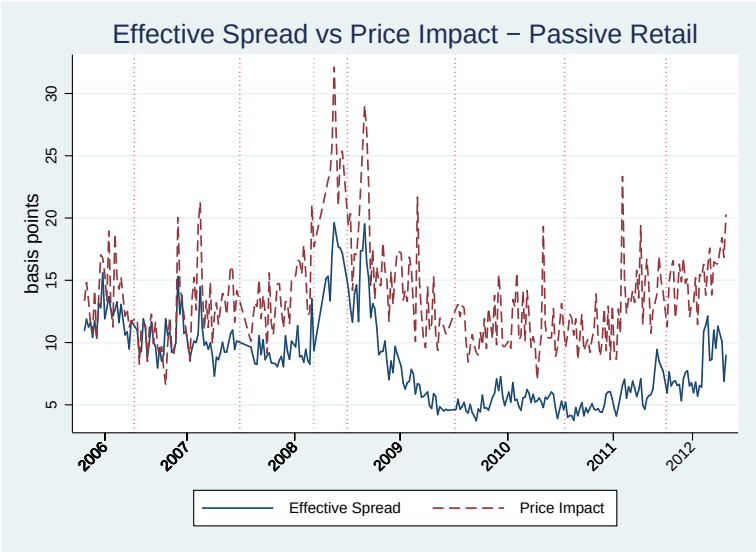


Figure 2
Effective Spreads and Price Impacts for Unsophisticated Traders



Panel A



Panel B

Figure 3
TSX Market Share of Dollar Volume

The Figure presents the share of dollar volume that was traded on the Toronto Stock Exchange. The underlying