Sunshine trading: Flashes of trading intent at the NASDAQ*

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Abstract

We use the introduction and subsequent removal of an actionable indication of interest (IOI), the flash order facility, from Nasdaq as a natural experiment to investigate the impact of voluntary preannouncement of trade interest, sunshine trading, on different groups of market participants and on market quality. We find that preannounced orders are predominantly placed by agency algorithms, i.e. buy-side investors, which are likely to be uninformed. Actionable IOIs fulfil their role as an advertisement for liquidity and attract responses from liquidity providers immediately after the announcement is placed. They contribute to an increase in liquidity in Nasdaq. In an event study and difference in difference analysis, we show that overall market quality improves substantially when the flash functionality is introduced and deteriorates when it is removed. Our study is important in understanding the impact of voluntary pre-trade disclosure, in guiding future market design choices, and in the debate on dark pools and IOIs.

Keywords: Actionable Indication of Interest; Flash orders; Market quality; Market transparency; Sunshine trading.

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1 Introduction

The recent proliferation of algorithmic trading and new trading venues raise many issues about financial regulation and market design. What is the impact of the financial innovations introduced by alternative trading systems (ATS) and electronic communication networks (ECN) on various market participants and market quality? What is the role of market transparency in today's fast moving markets? These questions have important implications for market liquidity, price efficiency, overall welfare and trading strategies of market participants. We study the role of transparency in market design, in particular the impact of voluntary pre-trade disclosure or the ability of a trader to voluntarily preannounce her trading interest to other market participants.

The role of market transparency on market quality is ambiguous and complex, as there is a tradeoff between the two.[1] On the one hand, an increase in transparency leads to lower information asymmetry which reduces adverse selection costs. On the other hand, transparency exposes liquidity traders to undue risk, which can reduce market liquidity, as liquidity providers are less willing to provide free-options to the market in the form of limit orders. The recent emergence of actionable indications of interest (IOI), a high frequency form of sunshine trading, in U.S. equity and option markets reopens the debate on using voluntary pre-trade disclosure. Pre-trade disclosure retains the benefits of lower information asymmetry and reduces the free option problem by allowing for better coordination between liquidity providers and uninformed liquidity demanders.

Admati and Pfleiderer (1991) theoretically show that trading costs can improve when liquidity demanders preannounce their liquidity needs, "sunshine trading". Sunshine trading is beneficial because it allows for the coordination of liquidity supply and demand and the identification of informationless trades. Preannouncers inform potential counterparties of their demand for liquidity, facilitating the match between supply and demand. In addition, preannouncers indicate to the counterparty that they are uninformed by voluntarily disclosing their order, thus reducing the cost of adverse selection. In addition, sunshine trading reduces the risk-bearing

[1] The literature on market transparency is vast and is often classified into pre- and post-trade transparency, see O'Hara (1995), Madhavan (2000) and Biais, Glosten, and Spatt (2005) for detailed discussions. Biais (1993), Madhavan (1995, 1996), Pagano and Röell (1996), Bloomfield and O'Hara (2000), Baruch (2005), Moinas (2006), Foucault, Moinas, and Theissen (2007) develop theoretical models of market transparency. Flood, Huisman, Koedijk, and Mahieu (1999) and Bloomfield and O'Hara (1999) use experiments to study the role of transparency. Anand and Weaver (2004), Boehmer, Saar, and Yu (2005), Hendershott and Jones (2005), Madhavan, Porter, and Weaver (2005), Foucault et al. (2007) carry out empirical studies on the impact of market transparency changes.

costs for both preannouncers and non-announcers, as it reduces the uncertainty of the liquidity demand of uninformed traders and the amount of noise in the price. In this paper, we empirically analyze the implications of voluntary demand disclosure on the trading costs of the announcer and on overall market quality.

We use the introduction and removal of actionable IOIs, flash orders, by Nasdaq OMX Group (Nasdaq hereafter) as a natural experiment to study the implications of sunshine trading. An IOI expresses a trading interest where price, side, and number of shares are not always specified, and execution can only occur after further interaction between the parties, O'Hara (2010).[2] An actionable IOI expresses a trading interest with specified price, side, and number of shares and allows the buy-side trader to immediately trade on the indication directed to them. Thus, flash orders have similar features to preannounced orders in sunshine trading strategies.

Marketable limit orders and flashed orders originate from impatient traders that demand liquidity, as opposed to non-marketable limit orders that reflect liquidity supply by patient traders. A crucial difference between flashed orders and marketable limit orders, however, is that flashing an order does not imply certain and immediate execution. Furthermore, by flashing an order, traders reveal their trading interest to other market participants. Both these features are unattractive to informed traders trading on short lived information. Thus, flash order users are more likely to be uninformed liquidity demanders that value immediacy.

The reputation cost for brokers, the potential delay cost of preannouncement, and the potential information leakage by informed traders ensure that preannounced trades are unlikely to contain information. To investigate whether users of flashed orders are informed traders, we first study the characteristics of the algorithms that submit preannounced orders, i.e. flashed orders. We follow Hasbrouck and Saar (2010) in dividing trading algorithms into agency and proprietary algorithms and classify preannouncers (users of actionable IOIs) into these two categories. We find that actionable IOIs are mainly submitted by agency algorithms, suggesting that their main users are large institutional investors or intermediaries such as brokers.[3] These users are likely to be uninformed. In addition, the adverse selection cost of executed flashed orders is substantially lower than other executed orders, implying that the market treats these orders as uninformed. This supports the assumption of Admati and Pfleiderer (1991) that preannounced

[2] Thus, IOIs are not considered as quotes and are not subjected to public dissemination. An IOI functionality, frequently associated with "dark pool" liquidity, is mainly provided by ECN and ATS to facilitate trades among market participants with large orders and is an important trading outlet for long term retail and institutional investors.

[3] See Goldstein, Irvine, Kandel, and Wiener (2009) for details on institutional brokerage market.

orders of liquidity traders are not likely to be based on private information.

We study the role of preannounced orders in coordinating liquidity demand and supply, by analyzing the state of liquidity in Nasdaq around actionable IOI submissions and executions. The analysis shows that preannounced orders are useful as an advertisement of liquidity demand. The signalling of liquidity demand lowers trading costs in Nasdaq after preannouncement. The saving in trading cost comes from the reduction of spread in Nasdaq, the avoidance of paying a routing fee, and potential price improvements offered by liquidity providers. Preannouncement activity also improves efficiency by narrowing the difference between the local Nasdaq quotes and National Best Bid Offer (NBBO) for individual stocks.

We further investigate the impact of sunshine trading by testing the following main implications of the Admati and Pfleiderer (1991) model: (i) trading costs of announcers are lower when preannouncement takes place than when it does not; (ii) adverse selection decreases with preannounced orders; (iii) market liquidity and price efficiency improve with preannouncement; (iv) preannouncement affects price volatility. We do this by investigating the state of liquidity, execution quality and price efficiency surrounding flash order submissions in Nasdaq's limit order book. In addition, we study the impact of sunshine trading on the overall market quality. We use two sources of identifying variation: (i) a ten day event study around the introduction and removal of the flash functionality from Nasdaq, (ii) a difference-in-difference analysis over the sample period: April - October 2009. The event study approach minimizes the impact of any confounding effects in our analysis. The difference in difference analysis and regression allows us to implement controls and account for potential estimation problems.

We find evidence that preannounced orders have higher execution rates and better fill rates compared to nonannounced orders submitted at the best quotes. In addition, the realized spread and adverse selection cost of executed flashed orders is substantially lower than other executed orders. The adverse selection costs of all market participants increase after the removal of flash orders, while they do not change when flash orders are introduced. These findings strongly support hypothesis (i) and (ii) of the model. Comparing various liquidity and activity measures around the flash introduction and removal periods, overall market liquidity (measured by the quoted spread, the relative spread, and the illiquidity ratio) improves (deteriorates) significantly when flash orders are introduced (removed), lending support to hypothesis (iii). While the impact of preannounced orders on market volatility is ambiguous in hypothesis (iv), we find that market volatility improves (deteriorates) substantially when flash orders are introduced (removed). The difference in difference analysis confirms these results beyond the event study window and shows that mainly the market quality for large and medium size stocks improves significantly during the flash period. These results taken together imply a reduction in risk bearing costs in the market.

An intuitive explanation for our findings is that the advertisement for liquidity demand using flash orders is successful in attracting liquidity providers and in lowering price uncertainty and overall trading costs in the market. Admati and Pfleiderer (1991) argue that sunshine trading reduces the risk-bearing costs for both announcers and non-announcers, because it reduces the uncertainty of the liquidity demand of the uninformed traders and the amount of noise in the price. This reduction in overall risk-bearing costs appears to be the driving force behind our results, as can be seen from the micro and macro analysis. The results seem to support the hypothesis that an actionable IOI indicates to a broker that uninformed liquidity is available at a particular venue so that the broker can quickly route to it, if it represents the best available trading opportunity. Flashed orders appear to be a coordinating mechanism for supply and demand and for identification of informationless trades.

An important and immediate application of our results is to the on-going policy debate on the withdrawal of the flash order practice. In September 2009, the Securities and Exchange Commission (SEC) proposed to ban the use of flash orders in both U.S. equity and option markets. However, the SEC has not banned the use of flash orders and has not taken any decisions on restricting dark pools and IOIs.[4] Our work provides the first analysis of actionable IOIs on market quality and might be useful to guide the debate as well as the final decision taken from the SEC or other European and Asian regulators considering these issues.

Our paper contributes to the literature on the impact of pre-trade transparency on market quality. Flood et al. (1999) conduct an experimental study and find that transparency reduces trading cost and price efficiency, while Bloomfield and O'Hara (1999) in a different experiment find that transparency increases price informational efficiency but widens spreads. More recently, the empirical work of Boehmer et al. (2005), Hendershott and Jones (2005) and Madhavan et al. (2005) uses the introduction/availability of information about the limit order book, as an indication of pre-trade transparency and finds contradicting results. The first two show that

[4] See http://www.bloomberg.com/news/2011-01-21/sec-dark-pool-rule-may-not-arrive-in-11-nasdaq-s-hyndman-says.html?cmpid=yhoo

the availability of quote information is associated with increased market quality in the U.S., the latter finds that execution costs increase with pre-trade transparency in the Toronto Stock Exchange.[5] Foucault et al. (2007) find a significant improvement in liquidity after the switch of Euronext Paris to an anonymous limit order book. While prior works focus on the impact of mandatory pre-trade transparency and of limit order book information on market quality, there is little work on how pre-trade disclosure by uninformed liquidity demanders affects the limit order exposure strategies of liquidity providers and overall trading costs. Our paper helps to fill this gap by testing the role of sunshine trading and voluntary pre-trade disclosure in a limit order book market, motivated by Admati and Pfleiderer (1991).

More broadly, this paper contributes to the literature on voluntary disclosure in accounting and finance. Several papers show that voluntary disclosure reduces information asymmetry and consequently the cost of capital (Diamond and Verrecchia, 1991; Coller and Yohn, 1997), facilitates externally financed firm growth (Khurana, Pereira, and Martin, 2006), and voluntary disclosure of firm specific information allows for better monitoring by investors and ensures that managers undertake optimal investments (Fama and Jensen, 1983; Diamond and Verrecchia, 1991; Bushman and Smith, 2001; Khurana et al., 2006). Consistent with this literature, we show that voluntary disclosure of trading intention reduces the cost of asymmetric information and facilitates the coordination of the supply and demand of liquidity among traders.

This paper is also closely related to the literature on order exposure strategies. The first stream of the literature focuses on trader's choice between limit and market orders. The aggressiveness and number of limit orders is related to the depth and spread of the limit order book (Biais, Hillion, and Spatt, 1995; Griffiths, Smith, Turnbull, and White, 2000; Ranaldo, 2004). Furthermore, Ranaldo (2004) finds that limit order trades are more aggressive with increased recent volatility, while Handa and Schwartz (1996) and Ahn, Bae, and Chan (2001) find that market depth increases with higher transitory volatility.[6] The second stream of the literature investigates the use of hidden orders. Harris (1996, 1997) provide the economic rationale behind the use of hidden orders. The empirical literature suggests that hidden orders reduce implicit transaction costs (Bessembinder and Venkataraman, 2004) and do not affect trading volume (Anand and Weaver, 2004), but they get worse execution quality than visible

[5] Bessembinder, Maxwell, and Venkataraman (2006), Goldstein, Hotchkiss, and Sirri (2007) and Edwards, Harris, and Piwowar (2007) investigate the impact of transparency in the corporate bond market and find that transparency improves market quality.

[6] Chakravarty and Holden (1995), Bae, Jang, and Park (2003), Anand, Chakravarty, and Martell (2005) and Ellul, Jain, Holden, and Jennings (2007) also study the choice between market and limit orders submissions.

limit orders (Bessembinder, Panayides, and Venkataraman, 2009).[7] While prior studies investigate order exposure strategies through regular and hidden limit orders, we examine the usage of flashed orders and compare their execution quality against limit orders. Our analysis shows that order exposure through actionable IOIs, which are more likely to be uninformed than informed, attracts trading interest from passive traders and have better execution quality. Thus, we provide insights on the order submission strategies of impatient uninformed liquidity takers.

