Latency Cost and Information: Does Trading Speed Matter for All Market Participants?

Ryan Garvey*

Abstract

I examine latency cost, i.e. a trading cost dimension arising from the delay in time between an order submission decision and execution, across traders with different levels of information in U.S. equities. I find that traders who appear both informed and uninformed about future prices experience a cost induced from latency. However, the uninformed pay a significantly higher cost. The results indicate that having access to faster trading speed is beneficial, even for traders using less speed-sensitive strategies.

*Ryan Garvey is with Duquesne University, Pittsburgh, PA. 15282. Telephone 412-396-4003, fax 412-396-4764, email Garvey@duq.edu.
When traders submit a buy (sell) order for immediate execution in U.S. securities markets, the national best offer (bid) quote that they observe, or which is quoted by a broker, at the time of their order submission decision, can differ from the execution price. The price difference arises from latency or the delay in time between an order submission decision and execution. Traders can mitigate price risk brought on through latency by submitting a price contingent order. However, delays with placing, updating, and/or canceling limit orders can result in costs, too.

Latency related issues have become increasingly important in recent years as advances in technology enable markets and traders to increase their execution speed continually. Although financial researchers have studied various dimensions of trading costs in different settings, there is relatively little research devoted to studying the trading cost dimension which arises from latency.¹ Recently, Moallemi and Saglam (2010) developed a theoretical model to quantify the cost of latency by means of a stylized trade execution problem, and Garvey and Wu (2010) empirically examined latency cost with respect to trader geographic location.

The focus of this study is to examine latency cost across market participants with different levels of information. Traders in securities markets are often classified as being informed or uninformed relative to future market prices. Do the informed and uninformed both pay a cost arising from latency? If so, how does latency cost vary across the two types of traders? In this paper, I provide some insights for answering these questions.

¹ In part, this is likely driven by data constraints. For example, most empirical studies assess trading costs using transaction-level databases provided by exchanges (e.g., NYSE TAQ data). However, exchange data sources do not allow researchers to measure latency cost because they do not provide any information related to trader order submission decision.
An examination into the relationship between latency cost and trader information is important for many reasons. For one, it can enable market participants and academics to understand the cost of trading in securities markets better. It is also useful to policy makers for setting new regulations. For example, The Securities and Exchange Commission recently launched an in-depth investigation into high-speed trading (i.e., high frequency trading) and is considering various regulatory proposals.\(^2\) A concern of the Commission is whether certain market participants who have access to faster trading speed through co-locating their computers at Exchanges or utilizing advanced trading systems gain an unfair advantage over others operating in the market. Thus, an examination into whether execution speed matters for different types of traders is of interest.

It is not obvious if an informed and/or uninformed trader would experience a systematic trading cost arising from latency. Consider an informed trader. On the one hand, informed traders might be better at finding ways to mitigate cost arising from latency. For example, they might be better at identifying stocks, times, etc., when latency cost is lower. On the other hand, perhaps latency cost is unavoidable for traders with information. For example, traders possessing information need to act quickly before competitive market forces erode their informational advantage. In the process, market prices may move systematically and adversely from order submission to execution.

It is also not obvious if an uninformed (liquidity) trader would experience a systematic cost arising from latency. For example, at any given moment, the likelihood of a stock price rising or falling over the next period is often considered to be near even. Thus, market prices

may be equally likely to rise or fall when an uninformed trader submits an order. However, studies (e.g., Bessembinder, 2003; Peterson and Sirri, 2003; Werner, 2003) have shown that midpoint quotes tend to move systematically and adversely between the arrival of orders at the New York Stock Exchange and execution.\(^3\)

In order to examine the relationship between latency cost and trader information, I first obtain proprietary data on individual traders from a U.S. broker-dealer over a six and one-half year period ending May 2006. I then estimate latency cost and trader information using the following methods. First, latency cost is computed for immediately executable buy orders as the share-weighted execution price minus the national best offer price at the time a trader submits an order (vice-versa for sell orders). Trader information is estimated by analyzing market prices following order execution. If prices tend to rise (fall) after a trader submits a buy (sell) order, I conjecture that the trader is informed (vice-versa for sell orders).