data has been retrieved from IIROC's public data on market shares, available on their website. The data is computed monthly and spans from January 2007 to December 2012.

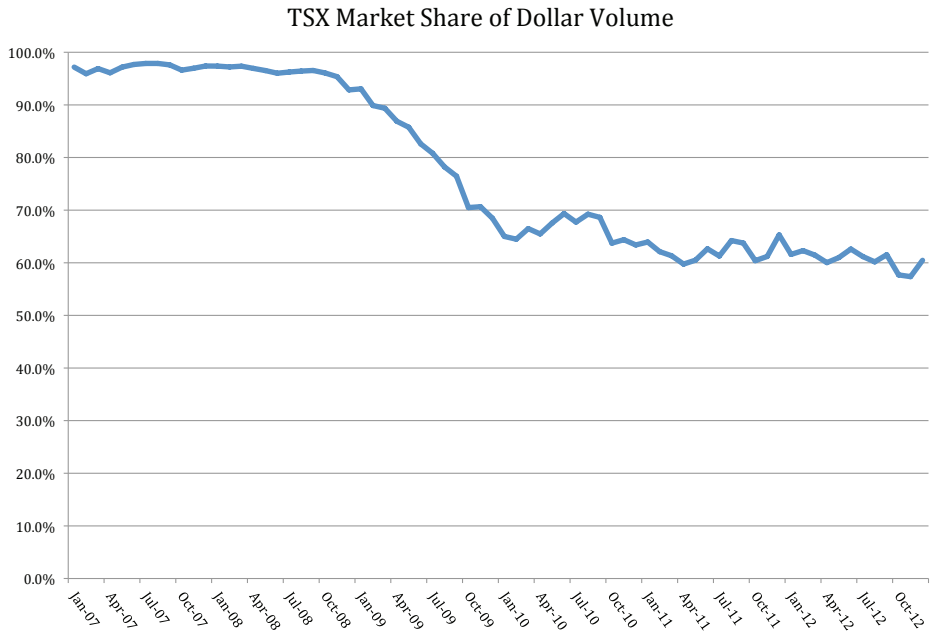
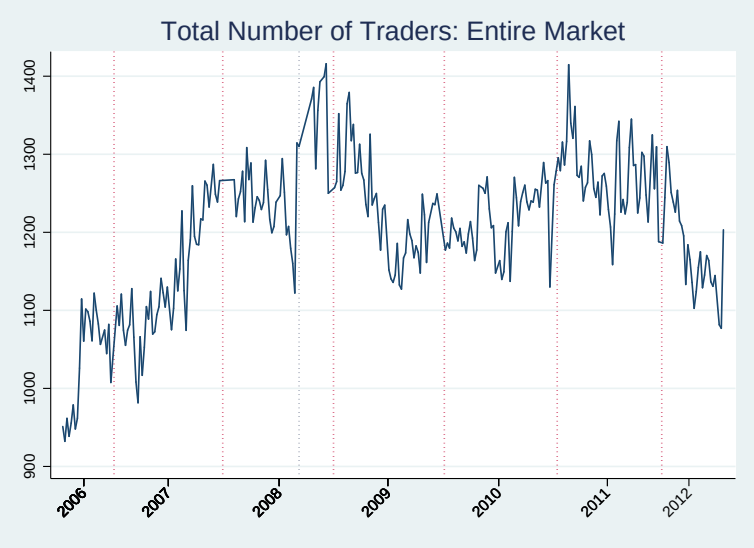
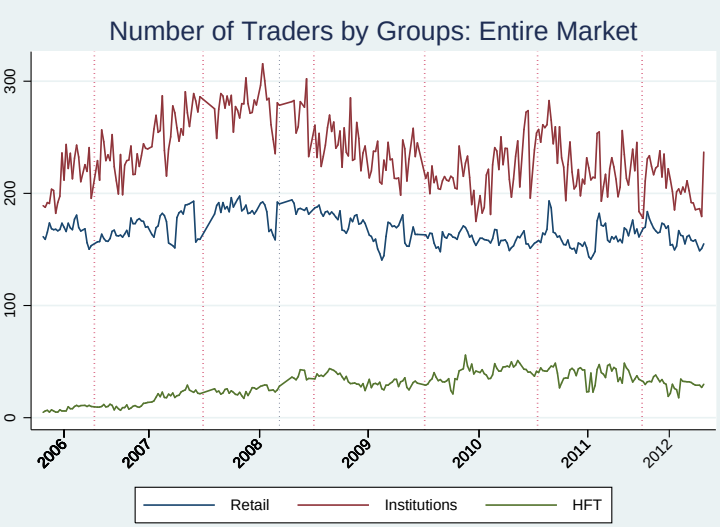