This paper also contributes to the literature on dark pools and algorithmic trading. In a recent theoretical paper, Buti, Rindi, and Werner (2010) show that IOIs that inform some traders on the state of liquidity in dark pools can draw orders away from the transparent market, but they also show that IOIs provide information about dark pool liquidity, which increases the welfare of both informed and uninformed large traders. Angel, Harris, and Spatt (2010) provide an excellent overview about equity trading in the 21st century and liken IOI to Craiglist advertisements that helps to coordinate the supply and demand of liquidity. They argue that IOIs lower the transaction cost of retail and institutional investors at the expense of informed traders. Understanding the characteristics of IOIs and how they are used by traders is important in shedding more light into dark pools. Despite its importance, there is no empirical work on IOI due to data unavailability. Our work contributes to this literature by providing a detailed illustration of the characteristics, users, and trading strategies related to actionable IOIs. As actionable IOIs are mostly used by algorithmic traders in Nasdaq, our results also provides some insights on trading strategies used by algorithmic traders.

This paper proceeds as follows. In the next section, we provide a history of flashed orders. Section 3 introduces the data used in the paper and presents descriptive statistics of flash order usage and the cross-sectional characteristics of stocks that are flashed. Who submits flashed orders and why are they submitted is investigated in Section 4. Section 5 discusses the results on the relation between flash orders and market quality. Section 6 concludes.

2 A Short History and Discussion of Flash Orders

Flashed orders have an extremely short duration and according to paragraph (a)(1)(i)(A) of Rule 602 (quote rule) of Regulation National Market System (NMS), they are not required to

[7] Hasbrouck and Saar (2004) find that traders use fleeting orders in Island ECN to sweep for hidden orders.

be included in the public consolidated quotation data.[8] The use of flash trading systems was first approved by SEC under Chairman William Donaldson for the options market, Boston Options Exchange, in 2004. Flashed orders were introduced when options trading took place mainly on exchange floors. It was expected that flashed orders would increase the speed and the likelihood of filling an order at the National Best Bid Offer (NBBO), since the floor quotes that constituted the NBBO were updated infrequently and could be unreliable.

Flash trading was an obscure practice in the options market and was introduced into the equity market in 2006 by a Direct Edge trading platform.[9] Since spring 2006, Direct Edge has offered the "enhanced liquidity programme" where an IOI can be sent to the liquidity providers participating in their network, typically brokers and high-frequency proprietary traders, if an order cannot be matched on Direct Edge's book. The flash order can be routed or canceled if there is still no match, according to the users' instructions. After offering this service, Direct Edge quickly captured market share from rivals, as its share of matched trades soared from 1% of the industry's volume to 12.55%.

In response, Nasdaq and BATS Global Markets (BATS hereafter) introduced their own flash quote programs, where orders are flashed to their members before routing them to rival platforms, to protect their market share. Nasdaq introduced Nasdaq Only Flash Orders on June 05, 2009. Flash orders, as implemented by Nasdaq, are actionable IOIs that expose submitted marketable orders for a pre-defined period of time to only its participants, at or improving the NBBO which is quoted at another trading venue.[10] Thus, a "flashed" order may execute locally at the NBBO or better, while normally it would have been routed away to the other exchange offering the NBBO. BATS introduced BATS Optional Liquidity Technology (BOLT Routing) which included an optional display period during which a marketable order could be displayed to its users (and market data recipients) prior to being routed, canceled, or posted to the BATS book. NYSE is the only major market center that has not offered any enhanced liquidity provider program or flash-order functionality.[11]

[8] Regulation NMS approved by the SEC is a series of initiatives designed to promote fair and efficient price formation across U.S. financial markets through competition among market participants. Rule 602 requires exchanges to make their best bids and offers in U.S.-listed securities available in the consolidated quotation data that is disseminated to the public. Paragraph (a)(1)(i)(A) of Rule 602, however, excludes bids and offers communicated on an exchange that either are executed, cancelled, or withdrawn immediately after communication (less then 500 milliseconds).

[9] Direct Edge was an ECN at the time, but is currently an equity exchange.

[10] Manual flash orders have long been practiced on floor-based exchanges, where brokers announce orders to the floor crowd for potential price improvements. Flash orders in electronic markets were introduced to replicate this auction market process.

[11] NYSE has vehemently protested against the trading practices of their competitors, especially those related

The flash order functionality provides an alternative means to trade and to transact, giving institutional investors more options to execute their trades. There are several pros and cons to the use of this functionality as summarized in Table 1. Flash order functionalities have the potential to improve the liquidity and the market share of the market centers that offer them, as well as to benefit venue members and their buy-side clients. Flash orders can reduce costs for venue members as they can benefit from a liquidity rebate or avoid paying a routing charge, if their flashed orders get filled. In addition, they allow buy-side clients and large institutional investors access to additional liquidity in off-exchange venues while minimizing the visibility of their orders. The flash order functionality is important for ECNs to compete with larger market centers, like Nasdaq and NYSE. This competition lowers execution costs and improves services to the buy-side market participants. While supporters of the flash functionality argue that it lowers the cost and improves the welfare of their members and clients, there are many commentators who question its impact on market quality and fairness for other market participants. There is also a concern about the prospect of front-running as not all market participants can see the flash order before it is publicly quoted, because they are disseminated to members of the exchange only. It is also widely argued that allowing flash-order functionalities promotes a two-tier market, where some market participants have an unfair advantage over other market participants.

Since mid-2009, there has been wide media coverage and intense debates by regulators, industry analysts, and commentators over the impact of flash trading on financial markets and participants. Many arguments in the current debate on flash orders have little or no empirical support. Does flash trading undermine the integrity, fairness, and efficiency of the U.S. national market system? Does the practice of flash trading harm market liquidity and price discovery? Will participants submitting flash orders be front-run by sophisticated high-frequency traders? Should the SEC remove the flash order exception? Answers to these questions have important implications for the information efficiency of prices, investors' trading strategies, market quality, market makers' behavior, and investors' welfare.

In view of the flash trading controversies, Nasdaq and BATS voluntarily discontinued support for flash orders at the end of August 2009 pending the review on flash orders by SEC. In March

to flash and dark pool trading. NYSE's concerns and complaints induced New York Senator Charles Schumer to request the SEC to ban flash trading and to increase monitoring of dark pool trading. Any ban or restriction of the flash functionality and provision of dark pool liquidity may help NYSE to win back market share in the U.S. equity market.

2011, DirectEdge also withdrew its enhanced liquidity programme. On September 18, 2009, the SEC proposed the elimination of the flash order exception from Rule 602 of Regulation NMS. On January 13, 2010, the SEC issued a Concept Release seeking public comments on high frequency trading, co-locating trading terminals, and markets that do not publicly display price quotations. No decision has been taken to date.

3 Data Description

This paper uses the complete set of quotes and trades in the Nasdaq system for the sample period from April 01, 2009 to October 31, 2009. The flash order period covers June 5, 2009 - August 31, 2009. The data is obtained from Nasdaq ITCH-TotalView system on special order.[12] We retain stocks for which information is available in Trades and Quotes (TAQ), Center for Research in Security Prices (CRSP), and Compustat. Following the literature, we use only common stocks (Common Stock Indicator Type=1) and common shares (Share Code 10 and 11) and stocks that do not change primary exchange, ticker symbol or CUSIP over the sample period (Hasbrouck, 2009; Goyenko, Holden, and Trzcinka, 2009; Chordia, Roll, and Subrahmanyam, 2000). We also exclude stocks that exhibit a price lower than $5 and higher than $1,000 or market capitalization less than $1,000,000 over the sample period. Finally, we exclude stock/dates with reported negative bid-ask spreads and trading volume equal to zero. As a result we are left with a sample of 1,867 stocks and 265,000 firm/day observations. Because some of the stocks in our sample are affected by the Troubled Asset Relief Program (TARP), we also carry out our analysis with a subsample that excludes all financial stocks (SIC 6000-7000) and non-financial stocks that received TARP funds, for robustness.

We employ the complete dataset of new order messages (A, F), updates (U), cancelations (X), deletions (D), executions (E), hidden orders (P), and cross-network orders (Q). Figure A1 presents an overview of the types of order messages posted in Nasdaq. Orders can only be flashed when a new order message of type A is submitted or an order is updated, U.

After attempting to sweep the Nasdaq book, a Nasdaq Only Flash Order allows the order up to 500 milliseconds additional exposure to market participants and vendors via a Nasdaq direct data-feed interface at the most aggressive price possible that would not result in a trade through. Executed flashed orders receive a rebate. Orders that remain marketable after the

[12] The intraday data where flash orders can be identified is available from June 10.

flash period will be deleted (D). Orders that become non-marketable and that do not execute in the flash period are inserted in the limit order book as a type V message, unless canceled by the customer.[13]

Using this information, we build the complete limit order book (LOB) for 188 stocks following Kavajecz (1999). The LOB stocks represent different industry, size, book-to-market, and liquidity characteristics. Panels A and B of Table 2 show that the LOB sample is a good representation of the full data sample. Limiting the number of stocks is necessary for computational purposes. We use the LOB sample for the intraday analysis, while we use CRSP data for the event study and difference in difference exercise.

3.1 Market Quality Variables

In order to measure market quality in the U.S. equity market, we use daily data from CRSP. We employ two kinds of spread as liquidity measures: quoted and relative spread. The quoted spread measures the difference between the inside quoted ask and bid for a stock, i.e. the absolute "round trip" cost of trading a small amount of shares at the inner quotes. The relative spread is the quoted spread divided by the bid-ask midpoint. To measure price impact at the market level, we calculate the Amihud (2002) illiquidity ratio (ILR), which is closely related to Kyle's lambda. ILR is calculated as $|r|$/VOLUME, where $|r|$ is the absolute returns over a fixed time period and VOLUME is the total dollar volume over the same period. Markets with lower volatility are deemed to be more efficient, as high depth at the inner quotes makes the trade prices less volatile. We calculate short-term volatility as returns squared. We censor observations where spread and ILR ratio are at the 99^{th} percentile of the distribution. This is particularly important for ILR, which exhibits large outliers when trading volumes are low.

From the limit order book, we construct several measures of market quality. To measure execution quality, we compute fill rates for preannounced and non-preannounced orders. To measure adverse selection, we decompose the effective spread into realized spread and adverse selection. As in Hendershott, Jones, and Menkveld (2011), the effective half spread, *espread* is defined as:

$$espread_{jt} = q_{jt}(p_{jt} - m_{jt})/m_{jt},$$

where q_{jt} is the buy (1)/sell(-1) trade indicator, p_{jt} is the traded price, and m_{jt} is the quote

[13] A marketable order is any buy (sell) limit order with a limit price that is greater (less) than or equal to the current ask (bid) price.

midpoint prevailing at the time of the trade. For each stock and day, we use all Nasdaq quotes and trades to calculate the effective spread for each reported transaction. We normalize the effective spread by the number of shares traded in the transaction. We calculate realized spread, $rspread_{jt}$, and adverse selection, $adv\_selection_{jt}$ as:

$$rspread_{jt} = q_{jt}(p_{jt} - m_{j,t+5min})/m_{jt},$$

$$adv\_selection_{jt} = q_{jt}(m_{j,t+5min} - m_{jt})/m_{jt}.$$

Autocorrelation is a measure of market efficiency and the lower the autocorrelation of returns the more efficient is the market. As Boehmer and Kelley (2009) and Boehmer, Chava, and Tookes (2010), we calculate intraday first order autocorrelation $|AR|$ using 30-minute quote midpoint return data and correct for the negative bias in autocorrelations: $\hat{\rho}(k) = \rho(k) + \frac{T-k}{(T-1)^2}[1 - \rho^2(k)]$ where $\rho(k) = \frac{Cov(r, r_{t+k})}{Var(r_t)}$, Fuller (1976). We also calculate 5 minute autocorrelation for robustness. A list of all the variables used and their definitions is provided in Table A1 in the Appendix.