Overall, I find costs arising from latency are fairly small when assessed on a per order basis. For example, the average cost of latency across all marketable orders (2.2 million) is one cent. Despite the small nature of latency cost on a per order basis, it is still economically important. For example, in my sample data alone, the trading cost dimension attributable to latency is approximately $13.5 million on 3.8 billion shares.

Controlling for various factors that might contribute to higher (lower) latency cost, such as the proximity of a trader to market central computers, I find that both informed and uninformed traders experience latency cost. However, traders who are less informed about

\(^3\) These studies use data at the exchange-level and do not examine the time horizon from when a trader submits an order to execution.
future prices experience higher latency cost. The results indicate that, irrespective of one’s motive for trading, access to faster trading speed is important for reducing transaction costs.

The remainder of this paper is organized as follows. In the first Section, I describe the data. In Section 2, I examine latency cost between informed and uninformed traders with marketable orders only. Although latency cost is not directly observable with non-marketable orders, execution delays with non-marketable orders can result in higher adverse selection cost. Therefore, in Section 3, I examine trader information content and adverse selection cost with non-marketable orders. Concluding remarks are provided in Section 4.

1. Data

I make use of several data sources in the study. The most important is proprietary order-level data obtained from a U.S. broker-dealer. The use of proprietary data is important because it provides information on individual trader order submission decisions (and resulting executions) which is needed for measuring latency cost. Historical intraday pricing data from Reuters\(^4\) is also used so that market conditions, such as the bid-ask spread, market depth, market volatility, and trading volume, etc., can be analyzed when traders make order submission decisions. Finally, The Center for Research and Security Price (CRSP) data are used to analyze overall trading information about the stocks being traded, such as a stock’s price, market capitalization, and trading activity.

There are multiple trading operations within the U.S. broker-dealer. The data used in the study originate from the firm’s brokerage operation where clients are provided with direct

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\(^4\) For information on Reuters tick history database, see [http://about.reuters.com/productinfo/tickhistory/](http://about.reuters.com/productinfo/tickhistory/).
market access (DMA) order execution software and administrative trading support. DMA brokers cater to a wide variety of retail and institutional clients with different trading styles (e.g., individual investors, hedge funds, day traders, proprietary traders, banks, etc.). They differ from traditional brokerage firms in that they allow their clients to choose where and how their order is routed for execution. In general, DMA brokers tend to attract market participants who are very sensitive about the order execution process.

The main limitation of the data is that they reflect trading activity originating from one brokerage firm, which may or may not be representative of the experiences of other traders in the market. Unfortunately, latency cost is not measureable with publicly available exchange databases. Despite this limitation, the sample data are fairly large. I examine latency cost on more than 5.2 million orders (7.7 million trades) and 9.8 billion executed shares. The data are matched with intraday and daily transaction records on approximately 4,000 stocks over a six and one-half year period ending May 2006. I know that a large percentage of U.S. equity trading volume flows through brokerage firms similar to this one. For example, Goldberg and Lupercio (2004) find that approximately 40% of Nasdaq and NYSE-listed trading volume is executed through brokers providing DMA. The sample traders are geographically dispersed and they exhibit trading activity patterns that mirror those in the overall marketplace. For example, aggregate intraday trading activity follows a pattern similar to the general U-shape market volume pattern. Trading volume steadily declines from morning to midday and then increases
as the close approaches. Moreover, the most actively traded stocks in my sample data are also the most actively traded stocks in the overall marketplace.\(^5\)

The sample period is from October 7, 1999 to May 25, 2006. For every order request, the brokerage firm data contain information such as the identity of the trader submitting the order, the location of the trader (in the U.S.), the time of submission, the time of execution, the stock symbol, the executed volume, the execution price, and various other types of information. In cases where an order received multiple fills, the information is listed for each fill.

The brokerage firm data are filtered prior to analysis. First, I examine orders for which all relevant order/trader information is available. Second, I filter data to exclude stocks for which I am unable to retrieve data from the Reuters tick history database and/or The Center for Research and Security Price (CRSP) database. Trading information from these two publicly available data sources is matched to the brokerage firm data. Third, I exclude orders executed outside of the main trading hours because trading before the open or after the close occurs in a different manner than during normal market hours (9:30 a.m. – 4:00 p.m.). Lastly, I focus on Nasdaq-listed stocks only because these stocks represent a majority of the orders in the data and because different trading protocols exist between NYSE and Nasdaq stocks during the sample period.\(^6\) The filters imposed do not limit the overall data very much. Overall, I analyze

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\(^5\) This is observable through volume comparisons with the brokerage data and market-wide data. The volume comparisons are omitted for brevity but are available upon request.