Figure 4
Trader Classification

Panel A displays the total number of unique identifiers that are active on the TSX across time; Panel B plots the total number of retail, HFT and institutional unique identifiers that we identify in our data. The data is aggregated by calendar week; horizontal lines signify the end of a year, except for the year 2008, where we add vertical line to indicate September 15, the day that Lehman Brothers filed for bankruptcy.



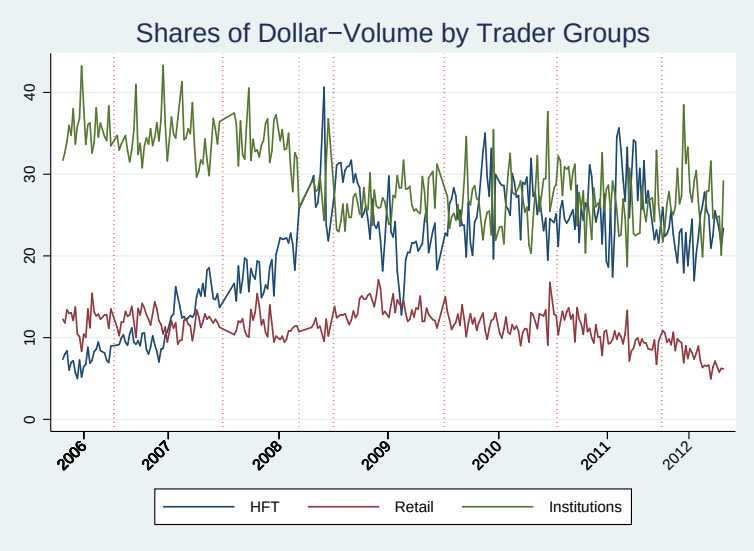
Panel A



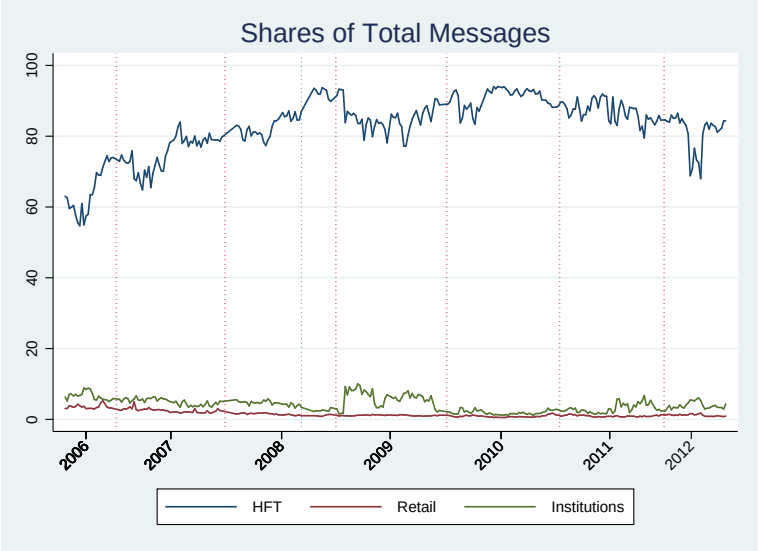
Panel B

Figure 5
Volume and Message Shares by Trader Groups

Panel A displays the shares of dollar volume by trader group; Panel B displays the shares of total messages by trader group. Since 2009, HFTs have a steady share of volume of around 25%. Moreover, they make up around 90% of the messages that are created on the TSX. The data is aggregated by calendar week; horizontal lines signify the end of a year, except for the year 2008, where we add vertical line to indicate September 15, the day that Lehman Brothers filed for bankruptcy.