3.2 Matching Sample

We need to construct a matching control group that is not directly affected by flashed orders for the difference in difference analysis. One potential control group are U.S. stocks that are not traded on Nasdaq. However, there are only 10 stocks that do not trade at Nasdaq during our sample period, which is too few to constitute a good control sample. One solution is to use Canadian stocks, represented by the Toronto Stock Exchange listed companies, as our control group. While this is clearly not a perfect control, it is a reasonable alternative given the similarity of market structures and regulation and the absence of controls on the free flow of capital between the countries. Moreover, U.S. and Canadian trading hours fully overlap, Canadian stocks trade as ordinary securities as opposed to American Depositary Receipts (ADRs) in the U.S. market, and competition across the two markets is vigorous.[14]

All data is downloaded from Datastream and converted to U.S. dollars using the end of day Canadian Dollar/U.S. Dollar exchange rate. We exclude TSE cross-listed stocks and stocks that

[14] Jorion and Schwartz (1986) and Foerster and Karolyi (1993) find that Canadian stocks have very similar market characteristics in Toronto as in the U.S. Eun and Sabherwal (2003) find that prices on the TSE and U.S. exchange are cointegrated and mutually adjusting. Bacidore and Sofianos (2002) find no significant statistical differences in the intraday participation and stabilization rates of NYSE specialist between U.S. stocks and cross-listed Canadian stocks.

exhibit a price lower than \$5 or market capitalization less than \$1,000,000 at any time over the sample period, as for the CRSP sample. The final match sample includes 481 stocks. The sample statistics presented in Panel C of Table 2 show that TSE stocks have lower prices and lower market capitalizations than U.S. stocks. In order to obtain meaningful matching results, we trim the CRSP sample to the maximum of the TSE price and market capitalization, resulting in 1820 CRSP stocks. The trimmed sample in Panel D of Table 2 exhibits similar characteristics as the full sample in Panel A, thus the exclusion of the largest CRSP stocks does not affect the generalizability of our difference in difference results.

3.3 Limit Order Book

Panel E of Table 2 presents the main characteristics of the limit order book. The size of executed flashed orders is larger than other orders. This is in line with the Admati and Pfleiderer (1991) model. The cumulative depth is calculated as the sum of all shares available at a particular price or better on the limit order book, at successively distant prices, following Goldstein and Kavajecz (2000). The table presents depth at 5 levels and 10 levels away from the best quotes. On average there are about 5,000 shares in the first five levels of the book and just about 10,000 in the first 10 levels of the limit order book.

3.4 Descriptive Statistics for Flashed Orders

First, we compare and contrast the usage and execution performance of preannounced orders relative to regular limit orders. Then we present some general statistics on the cross-sectional characteristics of flashed stocks, where we investigate how flash intensity is related to stock characteristics such as market capitalization and trading volume. As flash orders cannot be posted during pre and post trading hours, all statistics are calculated within the trading hours 9:30-16:00 Eastern Standard Time.[15]

Panel A of Figure 1 presents the total number of submitted flashed orders (*Flash*) and the ratio of flash orders to total orders (*Ratio*) across our sample period. The daily number of submitted flash orders is about four million and it constitutes about three percent of the total number of all submitted orders.

[15] Trading begins and orders are accepted at 7:00 AM for all Nasdaq-listed stocks. Any open quotes or extended hours orders that lock or cross other open quotes or extended hours orders will execute. Pre-opening quotes are non-binding as market makers are not obliged to trade at pre-opening prices. Orders can be canceled.

Intraday characteristics of flash order usage

Panel B of Figure 1 presents the intra-day variation of flashed orders at a five minute interval across the trading day. There is a distinct pattern in the submission of flash orders, both in the flash frequency and flash ratio. Orders are flashed less frequently at the beginning of the day, less than 1% of total orders and increase up to 4% at the end of the day.

Panel A of Table 3 presents an overview of the type of orders that are flashed, how often this occurs, and what happens to these orders. 5% of all the initiated orders are flashed at least once. 87% of these is flashed upon initial submission rather than during an update. 14% of the orders that are flashed at least once are executed compared to 4% of orders that are never flashed. The statistics suggest that non-flashed orders are proportionally executed less frequently than flashed orders. In addition, the average daily proportion of flash related executed orders to total executed orders is greater than 16%. Despite the fact that flash order submissions are a small proportion of total submitted orders, they are a more substantial part of executed orders.

The execution quality of orders is also presented in Table 3. Panel B of Table 3 shows that the average fill rate of orders that are flashed at least once is 9.17% and is much higher than that of non-flashed aggressive limit orders (at or improving the best price) during the flash period. The difference in fill rates of all non-flash orders before and after the introduction and removal of flash functionality from Nasdaq, using a ten day event window, suggests that the average fill rate of non-flashed orders decreases during the flash period. These results indicate users of flash orders have better execution quality than non-users, and the execution quality of non-announcers deteriorates as in Admati and Pfleiderer (1991).

Table 3 also presents statistics on the execution quality of orders that include at least one flash, Panel C. The largest part of executions occurs right after preannounced orders are entered into the book. Only 25% of the executed flashed orders are executed right after the flashed order submission. The finding is consistent with Angel et al. (2010)'s suggestion that IOIs are messages on Craigslist advertising about the availability of liquidity.

Cross-sectional characteristics and flash intensity

Table 4 provides statistics on stock characteristics: price, dollar volume traded, number of trades, market capitalization, and market quality measures: quoted and relative spreads, ILR, and volatility over three terciles sorted on flash frequency. Panel A of Table 4 provides statistics based on stocks sorted by the daily number of flash orders. Results in Panel B are based on stocks sorted by the average number of flash orders across the flash period. Panels C and D are sorted based on the daily flash ratio and the average daily flash ratio across the flash period respectively.

Panels A and B of Table 4 show a monotonic improvement in the liquidity variables from the first to the third tercile, when sorted according to the number of flash orders. Stocks that are most frequently preannounced are also stocks with the largest market capitalization, have the largest numbers of trades and traded volume, and have the lowest spreads and volatility. We observe the opposite results for liquidity when sorting according to the flash ratio in Panels C and D. The stocks with the highest flash ratio exhibit the largest spreads and ILR. This implies that there are small stocks that are preannounced relatively heavily compared to large stocks. Some of the effects observed in Panels A and B are driven by the size effect, thus the flash ratio seems to be a better measure of flash activity and will be used throughout the analysis.[16]

Table A3 in the Appendix presents the liquidity characteristics for stocks double sorted by market characteristics: volume and market capitalization, and flash ratio. Under the different types of sorting, the liquidity ratios deteriorate from the first to the last flash tercile for the smaller stocks while they improve monotonically for the other terciles. One explanation for this result may be that the smallest, and most illiquid stocks, are those stocks that most frequently experience a large discrepancy between the NBBO and the local best bid and offer. Thus, traders use the flash functionality for the possibility of saving the routing fee and having price improvement if their flash orders are executed.

4 Preannounced Orders: Who and Why?

Traders must always decide on their order submission strategy: when and where to submit a market and/or a limit order. Traders who submit market orders demand for liquidity ("takers") and those who submit limit orders are liquidity suppliers ("makers"). The decision on one's order submission strategy depends on the trading problem at hand. Traders who face early deadlines (rebalancing/liquidity needs) or those with short lived private information will be more impatient and are more likely to submit market orders or aggressive limit orders. We can think about them as impatient uninformed liquidity traders and impatient informed traders.

[16]The same results hold when TARP stocks are excluded, as presented in Table A2 in the Appendix. We will report the results using the total number of flashed orders wherever possible.

When the deadline is distant and the spread is wide, liquidity traders are often patient and submit limit orders. As the deadline draws nearer and their orders are not filled, they become impatient and might resort to using more aggressive limit orders and market orders to assure execution. Thus, liquidity traders are liquidity makers when they are patient and takers when the deadline to invest or divest due to exogenous cash flow needs draws nearer, see Harris (1998).

Informed traders have private information about the underlying value of an asset but this information is often transitory. Thus, they can be impatient as they strive to exploit their information superiority before the information becomes common knowledge. For this reason, informed traders with short-lived information are more likely to use market orders to trade quickly. Depending on the deadline of their information superiority, they might also use limit orders if the spread is wide and deadline is distant. Thus, informed traders can be liquidity makers as well as takers.

Actionable IOIs are orders that are more aggressive than all limit orders but less aggressive than market orders, i.e. they are not ensured immediate execution. As actionable IOIs reveal one's trading needs and intention, the response by other liquidity suppliers to IOIs depends critically on whether the IOI submitter is perceived to informed or uninformed. If actionable IOIs are submitted by uninformed liquidity demanders, they will trigger responses from liquidity suppliers and will execute with lower transaction costs because of lower adverse selection. Admati and Pfleiderer (1991) argue that preannounced orders, like actionable IOIs, are likely to be informationless trades because of the potential costs of preannouncement for an informed trader. As preannouncement entails a delay in the execution of the order, this delay cost is likely to be more costly for informed traders than for liquidity traders. This is because short-lived private information might become common knowledge during the execution delay. Moreover, preannouncements reveal the private information of informed traders. If other traders acquire information through observing preannounced orders, the trading profit of informed traders will be severely reduced. However, preannouncements of trading intentions by uninformed liquidity demanders are unlikely to be front-run.[17] Admati and Pfleiderer (1991) provides a good example on why front-running is unlikely. If a large sale is preannounced and the public can observe this preannouncement, all market participants will have similar valuation of the stock, conditioning on this information. Thus, it is unlikely that any trader will buy from the front

[17] Front running is an exploitation of information about future order placement of other traders by trading in the same direction before the order is executed.

runner at an unfavorable price conditioning on the preannouncement information. A trader that is willing to buy at the unfavorable price is an impatient liquidity demander, with high demand for immediacy. Hence, the front runner is providing a valuable market making service by transferring through time the demand to buy and sell, which is unlikely to be detrimental to the preannouncers in a competitive market.

In order to investigate if actionable IOIs are uninformed orders, we study the kind of algorithmic traders that use flash orders and the predictive ability of flash order flows. In addition, we investigate the adverse selection costs for announced and nonannounced orders, and the impact of the introduction and removal of the flash facility on adverse selection.

4.1 Identifying Flash Order Submitters: Proprietary and Agency Algorithms

As flashed orders are only actionable for a maximum of 500 milliseconds, it is only machines from algorithmic traders that can respond to them . Trading algorithms can be classified in two categories: agency and proprietary, see Hasbrouck and Saar (2010). Agency algorithms (AA) are frequently used by buy-side institutions like mutual funds, pension funds, and insurance firms, who submit nonmarketable limit orders as part of their strategies. They are normally used to break large orders into small portions to be sent to multiple trading venues over time. It is more likely that these traders are uninformed. Algorithms which aim to profit from the trading environment are classified as proprietary algorithm (PA). These algorithms are often associated with electronic market makers, hedge funds, proprietary trading desks of large financial firms, and independent statistical arbitrage firms. Some PAs aim to identify the trading needs of other market participants (such as those of buy-side institutions) and profit at the expense of these less sophisticated participants.

A typical characteristic of PAs is the repeated submissions and cancelations of orders that aim to trigger actions from other algorithms.[18] The observation of such trading patterns might be associated with PAs and is called a "strategic run". All orders that are not part of a strategic run can be considered as agency algorithms.

We construct "strategic runs" for flashed and non-flashed orders, to identify whether flash order submitters are PAs or AAs. We construct strategic runs in two ways using messages posted in Nasdaq trade and quotes data. First, we follow Hasbrouck and Saar (2010) and

[18] An example of such an algorithm is a "pinging" algorithm used by sell-side investors to identify reserve book orders. In pinging, the PA issues an order ultra fast and if nothing happens, it cancels it. But if it is successful, the PA learns about hidden information on the reserve book orders that it can use to its advantage.

link sequences of submissions, cancelations, and executions that are likely to be part of a PA's dynamic strategy. We link an individual limit order with its subsequent cancelation or execution using the unique order reference numbers supplied with the data. Then, we link a cancelation to either a subsequent submission of a nonmarketable limit order, when the cancelation is followed within one second by a limit order submission, or an execution, when the cancelation is followed by an execution, in the same direction and for the same size. If a limit order is partially executed and the remainder is canceled, we look for a subsequent resubmission or execution of the canceled quantity.[19] As highlighted in Hasbrouck and Saar (2010), such methodology might introduce some noise into the identification of low-latency activity as it is not certain that the subsequent resubmission and execution are linked to the initial individual limit order, but it is useful in identifying runs during the period when Nasdaq did not have the "update" function.

From 2008, Nasdaq provides the possibility to change and update the price and/or volume of orders without having to cancel and resubmit them (message type U). We use update messages in our second approach to measure strategic runs, as they serve the same purpose as the cancel and submit orders that are identified in Hasbrouck and Saar (2010). We identify an update strategic run by tracking the reference number associated with an individual limit order and subsequent update messages in the same direction or a subsequent execution within one second. Different from Hasbrouck and Saar (2010), with the update function, we are certain that order update sequences and alterations are related to the initial individual limit order that we track.

However, PAs might make use both mechanisms to fulfil their strategies, thus Table 5 shows the number of runs and the associated messages for flashed and non-flashed orders for Hasbrouck and Saar (2010) runs (HS) and update runs. One update corresponds to two messages in the HS run (cancel+resubmit), thus the number messages in an update run is normalized to be comparable to the HS runs. A run is classified under flash, if there is a flash message that is part of the run. The total number of monthly runs and their message length is comparable to those in Hasbrouck and Saar (2010), given the smaller sample and the smaller size stocks included in our sample. The total number of runs is smaller for the month of June because our sample only starts on June 10. Most flash runs, HS and Update, are part of runs shorter than 10 messages. A run is considered to be strategic when it includes more than 10 messages. On average less than 3% of the runs with a flashed order are longer than 10 messages, and this is consistent through the different months and different algorithm submission strategies. Over

[19]See Hasbrouck and Saar (2010) for a detailed description and examples of strategic runs.