\(^6\) During the sample period, Nasdaq stocks trade in multiple trading venues with automated execution. In contrast, NYSE-listed trading is mainly confined to a single physical trading floor location. Trading is much slower on the NYSE trading floor than on Nasdaq trading venues, and automated trading is heavily restricted. Consequently, most order executions through DMA brokers occur on Nasdaq-listed stocks. Although the sample period precedes the implementation of Regulation NMS, from the perspective of a DMA trader, the Nasdaq (unlike NYSE) order execution process is very similar before and after the implementation of Regulation NMS. For example, the
more than 90% of the trading activity originating from the sample firm’s DMA brokerage operation.

2. Empirical results

2.1. Latency cost measurement

Latency cost arises from the delay in time between an order submission decision and execution. Because market participants cannot execute their orders instantaneously, or without delay, latency cost will always exist to some degree in financial markets. Latency cost occurs on all order types, but is more easily identifiable when orders are submitted for immediate execution (i.e., marketable orders). For example, suppose a trader observes the national best offer quote on a stock for $10.00 with an available size of 10,000 shares. If the trader submits a market order for 100 shares and ends up executing at a price of $10.01, then the cost of latency per share is $0.01 (execution price of $10.01 minus $10.00 quoted price at order submission time). The total dollar loss resulting from latency is $10 (100 shares * $0.01).

Some traders might recognize from the onset that latency cost exists, which may lead them to submit a price contingent order for immediate execution (i.e., marketable limit order). For example, in the above case, suppose that a trader submits a marketable limit order for $10.01 and that the order executes accordingly. The cost of latency is, again, $0.01 per share or $10 per order. measuring latency cost with non-marketable orders is difficult because execution is

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7 Throughout the paper, empirical results are conducted separately for market orders and marketable limit orders. The results are qualitatively similar and, for brevity, marketable order results are reported only. In some cases, traders themselves do not even know if they are submitting a market order or a marketable limit order. For
not immediate. When (if) execution occurs, it is driven by multiple factors such as how a trader prices an order, market conditions, etc., and disentangling the true cost of latency for limit orders is difficult. Delays with placing, updating, and/or canceling limit orders can result in greater adverse selection cost, partial or non-execution, etc. Because I am able to observe latency cost with marketable orders directly, I focus on this order type. However, I do provide an indirect analysis of latency cost with limit orders.

For marketable buy orders, latency cost is defined as the share-weighted execution price minus the national best offer price at the time a trader submits an order. For marketable sell orders, latency cost is defined as the national best bid price at the time a trader submits an order minus the share-weighted execution price. It is important to recognize that measurement error can occur when using multiple data sources because different computer time clocks are used to record data. To mitigate this (potential) problem, I only analyze data about traders whose physical location can be determined (i.e., branch office traders). The electronic trading terminals at the firm’s branch offices (headquarters) are all closely aligned with the official U.S. time and the traders have direct access to the multiple electronic markets using an uniform trading software.\(^8\) The Reuters data is also closely assigned with the official U.S. time as it comes from the Consolidated Tape Association (CTA). Nasdaq, which acts on behalf of the CTA, is the Security Information Processor (SIP) for Nasdaq-listed securities.

Nasdaq collects raw quote and trade data from the various exchanges, standardizes the example, some market centers do not accept non-priced orders. If a trader submits an order to execute immediately at the best market price (rather than specifically routing the order to a designated market center), the order type may change from market to marketable limit depending on which market center where the order is eventually routed. In either case, the order is sent for immediate execution.

\(^8\) The firm is headquartered in the New York City area and has 36 branch office locations in 17 states. The branch offices are located in New York, New Jersey, Connecticut, Pennsylvania, Virginia, Michigan, Tennessee, Illinois, Georgia, Florida, Missouri, Oklahoma, Texas, Arizona, California, Washington, and Oregon.
different data feeds, and consolidates them into an uninform, time-stamped viewable (recordable) data. The data are then supplied to the CTA for distribution to market data vendors such as Reuters.