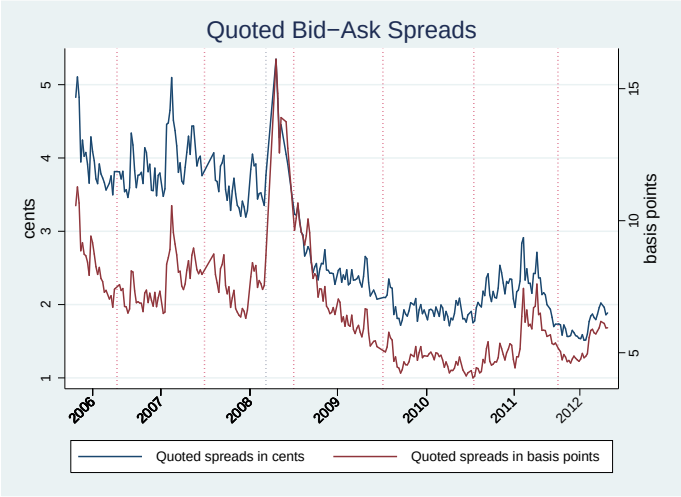
Panel A



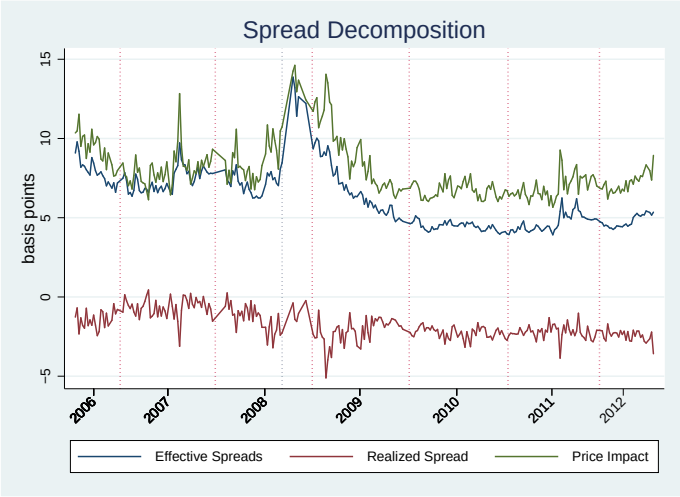
Panel B

Figure 6
Market Evolution since 2006

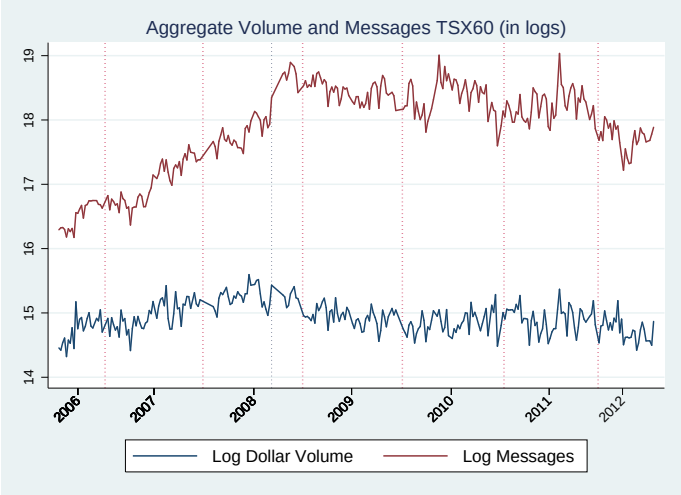
The figures plot some major market variables for the S&P/TSX60 stocks across time. Panel A plots the time-weighted quoted bid ask spreads. Between 2006 and 2009, quoted spreads roughly halved. Panel B plots the spread decomposition, i.e., the effective spread, the realized spread and the price impact. Before 2009, the effective spread was almost synonymous with the price impact. Since 2009, however, the realized spread is negative and the price impact exceeds the effective spread suggesting that, on average, quoted spreads do not compensate liquidity providers sufficiently for the adverse selection cost that they incur. Panel C displays the total dollar volume and the total number of messages on the TSX in logs. While volume is reasonably stable, the number of messages has increased substantially and remains at a high level. Panel D displays the average transaction sizes, both for the entire market and by trader group. Since 2006, the average transaction size has roughly halved. The data is aggregated by calendar week; horizontal lines signify the end of a year, except for the year 2008, where we add vertical line to indicate September 15, the day that Lehman Brothers filed for bankruptcy.