7% of non flashed orders is part of runs longer than 10 messages, which is substantially more than flashed orders. The results show that preannounced orders are predominantly submitted by agency/buy-side investors.

4.2 Adverse Selection Costs

One of the main reasons to submit preannounced orders in the Admati and Pfleiderer (1991) model is to signal to other market participants that the trader is uninformed. As a result, the preannounced trade would get a lower effective spread due to lower adverse selection. Panel A of Table 6 presents the difference in the mean and median effective and realized spread and adverse selection costs for flashed and non-flashed orders, aggregated by stock. Executed preannounced orders exhibit lower effective and realized spreads and lower adverse selection costs than other executed orders, as hypothesis (i) of the model posits. Panel B of Table 6 shows the mean and median difference in costs aggregated by stock, for the introduction and removal of flash orders. When flash orders are removed, adverse selection costs increase for the whole market, while there are no changes when flashed orders are introduced. These results are in direct corroboration of hypothesis (ii) and indicate that the market prices flashed orders as coming from uniformed traders.

4.3 Why Submit Flash Orders?

Flashed orders are used when the Nasdaq quotes are not the national best bid or offer.[20] We first construct the NBBO for our sample of 188 stocks at the one second frequency using the TAQ database following Hasbrouck (2010).[21] We then merge the Nasdaq LOB data with the NBBO. While the NBBO is fixed over each second, the quotes at the Nasdaq may move within the second. We use a distance measure *SRATIO* to examine the status of the Nasdaq spread relative to the NBBO spread at points in time when there is flash activity. SRATIO is the ratio of the local spread to the NBBO spread minus one for each message. Thus, the SRATIO measures the relative deviation of the Nasdaq spread from the NBBO spread, for example when

[20] Flash orders that are motivated by liquidity needs may also occur when the NBBO is at the Nasdaq if the volume at the best quotes is low.

[21] TAQ data is reported in one second intervals, and the Nasdaq ITCH data is time stamped at the millisecond. While there are quotes from several exchanges at each second in the TAQ data, we do not know at which millisecond the quote is received. Thus, we use the best quotes across all exchanges for each second as our proxy for the prevailing NBBO for each second.

SRATIO>0 the Nasdaq spread is greater than the NBBO spread.[22]

Flash Order Submissions and Expirations

First, we study how the SRATIO changes around new flashed order submissions and expirations. We set up an event study around flash order submissions with an event window of 50 messages before and after the submission. Only events where flashed orders are not preceded by other flashed orders in the pre-event window are used.[23]

Panel A of Figure 2 shows the change in the SRATIO surrounding flash order submissions to buy and sell. The first flashed order submission is centered at message time 0. The bars shows the total number of flash submissions (buys and sells) across all events, and at message time 0 the bar shows the total number of events in the sample. Panel B of the figure shows the SRATIO around flash orders that expire, i.e. flash orders that are not executed after 500 milliseconds and are moved into the limit order book, message type "V". The first thing to note from Panel A of Figure 2 is that the SRATIO increases prior to the flash event at time 0 on the x-axis. This suggests that an important determinant of order flashing is that the quotes at the Nasdaq move away from the national best bid or offer. We also see that there is a decreasing rate of flash order submissions occurring after the initial flash as the Nasdaq spread moves closer to the NBBO. As long as the Nasdaq quotes are worse than the NBBO one would expect there to be flash interest. The figure shows a very similar pattern for buy and sell orders.

Panel B of Figure 2 shows that the SRATIO improves (falls) quickly as the expired flashed orders immediately improve the best quotes in Nasdaq and move the spread closer to the NBBO spread. In other words, flash orders that expire are essentially quote improving limit orders that both improve the spread and add depth to the limit order book. In the post-event window, we see that the SRATIO increases slightly. Since these orders are improving the Nasdaq quotes, they are relatively favorable and are likely to be hit quickly by marketable orders.

[22]Since the best prevailing NBBO quotes are sampled at the 1 second frequency while the best Nasdaq quotes are sampled at the millisecond frequency, the Nasdaq spread can become lower than the NBBO spread within the second.

[23]We also investigate the case when there are no flashed orders subsequent to the initial flash order. This lowers the number of events, but does not affect the results qualitatively. The results are available from the authors upon request.

Flash Order Executions

We also investigate the third type of flash order events, executions. We perform a similar analysis as above, but instead of conditioning on new flash order submissions and expirations, we now condition the on flash order executions. As previously discussed, a flashed order is quite different from a marketable limit order. We compare and contrast the Nasdaq spread and changes in the full depth of the LOB around the execution of each of these types of orders. In the LOB set up, the main difference between a marketable limit order and a flashed order is that the marketable limit order executes immediately at the best prevailing quote, while a flash order fishes for liquidity at the NBBO quotes without the certainty of execution. In addition, a flash order that executes does not take liquidity from the Nasdaq limit order book directly as a marketable limit order does. However, there might be an indirect effect if responding traders cancel their limit orders resting in the limit order book to fill the flashed orders.

Panel A of Figure 3 shows the average spread around marketable limit order and flash order executions. Marketable limit orders arrive when the spread is low and the spread is improving prior to their submission, which is consistent with liquidity takers consuming liquidity when the spread is low, i.e. the take period in Foucault, Kadan, and Kandel (2011). The spread increases immediately after marketable limit orders execute as the best level(s) of the limit order book is taken out. In contrast, a flash order arrives when the bid-ask spread is large, and when it executes the spread improves substantially, i.e. the make period. The average price improvement that executed flashed orders get, compared to the best prevailing quote in Nasdaq, is 0.09% both for buys and sells. The improvements after flash order executions are probably partly due to competitive liquidity providers coming with quote improving limit orders, but also due to some unexecuted flash orders routed into the Nasdaq limit order book as in Panel B of Figure 2.

Panel B of Figure 3 shows the cumulative change in total depth of the limit order book for marketable limit order executions and flash order executions. When a marketable limit order executes, the total depth of the limit order book decreases immediately, while when a flash order executes the depth in the limit order book is replenished.

Overall, it appears that preannounced orders make the local market more efficient and reduce the spread at the Nasdaq and hence the spread gap with the national market. Market participants choose to flash their orders for the possibility of a price improvement, quicker execution, getting paid a maker fee, and avoiding paying the routing fees.

5 Flash Orders and Market Quality

First, we conduct an event study around the introduction and removal of the flash functionality. We use ten day event windows, five days prior and after the introduction and removal of the flash functionality, to investigate the change in market quality variables caused by flashed orders. The ten-day event window is chosen to eliminate the possibility of corporate or market wide events confounding our analysis, while still keeping a reasonably long sample period. The pre-introduction period is from May 28-June 4, the post-introduction period is June 5-11, the pre-removal period is August 25-31, and the post removal period is September 1-8.

Panel A of Table 7 shows the proportional changes in the market quality variables. Results based on the mean and median of various illiquidity measures suggest that there is statistically significant improvements in liquidity after the introduction and a deterioration after the removal of the flash functionality. There is an 11 percent improvement in liquidity during the flash period for both the quoted and the relative spread and they are statistically significant. In addition, short term volatility decreases significantly after the introduction and increases after the removal of flashed orders.[24]

In the analysis in Section 3.4 and Table 4, we find a size effect in the use of flash orders. To better understand the impact of flashed orders on market quality, we conduct the event study on the sample sorted into three terciles based on market capitalization. Panel B of Table 7 shows that there is a significant improvement in liquidity and reduction in volatility for mid-cap and large stocks. Flash orders appear to have less impact on smaller stocks.[25] Although the results suggest a positive impact of flash order on market quality, these findings might be influenced by various confounding effects at the stock price and size level. Thus, we use a matched sample approach to address this issue.[26]

[24]The results for the non-TARP sample confirm the findings, see Table A4 in the Appendix. Also, the same results hold when using the whole market sample, i.e. including all stocks and all types of shares above $5 shown in Table A5 in the Appendix.

[25]This result is also well-supported by the non-TARP subsample in Table A4 in the Appendix. Tables A6, A8, and A7 in the Appendix show that the same results hold when sorting according to flash ratio or total flashed orders, and double sorting by market capitalization and flash ratio.

[26]We also replicate these results using TAQ data aggregated at the daily level and find qualitatively similar results. We use CRSP data in order to be able to compare with our match group, but TAQ results are available from the authors upon demand.

5.1 Difference in Difference Analysis

Propensity score matching

Our matching procedure relies on a matching of propensity scores in the spirit of Rosenbaum and Rubin (1983) and Heckman, Ichimura, and Todd (1998). The matching procedure begins by defining the treatment and control groups, which correspond to the CRSP sample of stocks and TSE stocks, respectively. Each CRSP stock is matched with a control firm from TSE that has the closest propensity score. More specifically, during the three months that the flash function is available in Nasdaq t=0, and t=-1 prior to the implementation. The propensity score is the estimated probability of belonging to the flash group in period t=0 based on firm characteristics in period t=-1. We estimate this probability using a logistic regression, where the dependent variable is equal to 1 if it is a CRSP stock and zero otherwise. The firm characteristics used are: price, log market capitalization and relative bid-ask spread. We use the predicted probabilities (i.e., propensity scores) to match each firm from the treatment group with a firm from the control group based on the smallest absolute difference between the estimated propensity scores. Our results, not presented to conserve space, show that our propensity score method matches the control and treatment groups well along the dimensions of the observable covariates.

Event study

Table 8 presents changes in market quality surrounding the introduction and removal of flash orders for a ten day event window. Panel A of Table 8 shows that short term volatility, quoted spread and realized spread decrease significantly five after the introduction of flash orders, while ILR does not change. With the introduction of the flash order, the quoted spread and relative spread decrease by about 19 basis points and three percent over the matched group, respectively. The average quoted spread and realized spread at Nasdaq increase by an additional 5.2 basis points and 2.7 percent when the flash functionality is removed.[27] When stocks are sorted according to market capitalization, show that the improvement in market quality comes from the large and medium cap stocks. Flash orders appear to have limited impact on smaller stocks.

[27] The results are robust to using a longer event window of 20 days, Table A9 in the Appendix. The magnitude of the decrease, relative to the matched group, in quoted and relative spread is even larger over the 20 days window with a decrease of 24.4 basis points and 5.33 percent respectively. When the flash facility is removed, the change in both the quoted and realized spreads is positive but insignificant. Short term volatility also increases after the removal of flash orders.

Regression analysis

To further control for the possibility that the observed relation between flash order introduction and removal and market quality is due to changes in the two markets over time, we study market quality changes around the duration of the flash order functionality in Nasdaq in a two-way fixed effect panel regression. The sample period, April 1 - November 1, 2009 covers two months before and after the introduction and removal of the flash order functionality from Nasdaq. We compare the 1820 CRSP sample stocks to the 1820 matched TSE control stocks without flash functionality.

The panel regression analysis in Panel B of Table 8 formally incorporates all 3640 stocks (treatment plus control) in the sample. We estimate the following two-way fixed effects model for a variety of left-hand side variables Y_{it} measured for matched pair i on day t:

$$Y_{it} = \mu_i + \phi_t + \beta D_{it}^{\text{flash period}} + \theta X_{it} + \epsilon_{it} \quad (1)$$

where Y_{it} is the difference between CRSP and TSE match in the: quoted spread, realized spread, ILR and short term volatility. μ and ϕ capture the match pair fixed effect and time fixed effects. $D^{\text{flash period}}$ is equal to one during the flash period, and zero otherwise. X_{it} is a vector of pairwise differences for the following control variables: market capitalization, dollar trading volume, and the daily volume-weighted average share price (VWAP).

The matched pair fixed effect account for any differences between two stocks in a pair that are present during the non-flash period. The time fixed effects remove any broad market moves in our variables of interest. The control variables pick up time variation in the matching variables due to size, trading volume and share price level. Statistical inference is based on Thompson (2010) two-way clustered robust standard errors.

Panel B of Table 8 shows the full-sample panel regression results for quoted spread, realized spread, ILR and short term volatility. During the flash period, one pays 2 basis points less in terms of quoted spread than the matched group compared to two months before and after the flash period. One pays 1.6 percent less in terms of relative spread. We also find that short term volatility decreases during the flash period. These results also hold for the non-TARP subsample.

5.2 Other measures of market quality

An additional measure of market quality is return autocorrelation. After the correction for the negative bias in the autocorrelation of returns, the mean and median autocorrelation at the 5 and 30 minute aggregation investigated remain negative and are statistically different from zero. Table 9 shows change in intra-day return autocorrelations at the five and thirty minute frequency for the introduction and removal of the flash facility. The 5 and 30 minute return autocorrelation decreases significantly after the introduction of flashed orders. The thirty minute return autocorrelations also decreases after the removal of the flash facility, but it does not change at the 5 minute frequency. This constitutes additional evidence of the improvement in market efficiency as posited in hypothesis (iii) of the model.

6 Conclusions

In this paper, we empirically analyze the implications of voluntary demand disclosure on the trading costs of the announcer and market quality. We use the introduction and removal of actionable indications of interest, flash orders, by Nasdaq as a natural experiment to study the implications of sunshine trading.