Table 1 provides some overall summary trading statistics and latency cost statistics for all traders. In total, data analyzed consist of ten billion executed shares with a trade value of $90 billion. There are five million orders and eight million trades. The orders are submitted by two thousand accounts on four thousand stocks. Approximately 43% of orders are marketable. The average cost of latency per marketable order is one cent. Although latency cost appears relatively small on a per order basis, it is still an economically important cost of trading. For these sample traders alone the cost of latency is approximately $13.5 million across all orders and shares.10

2.2. Latency cost, trader location and time of day

Although prior studies often lack the ability to measure the dimension of trading cost which arises from latency, some researchers have analyzed order execution quality dimensions as of the time when a trader submits an order (see, more recently, Garvey and Wu, 2009; 2010). These studies provide some (other) factors that potentially drive latency cost. For example, Garvey and Wu (2009) find that order execution times are slower and order execution costs (i.e., effective spread) are higher during the opening and closing hours of the trading day. If effective spreads are higher around the open and close of trading, then latency cost may be

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9 According to the Securities Industry Automation Corporation, which acts as the SIP for NYSE- and Amex-listed securities, it takes milliseconds for data to get processed into the consolidated data feed.
10 There are other factors not captured in the latency cost numbers reported. For example, traders often make order submission decisions contingent upon another order execution. Submission delays experienced on one order may lead to a missed opportunity on another, and this cost is unobservable.
higher during these times too. Garvey and Wu (2010) show that market participants located in the financial center (New York City area) experience faster trading speed and lower latency cost.

In Figures 1A and 1B, I examine whether or not latency cost patterns, with respect to trader location and time of day, exist in the sample data. The latency cost and trader distance results are provided in Figure 1A. Trader distance (miles) from New York City is measured by each trader’s actual U.S. trading location with respect to the corner of Canal and Centre Streets in lower Manhattan. Nearly all market data centers are located within the NYC vicinity during the sample period.11 The cost of latency clearly rises with trader distance to New York City. Figure 1B provides results demonstrating how latency cost varies across the trading day. The cost of latency rises during the opening and closing hours of the day. Both the trader location and time of day results are consistent with prior research.

2.3. Latency cost and trader information

The focus of this study is an examination of latency cost patterns across traders with varying levels of information. In securities markets, traders are often classified as being informed or uninformed based on their ability to predict future prices. Informed traders engage in trade to profit from their private information, whereas uninformed traders engage in trade for liquidity reasons. In order to examine the role between trader information and latency cost, I begin by using the change in price following order execution as a proxy for

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11 The lone exception is the Archipelago ECN, which switched its data center from Chicago to New Jersey early in our sample period (2002). Very few orders (< 1%) are routed to Archipelago and results are qualitatively similar throughout whether we include or exclude Archipelago orders.
identifying (un)informed traders. For a buy order, price change is measured as the NBBO quote midpoint five minutes after the last trade execution of an order, one hour after the last trade execution of an order, and, at the end of the trading day, minus the NBBO quote midpoint at the time of order submission. For a sell order, price change is measured as the NBBO quote midpoint at the time of order submission minus the subsequent five-minute, one-hour, and, end of day NBBO quote midpoint. Three time intervals are used because there are no theoretical guidelines for choosing an appropriate information horizon. A five-minute interval is often used in financial studies, but this is based on the assumption that the nature of information is short-lived and that information is impounded into prices rather quickly. Huang and Stoll (1996) and Kaniel and Liu (2006) use alternative definitions of what constitutes an informed order and assume that information is incorporated into prices over longer periods of time. The use of both short- and longer-term horizons for identifying information-based trading allows for more robust results.

I classify traders into hypothetical informed and uninformed groups based on their average order price change (under the three different time intervals). I use two methods to allow for more robust results. First, traders who are in the top (bottom) 50th percentile with respect to average price change are considered hypothetical informed (uninformed) traders.12 Second, traders who have an average positive (negative) price change over the sample period are classified as hypothetical informed (uninformed) traders. Figure 2 shows plots of the average latency cost for both groups of traders under each time interval. For each method and

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12 For each time interval, the average price change is positive (negative) for hypothetical informed (uninformed) traders.
information horizon, hypothetical informed traders experience lower latency cost. The differences in means are all significantly different from zero at the 1% level.