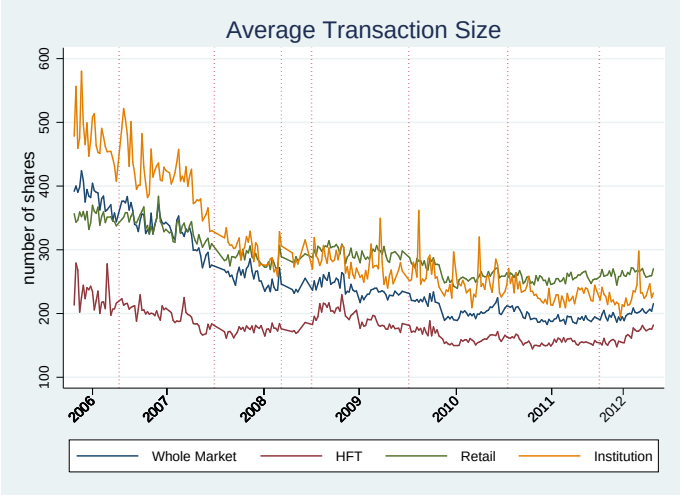
Panel A



Panel B



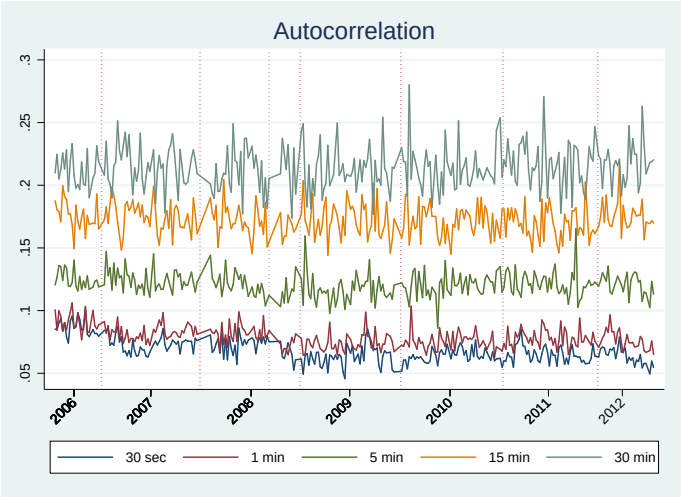
Panel C



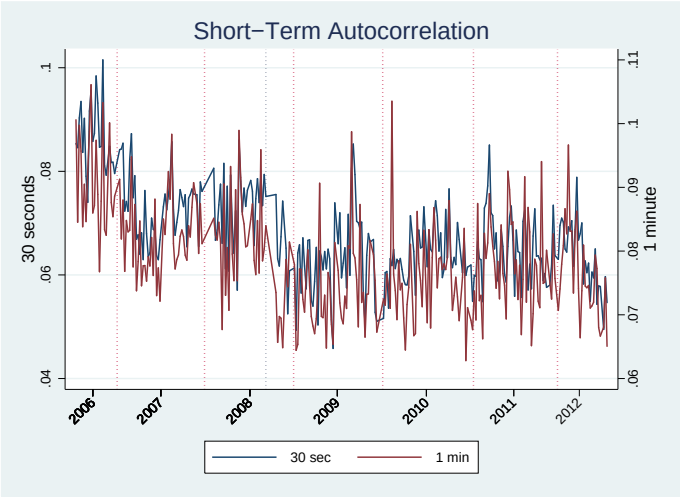
Panel D

Figure 7
Price Efficiency since 2006

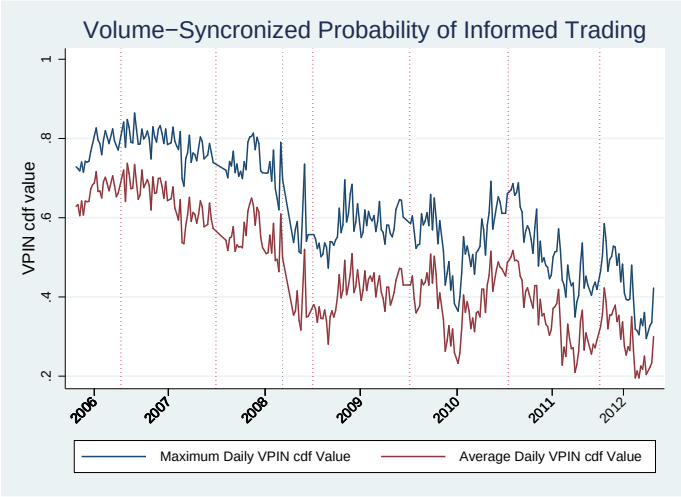
The figures plot some autocorrelations (30 seconds, 1 minute, 5 minutes, 15 minutes 30 minutes), variance ratios and the Volume-Synchronized Probability of Informed Trading major market variable for the S&P/TSX60 stocks across time. The data is aggregated by calendar week; horizontal lines signify the end of a year, except for the year 2008, where we add vertical line to indicate September 15, the day that Lehman Brothers filed for bankruptcy.