We find that flash orders are mainly submitted by agency algorithms, indicating that the main users of flash orders are large institutional investors. Executed flashed orders have lower adverse selection costs, implying that the market treats them as informationless. Our findings are consistent with Admati and Pfleiderer (1991), where they argue that the potential delay cost of preannouncement and information leakage by informed traders ensure that preannounced trades are unlikely to contain information. Identification of uninformed traders allows other market participants to lower the adverse selection cost they impose and encourages the provision of liquidity. We find that flash intensity increases when the local quotes for individual stocks diverge from the NBBO and flash orders drive the Nasdaq spread towards the NBBO. It appears that flashed orders are used to advertise demand for liquidity and to avoid routing costs. The signalling of liquidity demand attracts volume to Nasdaq immediately after an order is flashed. The use of flash orders leads to improved execution quality. Furthermore, the removal of flash orders leads to an overall increase in adverse selection costs. Thus, flashed orders improve the market quality in Nasdaq.

The improvement in Nasdaq quality leads to improvement in the overall market. Comparing various liquidity and activity measures around the flash introduction and flash removal periods, overall market liquidity improves (decreases) significantly when flash orders are introduced (removed). Market efficiency also improves (deteriorates) when flash orders are introduced (removed). The difference in difference analysis shows that market liquidity for large and medium size stocks that are flashed more frequently improves significantly during the flash period and deteriorates after its removal, while that of small stocks does not change.

Admati and Pfleiderer (1991) argue that while sunshine trading decreases the adverse selection cost of preannounced trades, it increases the adverse selection cost of the non-announcers. However, sunshine trading reduces the risk-bearing costs for both announcers and non-announcers, because it reduces the uncertainty of the liquidity demand of the uninformed traders and the amount of noise in the price. Overall, the improvement in trading cost of the uninformed traders comes at the expense of the informed traders as informed traders are able to extract less consumer surplus from the uninformed as the price becomes less noisy. This reduction in overall risk-bearing costs appears to be the driving force behind our results.

An important and immediate application of our results is to the on-going policy debate on the withdrawal of the flash trade practice in the U.S.. Our analysis and results help to understand the impact and implications of similar competition enhancing mechanisms that might are also used by dark pools, like Getco and Knight Link, who are establishing new trading venues in Europe and Asia. Nonetheless, further research on the option and European markets where flash orders are still widely used would be useful. Furthermore, our results inform future decisions on market design and transparency.

Table 1
Arguments on Flash Orders

Against	For
Market Quality	
Discourage the public display of trading interest and harm quote competition among markets, reduce incentives for public display of quotations.	Increase in volume and reduction of spreads, increase in liquidity
Deprive those who publicly display their interest at the best price from receiving a speedy execution at that price. Harm price discovery.	Attract liquidity from market participants who are not willing to display their trading interest publicly. Flash orders may provide an opportunity for better execution than if orders were routed elsewhere.
Front-running (flashed orders that do not receive an execution in the flash process are less likely to receive a quality execution elsewhere.) Quotes being taken away.	Increase the chance of execution at the best price and lower cost.
Harm the interest of long-term investors to the benefit of high-frequency traders.	Decrease volatility and provide more liquidity in volatile markets.
Diverts a certain amount of order flow that otherwise might be routed directly to execute against displayed quotations in other markets.	Orders to be routed could go to dark pool, thus flash reduce dark pool volume.
Fairness	
Detract from the fairness and efficiency of the national market system as the best quotations from specific markets are made available to a limited number of market participants.	
"Last mover" advantage, cannot have price and time priority because flash order comes at same price but later time and is still executed immediately, i.e. before outstanding orders.	
Maximize an exchange's competitive advantage, since exchanges compete on volume of executed trades.	Reduce flight to overseas markets
Those who are highly concerned about information leakage generally would be unlikely to flash their order information to a large number of professional traders.	

Table 2
Sample Characteristics

The table shows the daily and intraday sample characteristics. Panel A presents the statistics for 1867 stocks in the sample over the period April 01, 2009 to October 31, 2009. Panel B presents the statistics for the 188 stocks used to rebuild the limit order book and are used for the intraday analysis. Panel C presents the characteristics of the Toronto Stock Exchange sample used as a match sample. Panel D presents the characteristics of the CRSP stocks that are of comparable price and market capitalization to the Toronto Stock Exchange stocks and are used in the difference in difference analysis. Panel E presents the intraday characteristics of the limit order book stocks. *F.Order Size* is the number of stocks in a submitted flashed order, *F.Trade Size* is the number of stocks traded during a flashed order, *Order Size* is the size of non-flash submitted orders, *Trade Size* is the size of trades for non-flashed orders. All variables are defined in Table A1.

	Price	Volume	Trades	Market Cap.	Spread	Rel. Spread	ILR	Volatility
Panel A. CRSP Daily Sample								
Mean	27	54	5	4,893	0.083	0.489	0.2962	0.0012
Median	21	8	1	910	0.020	0.109	0.0016	0.0002
25th	14	2	0	324	0.010	0.057	0.0003	0.0000
75th	33	37	4	2,809	0.050	0.240	0.0010	0.0009
St. Dev.	29	176	15	17,202	0.234	1.583	2.9206	0.0051
Panel B. Limit Order Book Sample								
Mean	29	52	5	4,310	0.102	0.589	0.3583	0.0011
Median	20	7	1	708	0.030	0.122	0.0020	0.0002
25th	13	1	0	255	0.010	0.064	0.0004	0.0000
75th	30	27	4	2,258	0.060	0.280	0.0143	0.0009
St. Dev.	47	208	11	13,288	0.269	1.770	3.0870	0.0088
Panel C. Toronto Stock Exchange Match Sample								
Mean	19	3		1,272	0.241	1.524	0.0215	0.0005
Median	15	0		255	0.134	0.863	0.0003	0.0001
25th	10	0		101	0.065	0.421	0.0000	0.0000
75th	23	2		1,036	0.268	1.800	0.0030	0.0005
St. Dev.	20	10		3,328	0.350	2.063	0.2781	0.0018
Panel D. CRSP Match Sample								
Mean	24	38	5	2,550	0.089	0.552	0.3527	0.0017
Median	19	8	1	788	0.030	0.136	0.0021	0.0004
25th	13	2	0	291	0.010	0.070	0.0004	0.0001
75th	29	35	4	2,349	0.060	0.291	0.0137	0.0015
St. Dev.	21	90	12	4,842	0.242	1.694	3.1744	0.0051

Panel E. Intraday Sample Characteristics

	Flash Trade Size	Trade Size	Slope 5	Slope 10	Depth 5	Depth 10
Mean	202	106	8.0	6.3	4,610	9,486
Median	145	96	1.7	1.7	2,069	5,767
25th	101	83	0.4	0.5	1,433	3,954
75th	226	108	5.8	5.7	3,666	9,363
St. Dev.	247	184	20	13	8,636	12,748

Table 3
Order Submission and Execution Quality

The table shows the daily average number of orders submitted at Nasdaq and execution quality. Panel A shows statistics related to all orders that involve at least one flash, divided into two categories, orders flashed at submission (*F. O. Submission*) and orders flashed during an update (*F.O. Update*). *F.O. Total* is the total of all flashed orders. The average number of daily non flashed orders is *Orders Non Flashed*, and the average total number of daily orders is *Total Orders*. *F.O. %* presents the share of the total orders that are flashed. *% Executed* is the percentage of submitted orders that are executed. Panel B shows the fill rates during the flash period divided over flashed and non-flashed orders, and the difference in fill rates at the introduction and removal of flash orders. *Introduction* is the difference in fill rates for the first five days of flash introduction and five days before (post-pre), and *Removal* is the difference between five days after the removal of flash and five days prior (post-pre). Panel C shows the proportion of flashed orders executed at submission, executed after updates, or executed right after entering the book. *Later execution* are flashed orders that are executed after they have been altered after entering the book. *,**,*** represent significance at the 10, 5, and 1% level, respectively.

Panel A. Order Submissions

	F. O. Submission	F. O. Update	F. O. Total	Orders Non Flashed	Total Orders	F.O. %
New Order	3,228,724	499,140	3,727,864	64,581,142	68,309,006	5%
	87%					
Executed	350,163	166,023	516,187	2,714,660	3,230,847	16%
	68%					
Deleted	2,878,561	333,117	3,211,677	61,866,482	65,078,159	5%
% Executed			14%	4%	5%	

Panel B. Fill Rates

	Flashed	Non-Flashed	Introduction	Removal
Mean	9.17%	3.85%	-1.00%***	0.06%

Panel C. Flash Executions

	Mean	%
Execution rate	13.84%	
Execution after initial posting	3.40%	24.54%
Execution after update	0.77%	5.59%
Execution after entered in book	7.63%	55.16%
Later execution	2.04%	14.71%

Table 4
Preannounced Stock Characteristics

The table shows the characteristics of the stocks according to the number of daily flash orders (Panel A), the mean number of flashed orders over the sample period (Panel B), the ratio of daily flashed orders to total orders (Panel C), and the mean ratio of flash to total orders for the sample period. Tercile 1 represents the stocks with the least flashes (at least 1), while tercile 3 the stocks with most flashes. There are approximately 620 stocks in each tercile. All variables are defined in Table A1.

Tercile	Volume	Trades	Size	Spread	Rel. Spread	ILR	Volatility	Flash
Panel A. Total Flashed Orders								
1	2	0.58	410	0.1714	1.088	0.72444	0.00129	13
2	20	2.98	1,825	0.0366	0.139	0.03753	0.00098	185
3	140	21.07	13,734	0.0191	0.076	0.00410	0.00071	10172
Panel B. Period Mean Flashed Orders								
1	2	497	348	0.1956	1.315	1.01489	0.00148	20
2	22	3,413	1,829	0.0328	0.114	0.01621	0.0011	272
3	158	22,852	14,372	0.0203	0.083	0.00258	0.00096	10414
Panel C. Flash Ratio Sorted Flashed/Total Orders								
1	7	1,233	764	0.0692	0.277	0.04247	0.00112	0.09%
2	32	3,050	2,750	0.0850	0.480	0.24861	0.00104	0.44%
3	108	13,939	10,949	0.0966	0.703	0.58455	0.00090	4.44%
Panel D. Period Mean Flash Ratio (Flashed/Total Orders)								
1	5	1,149	632	0.0660	0.270	0.04493	0.00127	0.15%
2	36	3,557	2,848	0.0991	0.576	0.32609	0.00121	0.61%
3	121	14,589	11,391	0.1228	0.955	0.91185	0.00116	4.50%

Table 5
Strategic Runs

The table shows the monthly total number of runs grouped according to the number of messages per run (*Run Length*) for 188 LOB stocks during the flash period. The runs are presented for flashed and non-flashed runs. A run is classified under flash, if there is a flash message that is part of the run. HS Run is a run as defined by Hasbrouck and Saar (2010), Update Run is a run consisting of subsequent update messages, Total Run is the sum of HS and Update runs. Strategic Runs is the percentage of runs with more than ten messages, Total runs is the total number of runs per period.