While Figure 2A and 2B are informative, it is important to examine the relationship between latency cost and trader information while controlling for other factors. As previously noted, factors such as where a trader is geographically located, the time of day, etc., can influence latency cost and need to be considered simultaneously. It is also important to control for differences in price across stocks when assessing the relative impact of latency cost. For example, experiencing an one-cent latency cost on a $1 execution is quite different than, say, experiencing a one-cent latency cost on a $100 execution. The adverse price movement on lower price stocks will, on average, have a greater overall impact on net returns.

To address these concerns, I estimate an ordinary least squares regression to provide more robust results. The dependent variable is the percentage latency cost ([latency cost/execution price]*100). The main independent variable of interest is a dummy variable that takes the value of 1 or, otherwise, 0, if the order is submitted by a hypothetical informed trader. Other independent (control) variables include:

**Distance control:**
- Trader distance in miles to New York City (or market central computers);

**Time of day controls:**
- Dummy variables for four one-hour intraday time intervals around the open and close of trading;

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13 Regressions are estimated by means of the dollar latency cost measure and results are qualitatively similar.
14 Orders are considered to be submitted by an informed trader if the trader has a positive average price impact. When orders are classified as being submitted by an informed trader using the alternative approach (i.e., the trader has an average price impact in the top 50% percentile) the results are qualitatively similar. These results are omitted for brevity but are available upon request.
Order characteristic controls:

- An order direction dummy variable that takes the value of 1 or, otherwise, 0, if a trader submits a buy order;
- Log order share size;

Market condition controls:

- NBBO percentage bid-ask spread (100*[ask price – bid price/midpoint price]) at the time a trader submits an order;
- Log depth at the inside price (offer (bid) depth for marketable buy (sell) orders) at the time a trader submits an order;
- Log total trading volume on the stock within the half-hour interval when a trader submits an order;
- Price volatility within the half-hour interval when a trader submits an order, which is computed by subtracting the minimum execution price from the maximum execution price and dividing the difference by the average execution price;
- Trend of the market, which is the log difference between the mid-point price five minutes before the order submission and the price one hour before the order submission;

Stock Controls:

- The prior year average daily turnover (volume / shares outstanding) for the stock;
- The prior year-end log market capitalization for the stock;
- The prior year-end price for the stock;

Year Controls:

- Dummy variables for yearly time intervals;

Trader Controls:

- Dummies for trader characteristic groupings. The traders are sorted in 25 groupings using a double sort procedure based on each trader’s average daily number of orders executed and average order size.\(^\text{15}\)

For each time horizon sort, the informed trader dummy in the respective regression is negative and significant at the 1% level. This indicates that, when a marketable order is

\(^{15}\text{Traders who have the highest (rank #1 out of 5) average daily number of orders executed and the highest average order size are classified as group 1. Traders who have the highest average daily number of orders executed and the second highest (rank #2 out of 5) average order size are classified as group 2, and so forth for the remaining 25 combinations.}\)
submitted by a trader who is more informed about future price direction, the cost of latency is lower, holding all else equal. The control variables reveal the impact of other factors on latency cost. Consistent with the figures, coefficients representing trader distance to NYC and dummies for opening and closing hours of the trading day are all positive and highly significant. Latency cost is higher when marketable orders are submitted from locations that are further away from market data centers in the NYC area, and are submitted around the open and close of trading, holding all other variables constant. Market condition proxies tend to be negatively related with latency cost. For example, when quoted depth is larger at the time of order submission and trading activity is higher in the half-hour period during which an order is submitted, latency cost is lower.

3. Non-marketable order analysis

Latency cost is easier to identify with orders sent for immediate execution. Although latency cost is not directly observable with non-marketable orders, it still exists. One implication of delays with placing, updating, and/or canceling limit orders is exposure to greater adverse selection cost. For example, limit orders are typically executed in electronic order books on a price-time priority basis. Traders who experience greater delays are likely to be further down the queue at various price levels and exposed to higher adverse selection cost. Moreover, if prices move quickly against traders, then those traders who experience greater

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16 For robustness, we also estimate marketable order regressions (and non-marketable orders regressions in Section 3) for partially filled and completely filled orders separately. The results are qualitatively similar and are available upon request.
delays will be less able to cancel/update their limit orders and will be exposed to higher adverse selection cost.