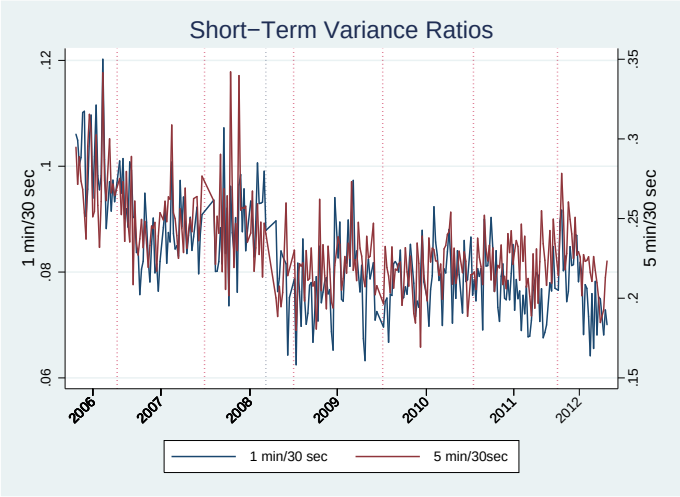
Panel A



Panel B



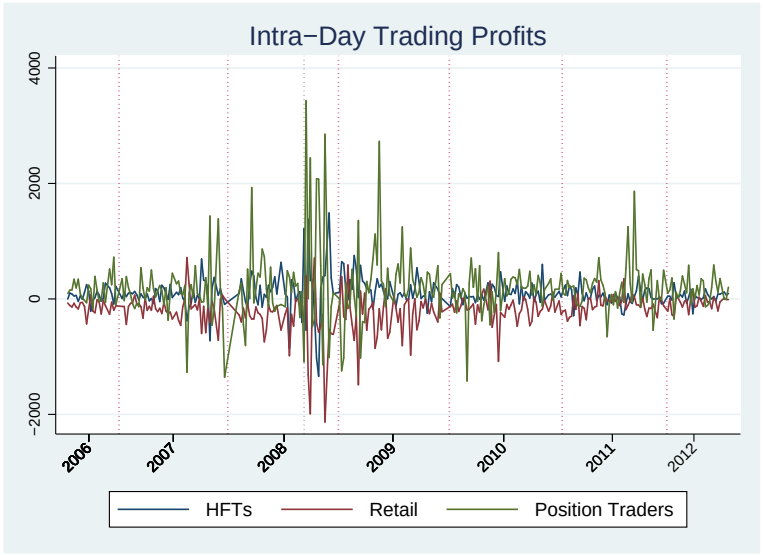
Panel C



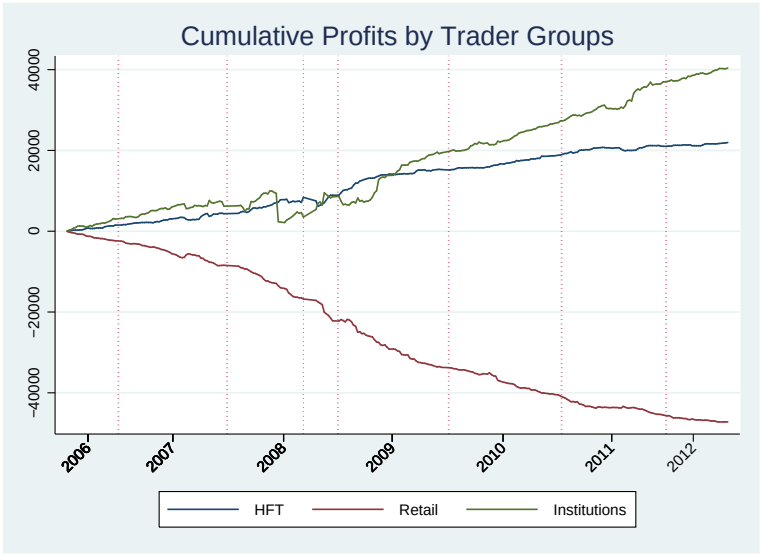
Panel D

Figure 8
Per Day and Cumulative Trader Profits

Panel A displays the aggregate profits by type of trader, where we sum over all stocks and all types of trader within a group (e.g., HFT); Panel B describes the cumulation of these profits across time. The data is aggregated by calendar week; horizontal lines signify the end of a year, except for the year 2008, where we add vertical line to indicate September 15, the day that Lehman Brothers filed for bankruptcy.



Panel A



Panel B

Figure 9
Cumulative Losses and Average Transaction Costs for Retail Traders

The blue line plots cumulative profits of the group of retail traders, where we aggregate over all stocks and all retail traders per day; the scale is in 10,000s of dollars, i.e. by 2012, cumulative losses by retail traders amounted to half a billion dollars. The red line signifies the transaction costs that retail traders would have incurred had they traded (passively or actively) at the average bid-ask spread (the line is negative to indicate that it is a cost). The green line signifies the aggregate transaction costs that retail traders did pay. The difference between these two lines highlights that through the day retail traders are trade at times when spreads are wide. The difference between the green line and the blue line highlight the portion of transaction costs that are not accounted for by bid-ask spreads. The figure thus indicates retail traders see prices move persistently against them after their trades.