	HS Run				Update Run				Total Run			
Run Length	Non Flash		Flash		Non Flash		Flash		Non Flash		Flash	
Panel A. June												
3-4	3,860,761	54.46%	164,606	74.88%	546,395	80.68%	688,504	77.57%	4,407,156	65.98%	853,110	77.04%
5-10	1,634,840	23.06%	49,130	22.35%	112,296	16.58%	172,677	19.46%	1,747,136	26.16%	221,807	20.03%
11-14	177,301	2.50%	2,641	1.20%	9,572	1.41%	16,626	1.87%	186,873	2.80%	19,267	1.74%
15-20	117,222	1.65%	1,421	0.65%	4,625	0.68%	6,549	0.74%	121,847	1.82%	7,970	0.72%
21-100	187,616	2.65%	1,678	0.76%	2,870	0.42%	2,531	0.29%	190,486	2.85%	4,209	0.38%
101-1000	23,859	0.34%	299	0.14%	1,207	0.18%	632	0.07%	25,066	0.38%	931	0.08%
1001-5000	790	0.01%	38	0.02%	302	0.04%	52	0.01%	1,092	0.02%	90	0.01%
>5000	73	0.00%	2	0.00%	1	0.00%		0.00%	74	0.00%	2	0.00%
Strategic Runs		7.15%		2.77%		2.74%		2.97%		7.87%		2.93%
Total Runs	6,002,462		219,815		677,268		887,571		6,679,730		1,107,386	
Panel B. July												
3-4	6,531,985	60.70%	340,753	75.36%	1,098,713	77.73%	1,636,214	77.59%	7,630,698	65.03%	1,976,967	77.20%
5-10	2,910,182	27.04%	99,865	22.08%	277,389	19.62%	425,000	20.15%	3,187,571	27.17%	524,865	20.50%
11-14	317,495	2.95%	5,475	1.21%	21,008	1.49%	30,409	1.44%	338,503	2.88%	35,884	1.40%
15-20	196,474	1.83%	2,687	0.59%	9,628	0.68%	11,971	0.57%	206,102	1.76%	14,658	0.57%
21-100	327,803	3.05%	2,873	0.64%	4,604	0.33%	4,040	0.19%	332,407	2.83%	6,913	0.27%
101-1000	35,092	0.33%	477	0.11%	1,723	0.12%	1,000	0.05%	36,815	0.31%	1,477	0.06%
1001-5000	677	0.01%	59	0.01%	422	0.03%	97	0.00%	1,099	0.01%	156	0.01%
>5000	89	0.00%	3	0.00%		0.00%		0.00%	89	0.00%		0.00%
Strategic Runs		8.16%		2.56%		2.64%		2.25%		7.80%		2.31%
Total Runs	10,319,797		452,192		1,413,487		2,108,731		11,733,284		2,560,920	
Panel C. August												
3-4	6,992,449	64.98%	349850	74.39%	1,677,283	79.76%	2,248,948	79.50%	8,669,732	67.57%	2,598,798	78.77%
5-10	2,911,205	27.05%	109,178	23.22%	363,498	17.29%	499,405	17.65%	3,274,703	25.52%	608,583	18.45%
11-14	304,753	2.83%	4,967	1.06%	29,243	1.39%	41,479	1.47%	333,996	2.60%	46,446	1.41%
15-20	186,866	1.74%	2,365	0.50%	15,136	0.72%	20,930	0.74%	202,002	1.57%	23,295	0.71%
21-100	310,883	2.89%	3,620	0.77%	10,712	0.51%	13,138	0.46%	321,595	2.51%	16,758	0.51%
101-1000	21,208	0.20%	282	0.06%	5,220	0.25%	4,643	0.16%	26,428	0.21%	4,925	0.15%
1001-5000	571	0.01%	24	0.01%	1,836	0.09%	428	0.02%	2,407	0.02%	452	0.01%
>5000	68	0.00%	2	0.00%	30	0.00%		0.00%	98	0.00%		0.00%
Strategic Runs		7.66%		2.39%		2.96%		2.85%		6.91%		2.78%
Total Runs	10,728,003		470,288		2,102,958		2,828,971		12,830,961		3,299,257	

Table 6
Effective Spread Decomposition

The table presents effective (*espread*) and realized (*rspread*) spreads and adverse selection costs (*adv_selection*). Panel A presents the difference between flashed and non-flashed orders during the flash order period. Panel B presents the mean and median change in costs for the introduction and removal of flashed orders. *Introduction* is the difference in costs for the first five days of flash introduction and five days before (post-pre), and *Removal* is the difference between five days after the removal of flash and five days prior (post-pre). All variables are defined in Table A1.

	espread	rspread	*adv_selection*
		Panel A. Flash - Non flashed Diff	
Mean	- 0.270	- 0.060	- 0.048
p-val	0.00	0.00	0.09
Median	- 0.024	0.000	- 0.007
p-val	0.00	0.04	0.00
		Panel B. Changes for All Market Participants	
		Introduction	
Mean	0.023	0.004	0.011
p-val	0.59	0.87	0.90
Median	0.001	-0.005	0.002
p-val	0.49	0.07	0.35
		Removal	
Mean	-0.016	-0.018	0.063
p-val	0.42	0.26	0.09
Median	0.007	0.000	0.004
p-val	0.14	0.99	0.00

Table 7
Flash Order Impact on Market Liquidity

The table presents the proportional change in liquidity variables after the introduction and removal of flash orders. *Introduction* is the proportional change between the first five days of flash introduction and five days before ((post-pre)/pre), and *Removal* is the proportional change between five days after the removal of flash and five days prior ((post-pre)/pre). The table presents results for the whole sample of 1867 stocks. Panel A presents the change in the impact on the whole market. Mean presents the change in mean and median the change in median. Panel B the proportional change in the mean of liquidity variables after the introduction and removal of flash orders for stocks sorted according to market capitalization. *,**,*** represent significance at the 10, 5, and 1% level, respectively. All variables are defined in Table A1.

Panel A. Whole Market

	Spread	Rel. Spread	ILR	Volatility
Introduction				
Mean	-0.11^{***}	-0.11^{**}	-0.06	-0.36^{***}
Median	-0.33^{***}	-0.23^{***}	-0.17^{***}	-0.54^{***}
Removal				
Mean	0.01	0.04	-0.11	0.31^{***}
Median	0.00	0.10^{***}	0.26^{***}	0.62^{***}

Panel B. Sorted by Market Capitalization

	Spread	Rel. Spread	ILR	Volatility
Introduction				
1	-0.08^{*}	-0.09^{*}	-0.06	-0.28^{***}
2	-0.15^{***}	-0.17^{***}	0.04	-0.35^{***}
3	-0.20^{***}	-0.24^{***}	-0.15^{**}	-0.54^{***}
Removal				
1	0.01	0.04	-0.11	0.19
2	-0.01	0.10^{***}	0.07	0.40^{***}
3	0.01	0.07^{***}	0.35^{***}	0.62^{***}

Table 8
Difference in Difference Match Group

The table shows results for the difference in difference analysis. Panel A shows the mean difference in difference between the CRSP and Toronto Stock Exchange liquidity variables (treatment-control) for an event study with a ten day event window. *Introduction* is the difference in liquidity measures between the flash introduction and before (post-pre), and *Removal* is the difference between the removal of flash and prior (post-pre). We show the results for the whole sample and the results CRSP stock sorted according to market capitalization. Panel B shows two-way fixed effect regressions of the liquidity difference between the Nasdaq and Toronto Stock Exchange (TSE) (treatment-control) on a flash period dummy for the sample period: April 1 - October 31, 2009. Market Cap is the difference in market capitalization between Nasdaq and TSE stocks, Volume is the difference in volume between Nasdaq and TSE stocks, VWAP (volume weighted average price) is the difference in VWAP between Nasdaq and TSE stocks. The coefficients for Volume and VWAP have been multiplied by 1000. Flash Dummy is a binary variable that is one for the period June 5 - August 31, 2009, and zero otherwise. All variables are defined in Table A1. *,**,*** represent significance at the 10, 5, and 1% level, respectively.

	Introduction	Removal
Panel A. Event Study		
Whole Sample		
Spread	-0.0187^{***}	0.0052
Relative Spread	-0.0301^{*}	0.0270^{*}
ILR	0.0189	0.0337
Volatility	-0.0023^{***}	0.0065^{***}
Market Cap Sorted		
Tercile 1		
Spread	0.0045	0.0029
Relative Spread	0.0744	0.0281
ILR	0.0769	0.0863
Volatility	-0.0016	0.0069^{***}
Tercile 2		
Spread	-0.0256^{***}	0.0122^{***}
Relative Spread	-0.0658^{***}	0.0559^{***}
ILR	0.0007	0.0003
Volatility	-0.0019^{**}	0.0060^{***}
Tercile 3		
Spread	-0.0356^{***}	0.0006
Relative Spread	-0.1022^{***}	-0.0032
ILR	-0.0226^{*}	0.0129
Volatility	-0.0035^{***}	0.0065^{***}

Panel B. Regression Analysis

	Market Cap	Volume	VWAP	Flash Dummy	R^2
Spread	0.004^{***}	-0.001	-0.009^{**}	-0.002^{**}	0.56
Rel Spread	-0.005^{**}	-0.001	-0.050^{***}	-0.016^{***}	0.17
ILR	-0.007	-0.007	-0.030	-0.011	0.13
Volatility	0.000	0.069	0.018	-0.002^{***}	0.23

Table 9
Return Autocorrelation

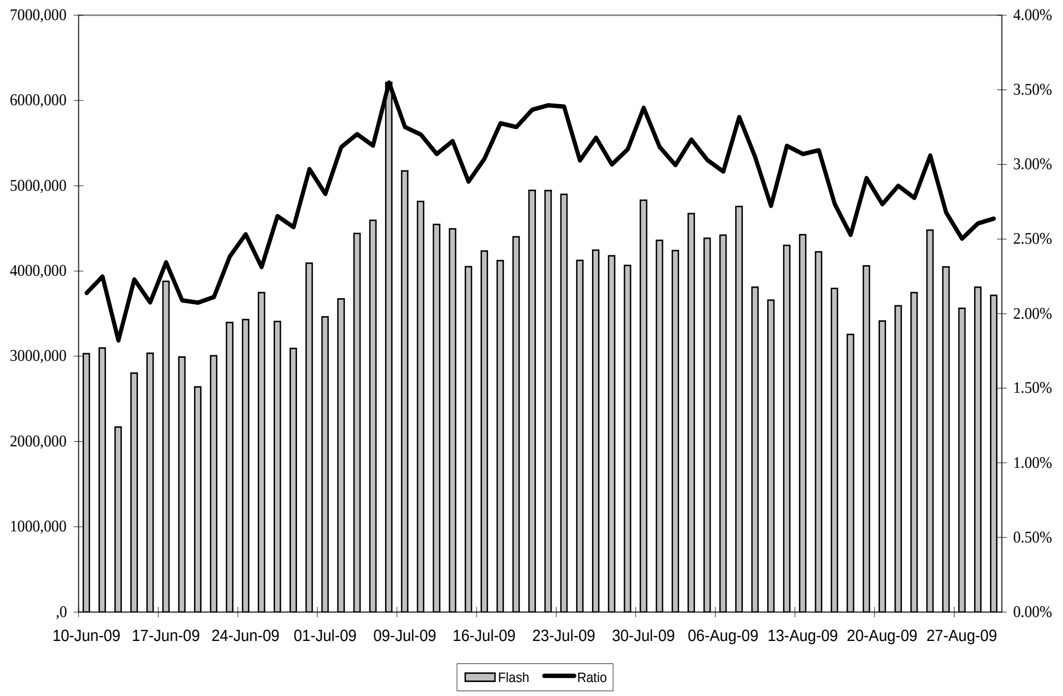
The table shows the return autocorrelation for the LOB stocks for an event study with a ten day event window for the introduction and removal of flash orders. *Introduction* is the difference in autocorrelation measures between the flash introduction and before (post-pre), and *Removal* is the difference between the removal of flash and prior (post-pre). Panel A presents the results for the 30 minutes return autocorrelation and Panel B the results for the 5 minute return autocorrelation.

	Introduction	Removal
Panel A. 30 Minutes		
Mean	0.0463	-0.046
p-val	0.00	0.00
Median	0.050	-0.033
p-val	0.00	0.01
Panel B. 5 Minutes		
Mean	0.076	0.027
p-val	0.00	0.40
Median	0.084	-0.007
p-val	0.00	0.25

Figure 1
Flashed Orders at Nasdaq

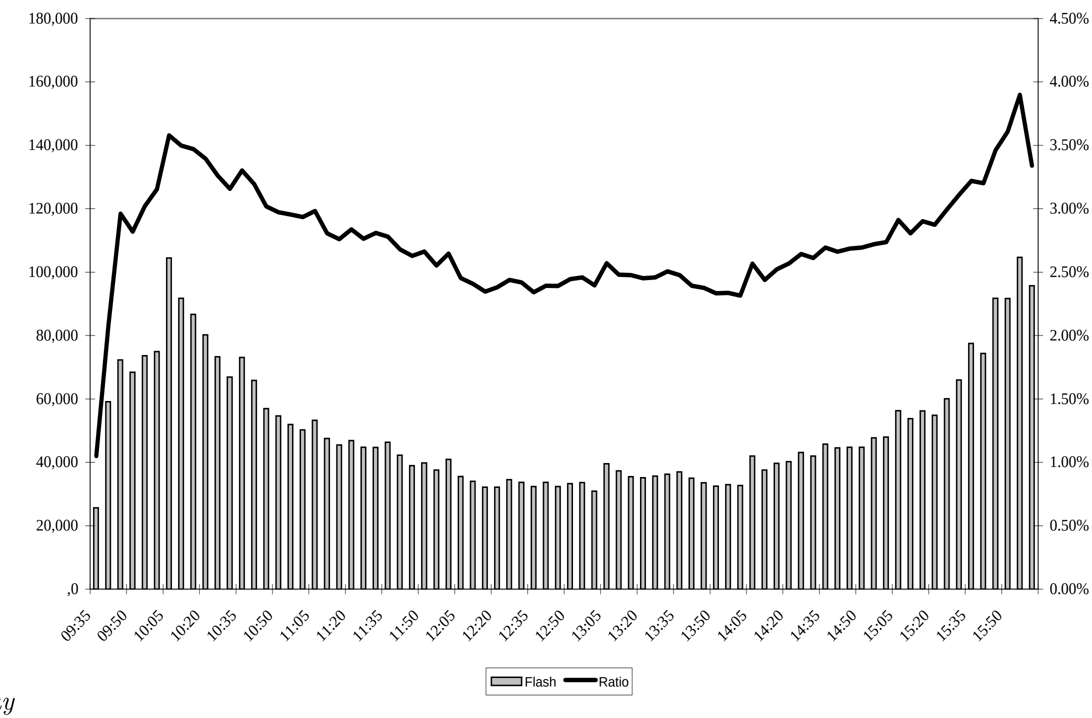
The figure presents the daily number of flashed orders in Panel A. Panel B presents the intraday variation in flashed orders submissions accumulated at the 5 minute level. *Flash* is the total number of flashed orders during the day, and *Ratio* is the ratio of flashed orders and total orders.