If uninformed traders experience higher latency cost with marketable orders and latency results in higher adverse selection cost, then presumably uninformed traders will experience higher adverse selection cost. In order to test this, I first approximate the adverse selection cost component incurred with limit-order execution by following a similar approach used by Peterson and Sirri (2003), which complements a like methodology used by Harris and Hasbrouck (1996). For the 2.9 million non-marketable order executions, on 3,741 stocks over the approximate six and one-half year period, I compute ex-post cost measures by matching the proprietary data to the Reuters tick history database. The ex-post cost of executing a limit buy order is the limit price minus the national best bid price five minutes after execution. The ex-post cost of executing a limit sell order is the national best offer price five minutes after execution minus the limit price. Figure 4 reports average ex-post cost measures in relation to trader information content. The results are very similar to the marketable order results. For example, in all cases, traders who are more informed about future price direction experience lower ex-post costs. All of the mean differences are significantly different from zero at 1% level.

In Table 5, I report results of ordinary least squares regressions using the ex-post cost measure as a dependent variable. As with marketable order results, I use a percentage ex post cost measure ([(latency cost/execution price) * 100]) as the dependent variable in order to control for differences in price across stocks. I also add an additional control on how aggressive a trader is with pricing their non-marketable order, which may (significantly) impact the
magnitude of adverse selection. Limit order aggressiveness for buy orders is the limit price minus the NBBO quote midpoint at the time a trader submits an order, and for sell orders it is the NBBO quote midpoint minus the limit price.

Many coefficient signs and significance levels are similar across the three regressions using different information horizons. Importantly, the informed dummy is negative and statistically significant at the 1% level across all three regressions. Adverse selection costs are less likely to occur when orders are submitted by more informed traders. The results are consistent with marketable order results.

4. Conclusion

Numerous reports and studies have portrayed various costs associated with trading in financial markets, yet there is little known about the cost of trading arising from latency or the delay in time between a market participant’s order submission decision and execution. In this paper, I examine latency cost across market participant’s with different levels of information.

I find that U.S. equity traders who appear informed and uninformed about future market prices experience a cost induced from latency, but the uninformed pay a significantly higher cost. This result is robust to various factors such as trader geographic location, time of day, market conditions, stock characteristics, trader characteristics, etc. Although the cost arising from latency is fairly small when assessed on a per order basis, it is economically important. For example, the trading cost dimension attributable to latency for the informed and uninformed is approximately $13.5 million on 3.8 billion shares executed in my sample data alone (marketable orders only).
The cost incurred from latency helps explain why so many market participants are increasingly demanding low latency order execution. In order to satisfy growing demand, exchanges around the world are continuously working to increase speed on their trading platforms.\textsuperscript{17} Although trading speeds are continually increasing in most electronic markets, they are not increasing correspondingly across market participants. A growing concern among securities regulators is whether certain market participants who have access to faster speed through trading location or utilizing advanced trading systems gain an unfair advantage over others operating in the market. While my study does not directly address this issue, the results herein suggest that having access to faster trading speed is advantageous, even for traders whose underlying motive for trading is less (not) dependent upon speed.

References


Table 1
Summary statistics

This table provides overall summary trading statistics and latency cost statistics for traders who trade through a U.S. broker-dealer over an approximate six and one-half year period ending May 2006. For marketable buy orders, latency cost is defined as the share-weighted execution price minus the national best offer price at the time a trader submits an order. For marketable sell orders, latency cost is defined as the national best bid price at the time a trader submits an order minus the share-weighted execution price. Total dollar cost of latency is the aggregated dollar cost of latency per order, which is calculated by multiplying the number of shares per order by the latency cost per order.

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<table>
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<td>Marketable shares executed</td>
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<td>Mean latency cost per order</td>
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<td>Median latency cost per order</td>
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<tr>
<td>Total dollar cost of latency</td>
<td>$13,467,942</td>
</tr>
</tbody>
</table>
Figure 1
Latency costs by trader location and time of day

The figures depict the average cost of latency for marketable orders in relation to trader distance to New York City (i.e., market central computers) and time of day.