Panel A:



Daily

Panel B:

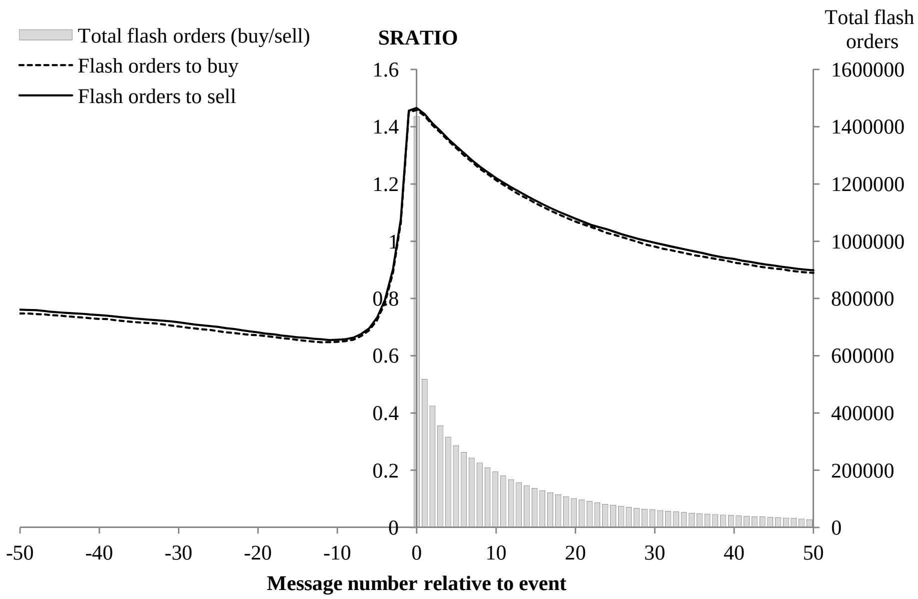


Intraday

Figure 2
Flash Order Submissions and Expirations

The figures show the cross sectional average SRATIO for 50 messages before and after the flashed order events for 188 stocks. The SRATIO is calculated as the Nasdaq spread divided by the NBBO spread minus one. In both panels the x-axis is the number of messages relative to the flashed order submission, which is the event of interest centered at zero. Panel A shows the SRATIO around flash order submissions, and Panel B shows the SRATIO around the flash order expirations (message type "V"). The bars show the total number of flash order submissions and expirations respectively.

Panel A: Flash order submissions



Panel B: Flash order expiration (V)

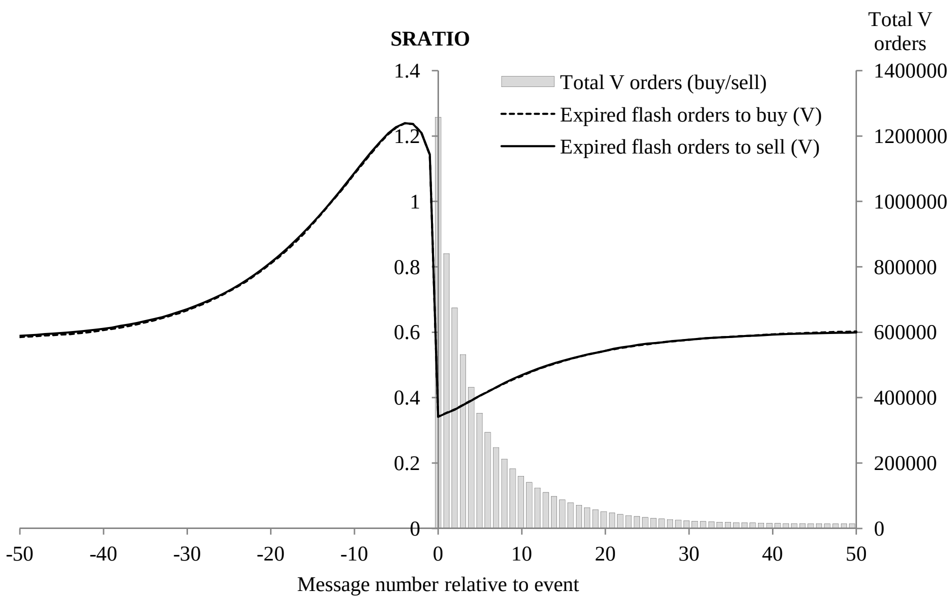
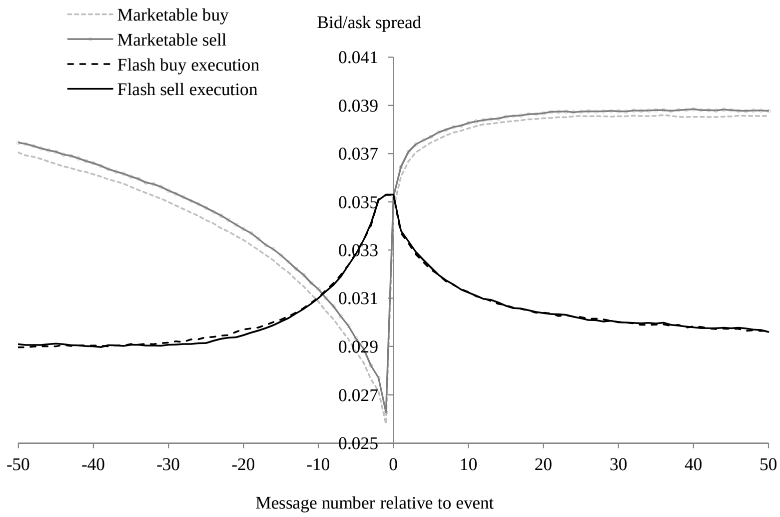


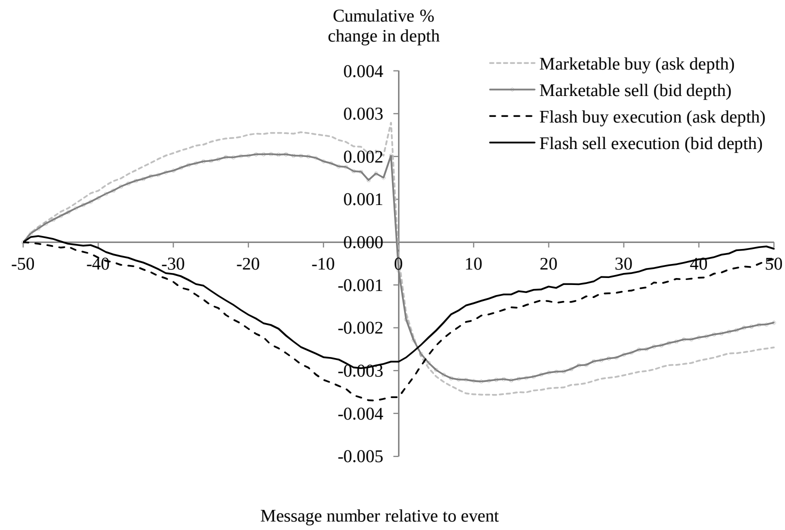
Figure 3
Flash Order Executions versus Marketable Limit Order executions

The figure shows Nasdaq liquidity around the execution of flashed and marketable limit orders 188 stocks. Panel A shows the bid-ask spread around the execution of the two types of orders. Panel B shows the change in cumulative depth (the total depth of the limit order book) around the execution of the two types of orders. Event time 0 is the execution time, and the event window is 50 messages before and after the execution.

Panel A: Nasdaq spread around market- and flash order executions



Panel B: Limit order book depth around market- and flash order executions



A Appendix

Table A1
Variable Definitions

Variable	Acronym	Definition
Market Wide		
Dollar volume	Volume	(Share volume*price)/1000000
Number of daily trades	Trades	Trading Volume/1000
Firm size	Mkt Cap	(Price*Outstanding Shares)/1000000
Spread		$bid - ask$
Relative Spread	Rel. Spread	$(bid - ask) * 100/((bid + ask)/2)$
Amihud Illiquidity Ratio	ILR	$\|return\|$/dollar volume
Volatility		$return^2$
Limit Order Book		
First level quoted spread	QS_1	$ask_1 - bid_1$
Midpoint price	m_t	$(ask_1 + bid_1)/2$
First level relative spread	RS_1	QS_1/m_t
Realized spread	rspread	direction*(price-m_{t+5min})/m_t
Adverse selection	$adv\_selection$	direction*(m_t -m_{t+5min})/m_t
Effective Spread	espread	direction*(price-m_{jt})/m_{jt}
Slope 5 Ask	$slope_{A5}$	$(askdepth_5 - askdepth_1)/(ask_5 - ask_1)$
Slope 5 Bid	$slope_{B5}$	$(biddepth_5 - biddepth_1)/(bid_5 - bid_1)$
Slope 5		$(slope_{A5} + slope_{B5})/2$
Slope 10		$(slope_{A10} + slope_{B10})/2$
Depth 5		(ask $depth_5$+bid $depth_5$)/2
Depth 10		(ask $depth_{10}$+bid $depth_{10}$)/2

Table A2
Flash Stock Characteristics - Non TARP

The table shows the characteristics of non TARP sample according to the number of daily flash orders (Panel A), the mean number of flashed orders over the sample period (Panel B), the ratio of daily flashed orders to total orders (Panel C), and the mean ratio of flash to total orders for the sample period. Tercile 1 represents the stocks with the least flashes (at least 1), while tercile 3 the stocks with most flashes. There are approximately 620 stocks in each bin. All variables are defined in Table A1.

Tercile	Volume	Trades	Size	Spread	Rel. Spread	ILR	Volatility	Flash
Panel A. Total Flashed Orders								
1	3	798	477	0.1066	0.573	0.19763	0.00130	15
2	21	3,100	1,857	0.0327	0.117	0.03203	0.00102	187
3	139	22,367	14,138	0.0187	0.074	0.00467	0.00071	9744
Panel B - Period Mean Flashed Orders								
1	3	693	417	0.1166	0.635	0.25543	0.00141	25
2	22	3,399	1,832	0.0315	0.112	0.01833	0.00109	248
3	152	23,878	14,631	0.0201	0.081	0.00290	0.00089	9815
Panel C - Flash Ratio Sorted (Flashed/Total Orders)								
1	7	1,415	782	0.0579	0.233	0.03309	0.00123	0.09%
2	37	3,968	3,153	0.0582	0.267	0.08176	0.00100	0.44%
3	120	19,361	12,628	0.0392	0.249	0.11413	0.00079	4.54%
Panel D - Period Mean Flash Ratio (Flashed/Total Orders)								
1	5	1,296	608	0.0556	0.230	0.02867	0.00128	0.15%
2	45	4,991	3,473	0.0661	0.295	0.08785	0.00116	0.58%
3	132	21,363	13,454	0.0453	0.305	0.16715	0.00094	4.66%

Table A3
Liquidity After Double Sorting on Stock Characteristics and Flash Ratio

The table shows the liquidity measures of the sample after sorting according to stock characteristics and flash ratio. Panel A shows the results for sorting according to volume and Panel B according to market capitalization. All variables are defined in Table A1.

Ratio	Spread	Rel. Spread	ILR	Volatility	Ratio
		Panel A. Volume			
		Volume Tercile 1			
1	0.07314	0.37763	0.07716	0.00157	0.14%
2	0.28263	1.86086	1.16696	0.00152	0.59%
3	0.60460	4.94253	5.08632	0.00194	3.19%
		Volume Tercile 2			
1	0.05110	0.14253	0.00639	0.00092	0.17%
2	0.02746	0.12420	0.02980	0.00123	0.60%
3	0.01684	0.13191	0.01523	0.00110	3.98%
		Volume Tercile 3			
1	0.20911	0.10677	0.00045	0.00080	0.17%
2	0.03695	0.07947	0.00129	0.00093	0.65%
3	0.01814	0.07684	0.00034	0.00096	4.95%
		Panel B. Market Capitalization			
		Market Cap Tercile 1			
1	0.06346	0.37072	0.07815	0.00167	0.15%
2	0.25870	1.74861	1.09250	0.00154	0.56%
3	0.60990	4.98590	5.13343	0.00200	3.29%
		Market Cap Tercile 2			
1	0.04651	0.15707	0.00837	0.00085	0.16%
2	0.03380	0.12602	0.03232	0.00146	0.61%
3	0.01643	0.12334	0.00236	0.00151	4.14%
		Market Cap Tercile 3			
1	0.29289	0.16631	0.00180	0.00058	0.16%
2	0.03601	0.08108	0.00166	0.00066	0.67%
3	0.01841	0.07593	0.00316	0.00082	4.94%

Table A4
Flash Order Impact on Market Liquidity Non TARP Stocks

The table presents the proportional change in liquidity variables after the introduction and removal of flash orders for 1420 non-TARP stocks. *Introduction* is the proportional change between the first five days of flash introduction and five days before ((post-pre)/pre), and *Removal* is the proportional change between five days after the removal of flash and five days prior ((post-pre)/pre). Panel A presents the change in the impact on the whole market. Mean presents the change in mean and median the change in median. Panel B the proportional change in the mean of liquidity variables after the introduction and removal of flash orders for stocks sorted according to market capitalization. *,**,*** represent significance at the 10, 5, and 1% level, respectively. All variables are defined in Table A1.