Figure 1A

![Bar chart showing average cost of latency by trader distance to New York City](image)

Figure 1B

![Bar chart showing average cost of latency by time of day](image)
Figure 2
Trader information and latency cost

The figures depict average latency cost in relation to trader information level. Traders are classified into hypothetical informed and uninformed groups based on the average price change that occurs after order execution (three different time intervals are used). In Figure 2A, traders who are in the top (bottom) 50th percentile with respect to average price change are considered hypothetical informed (uninformed) traders. In Figure 2B, traders who have an average positive (negative) price change are considered hypothetical informed traders. For buy orders, price change is measured as the NBBO quote midpoint five minutes after the last trade execution of an order, one hour after the last trade execution of an order, and at the end of the trading day, minus the NBBO quote midpoint at the time of order submission. For sell orders, price change is measured as the NBBO quote midpoint at the time of order submission minus the subsequent five minute, one hour, and end of day NBBO quote midpoint.

Figure 2A – Top/Bottom Price Change Sort

Figure 2B – Positive/Negative Price Change Sort
Table 2
Regression results: latency cost and trader information

This table presents ordinary least squares regression results highlighting the relation between latency cost and trader information. The results are based on the trading activity of two thousand traders who trade through a U.S. broker-dealer over an approximate six and one-half year period ending May 2006. For marketable buy orders, latency cost is defined as the share-weighted execution price minus the national best offer price at the time a trader submits an order. For marketable sell orders, latency cost is defined as the national best bid price at the time a trader submits an order minus the share-weighted execution price. The dependent variable is the percentage latency cost ([latency cost/execution price]*100). The main independent variable is a dummy variable that takes the value of 1 or, otherwise, 0, if an order is submitted by a trader in the hypothetical informed trader group. Traders who have an average positive (negative) price change are considered hypothetical informed traders. For buy orders, price change is measured as the NBBO quote midpoint five minutes after the last trade execution of an order, one hour after the last trade execution of an order, and at the end of the trading day, minus the NBBO quote midpoint at the time of order submission. For sell orders, price change is measured as the NBBO quote midpoint at the time of order submission minus the subsequent five minute, one hour, and end of day NBBO quote midpoint. Other independent variables include: the trader’s distance in miles to New York City; dummy variables for four one-hour intraday time intervals around the open and close of trading; a dummy variable that takes the value of 1 or, otherwise, 0, if a trader submits a buy order; log order share size; NBBO percentage bid-ask spread (100*[ask price – bid price]/midpoint price) at the time a trader submits an order; log depth at the inside price (offer (bid) depth for buy (sell) orders) at the time a trader submits an order; log total trading volume on the stock within the half-hour interval when a trader submits an order; price volatility within the half-hour interval, which is computed by subtracting the minimum execution price from the maximum execution price and dividing the difference by the average execution price within the half-hour interval when a trader submits an order; and the trend of the market, which is the log difference between the mid-point price five minutes before the order submission and the price one hour before the order submission. In addition to the reported variables, the regressions include stock, trader, and time controls (not reported for brevity). Stock controls consist of the prior year average daily turnover (volume/shares outstanding) for the stock; the prior year-end log market capitalization for the stock; and the prior stock price (1/year-end price for the stock). Trader controls consist of dummies representing 25 trader characteristic groupings (the first group is included in the intercept). The traders are sorted in 25 groupings in accordance with a sorting procedure based on each trader’s average daily number of orders executed and average order size. Time controls consist of dummies for each year (the first year is included in the intercept).