Panel A. Whole Market

	Spread	Rel. Spread	ILR	Volatility
		Introduction		
Mean	−0.14***	−0.17***	-0.22	−0.39***
Median	−0.33***	−0.24***	-0.20	−0.56***
		Removal		
Mean	0.06	0.07	0.09	0.42**
Median	0.00	0.09***	0.29***	0.69***

Panel B. Sorted by Market Capitalization

	Spread	Rel. Spread	ILR	Volatility
		Introduction		
1	−0.11*	−0.16**	-0.22	−0.25***
2	-0.10	−0.17***	0.13	−0.44***
3	−0.22***	−0.25***	−0.22***	−0.59***
		Removal		
1	0.06	0.07	0.09	0.46***
2	0.07	0.08***	-0.01	0.33**
3	0.05	0.08***	0.345***	0.49***

Table A5
Flash Order Impact on Market Liquidity - Other Samples

The table presents the proportional change in liquidity variables after the introduction and removal of flash orders for two additional samples. *Introduction* is the proportional change between the first five days of flash introduction and five days before ((post-pre)/pre), and *Removal* is the proportional change between five days after the removal of flash and five days prior ((post-pre)/pre). Mean presents the change in mean and median the change in median. Panel A presents the results for the whole sample unrestricted to common stocks and common shares of 4095 stocks, while Panel B presents the results for 2162 non-TARP stocks unrestricted to common stocks and common shares. *p*-values are presented in brackets. All variables are defined in Table A1.

	Spread	Rel. Spread	ILR	Volatility
Panel A. All Sample				
Introduction				
Mean	-0.07	-0.08	0.05	0.00
	(0.01)	(0.00)	(0.46)	(1.00)
Median	-0.25	-0.15	-0.14	-0.54
	(0.00)	(0.00)	(0.00)	(0.00)
Removal				
Mean	0.03	0.06	0.13	0.02
	(0.23)	(0.03)	(0.08)	(0.71)
Median	0.03	0.06	0.13	0.02
	(1.00)	(0.00)	(0.00)	(0.00)
Panel B. Non TARP				
Introduction				
Mean	-0.12	-0.15	-0.12	-0.13
	(0.00)	(0.00)	(0.49)	(0.50)
Median	-0.33	-0.21	-0.22	-0.57
	(0.00)	(0.00)	(0.34)	(0.00)
Removal				
Mean	0.06	0.07	0.08	0.15
	(0.12)	(0.11)	(0.03)	(0.46)
Median	0.00	0.07	0.25	0.78
	(1.00)	(0.00)	(0.33)	(0.00)

Table A6
Flash Order Impact on Market Liquidity in Terciles by Flash Ratio

The table presents the proportional change in the mean of liquidity variables after the introduction and removal of flash orders for stocks sorted according to the flash ratio. *Introduction* is the proportional change between the first five days of flash introduction and five days before ((post-pre)/pre), and *Removal* is the proportional change between five days after the removal of flash and five days prior ((post-pre)/pre). Panel A presents the results for the whole sample of 1867 stocks, while Panel B presents the results for non-TARP stocks, 1420. All variables are defined in Table A1. *,**,*** represent significance at the 10, 5, and 1% level, respectively.

Panel A. Whole Sample

	Spread	Rel. Spread	ILR	Volatility
Introduction				
1	-0.08	-0.16^{***}	-0.12	-0.37^{***}
2	-0.14^{***}	-0.13^{**}	-0.21	-0.30^{***}
3	-0.10	-0.07	0.02	-0.44^{***}
Removal				
1	0.04	0.10	0.04	0.35^{*}
2	0.06	0.07	0.35	0.26^{*}
3	-0.06	0.02	-0.25	0.35^{**}

Panel B. Non TARP

	Spread	Rel. Spread	ILR	Volatility
Introduction				
1	-0.03	-0.15^{***}	-0.02	-0.36^{***}
2	-0.16^{**}	-0.15^{**}	-0.34	-0.32^{***}
3	-0.24^{**}	-0.23^{*}	-0.17	-0.53^{***}
Removal				
1	0.06	0.11^{***}	0.08	0.43^{*}
2	0.09	0.07	0.15	0.33^{*}
3	-0.01	0.04	0.06	0.56^{***}

Table A7
Flash Order Impact on Market Liquidity Double Sorted by Market Cap and Flash Ratio

The table presents the proportional change in the mean of liquidity variables after the introduction and removal of flash orders for stocks double sorted according to market capitalization and the flash ratio. *Introduction* is the proportional change between the first five days of flash introduction and five days before ((post-pre)/pre), and *Removal* is the proportional change between five days after the removal of flash and five days prior ((post-pre)/pre). All variables are defined in Table A1. *,**,*** represent significance at the 10, 5, and 1% level, respectively.

Ratio	Spread	Rel. Spread	ILR	Volatility
		Panel A. Introduction		
		Market Cap Tercile 1		
1	-0.08	−0.15***	-0.15	−0.31***
2	-0.08	−0.12*	-0.18	-0.04
3	-0.06	-0.06	0.02	−0.24*
		Market Cap Tercile 2		
1	−0.15**	−0.18***	0.20	−0.48***
2	−0.27***	−0.27***	-0.85	−0.37***
3	−0.10***	−0.12***	−0.22***	−0.36***
		Market Cap Tercile 3		
1	0.06	-0.05	-0.19	-0.53***
2	−0.26***	−0.27***	−0.70***	−0.64***
3	−0.29***	−0.23***	−0.70***	−0.56***
		Panel B. Removal		
		Market Cap Tercile 1		
1	0.07	0.11	0.05	0.30
2	0.09	0.06	0.46	0.24
3	-0.08	0.01	-0.26	-0.23
		Market Cap Tercile 2		
1	0.08	0.09**	-0.15	0.51***
2	-0.12	0.10	-0.38	0.21
3	0.04	0.09**	0.41	0.96***
		Market Cap Tercile 3		
1	-0.11	-0.07	0.29	0.80***
2	0.08	0.10*	-0.67	0.56***
3	0.10***	0.09***	2.29	0.60***

Table A8
Period Statistics in Terciles by Total Flash

The table presents the proportional change in the mean of liquidity variables after the introduction and removal of flash orders for stocks sorted according to the number of flashed orders. *Introduction* is the proportional change between the first five days of flash introduction and five days before ((post-pre)/pre), and *Removal* is the proportional change between five days after the removal of flash and five days prior ((post-pre)/pre). All variables are defined in Table A1. *,**,*** represent significance at the 10, 5, and 1% level, respectively.

	Spread	Rel. Spread	ILR	Volatility
		Introduction		
1	-0.06	-0.09^{*}	-0.04	-0.28^{***}
2	-0.27^{***}	-0.26^{***}	-0.80	-0.37^{***}
3	-0.27^{***}	-0.21^{***}	-0.68	-0.53^{***}
		Removal		
1	-0.02	0.02	-0.11	0.24
2	0.11^{**}	0.14^{***}	-0.39	0.24
3	0.10^{***}	0.09^{***}	0.98	0.79^{***}

Table A9
Difference in Difference Match Group Robustness

The table shows the mean difference in difference between the Nasdaq and Toronto Stock Exchange liquidity variables (treatment-control) of a 20 day pre/post window event study. *Introduction* is the difference between the flash introduction and before (post-pre), and *Removal* is the difference between the removal of flash and prior (post-pre). Panel A shows the results for the whole sample, and the results sorted according to market capitalization. Panel B shows the regression results for non-TARP stocks. All variables are defined in Table A1. *,**,*** represent significance at the 10, 5, and 1% level, respectively.

Panel A. Event Study

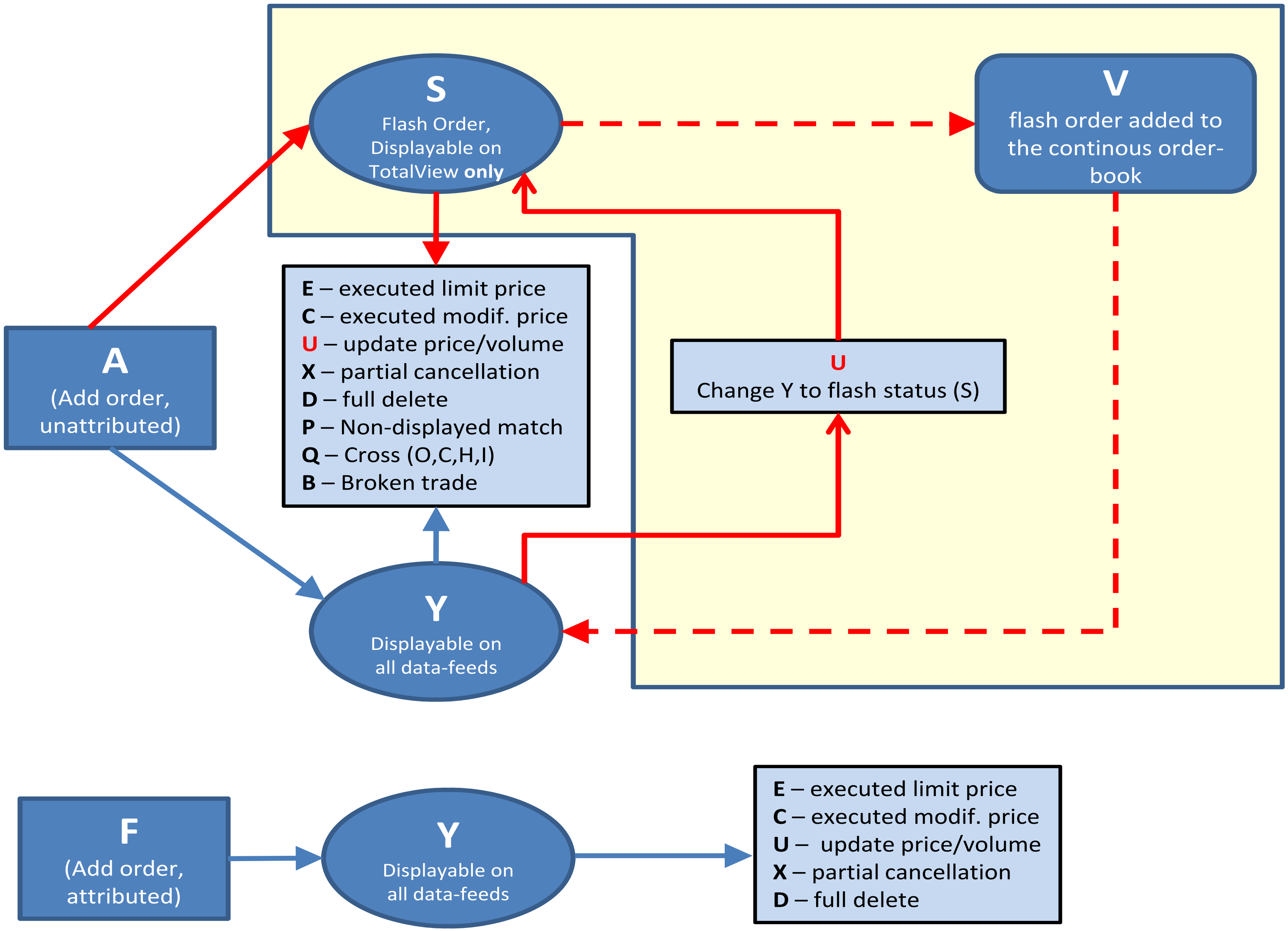
	Introduction	Removal
Whole Sample		
Spread	−0.0244***	0.0029
Relative Spread	−0.0533***	0.0077
ILR	-0.0225	0.0287
Volatility	-0.0005	0.0018***
Market Cap Sorted		
Tercile 1		
Spread	-0.0077	0.0018
Relative Spread	0.0171	-0.0059
ILR	-0.0571	0.0709
Volatility	0.0000	0.0017***
Tercile 2		
Spread	−0.0301***	0.0083***
Relative Spread	−0.0886***	0.0406***
ILR	-0.0005	-0.0012
Volatility	-0.0004	0.0023***
Tercile 3		
Spread	−0.0360***	-0.0014
Relative Spread	−0.0906***	-0.0113
ILR	-0.0088	0.0152
Volatility	−0.0010**	0.0013***

Panel B. Non TARP

	Market Cap	Volume	VWAP	Flash Dummy	R^2
Spread	0.005***	-0.004	−0.008*	−0.002*	0.58
Rel Spread	−0.004**	0.004	−0.050***	−0.011***	0.21
ILR	−0.008***	-0.006	-0.030	-0.005	0.16
Volatility	0.000	0.081	0.016	−0.001***	0.26

Figure A1
Message Types in Nasdaq

The figure presents the different message types that appear on the Nasdaq tape and how they are related to flash orders.



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