<table>
<thead>
<tr>
<th>Independent variables:</th>
<th>5 minute interval</th>
<th>Coefficient</th>
<th>p-value</th>
<th>1 hour interval</th>
<th>Coefficient</th>
<th>p-value</th>
<th>End of day interval</th>
<th>Coefficient</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td></td>
<td>0.0545</td>
<td>0.0306</td>
<td>0.0817</td>
<td>0.0012</td>
<td></td>
<td>0.0609</td>
<td>0.0157</td>
<td></td>
</tr>
<tr>
<td><strong>Informed trader dummy</strong></td>
<td></td>
<td><strong>-0.0289</strong></td>
<td><strong>&lt;.0001</strong></td>
<td><strong>-0.0551</strong></td>
<td><strong>&lt;.0001</strong></td>
<td></td>
<td><strong>-0.0375</strong></td>
<td><strong>&lt;.0001</strong></td>
<td></td>
</tr>
<tr>
<td>Log trader distance to NYC + 1</td>
<td></td>
<td>0.0186</td>
<td>&lt;.0001</td>
<td>0.0168</td>
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<td></td>
<td>0.0179</td>
<td>&lt;.0001</td>
<td></td>
</tr>
<tr>
<td>9:30 – 10:30 a.m. dummy</td>
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<td>0.0154</td>
<td>&lt;.0001</td>
<td>0.0157</td>
<td>&lt;.0001</td>
<td></td>
<td>0.0154</td>
<td>&lt;.0001</td>
<td></td>
</tr>
<tr>
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<td></td>
<td>0.0146</td>
<td>&lt;.0001</td>
<td>0.0144</td>
<td>0.0031</td>
<td></td>
<td>0.0145</td>
<td>&lt;.0001</td>
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</tr>
<tr>
<td>2:00 – 3:00 p.m. dummy</td>
<td></td>
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<td>0.0034</td>
<td>0.0076</td>
<td>&lt;.0001</td>
<td></td>
<td>0.0077</td>
<td>0.0030</td>
<td></td>
</tr>
<tr>
<td>3:00 – 4:00 p.m. dummy</td>
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<td>0.1027</td>
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<td>0.1274</td>
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<td>0.0040</td>
<td>0.1120</td>
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<tr>
<td>Buy dummy</td>
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<td>&lt;.0001</td>
<td>0.0102</td>
<td>&lt;.0001</td>
<td></td>
<td>0.0101</td>
<td>&lt;.0001</td>
<td></td>
</tr>
<tr>
<td>Log order share size</td>
<td></td>
<td>0.0241</td>
<td>&lt;.0001</td>
<td>0.0244</td>
<td>&lt;.0001</td>
<td></td>
<td>0.0243</td>
<td>&lt;.0001</td>
<td></td>
</tr>
<tr>
<td>Bid-ask spread</td>
<td></td>
<td><strong>-0.2008</strong></td>
<td><strong>&lt;.0001</strong></td>
<td><strong>-0.2010</strong></td>
<td><strong>&lt;.0001</strong></td>
<td></td>
<td><strong>-0.2010</strong></td>
<td><strong>&lt;.0001</strong></td>
<td></td>
</tr>
<tr>
<td>Log bid/ask depth</td>
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<td>-0.0265</td>
<td>&lt;.0001</td>
<td>-0.0263</td>
<td>&lt;.0001</td>
<td></td>
<td>-0.0263</td>
<td>&lt;.0001</td>
<td></td>
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<tr>
<td>Log market trend</td>
<td></td>
<td>0.3236</td>
<td>&lt;.0001</td>
<td>0.3213</td>
<td>&lt;.0001</td>
<td></td>
<td>0.3234</td>
<td>&lt;.0001</td>
<td></td>
</tr>
<tr>
<td>Log volume</td>
<td></td>
<td>-0.0031</td>
<td>&lt;.0001</td>
<td>-0.0031</td>
<td>&lt;.0001</td>
<td></td>
<td>-0.0031</td>
<td>&lt;.0001</td>
<td></td>
</tr>
<tr>
<td>Price volatility</td>
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<td>0.0070</td>
<td>-0.0204</td>
<td>0.0071</td>
<td></td>
<td>-0.0207</td>
<td>0.0063</td>
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Other controls - not reported
Trader controls (24)
Stock controls (3)
Time controls (7)

<table>
<thead>
<tr>
<th>R²</th>
<th>7.29%</th>
<th>7.31%</th>
<th>7.29%</th>
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</thead>
<tbody>
<tr>
<td>Number of observations</td>
<td>2,224,376</td>
<td>2,224,376</td>
<td>2,224,376</td>
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</tbody>
</table>
Figure 3
Non-marketable orders, trader information, and average ex-post cost

The figures depict the average ex-post cost of non-marketable orders in relation to trader information (see Figure 2 caption). The ex-post cost of executing a limit buy order is the limit price minus the national best bid price five minutes after execution. The ex-post cost of executing a limit sell order is the national best offer price five minutes after execution minus the limit price.

Figure 3A Top/Bottom Price Change Sort

![Bar chart showing average ex-post cost for different intervals and trader types.]

Figure 3B Positive/Negative Price Change Sort

![Bar chart showing average ex-post cost for different intervals and trader types.]

0 0.005 0.01 0.015 0.02 0.025 0.03 0.035 0.04
5 minute interval 1 hour interval End of day interval

■ Hypothetical informed traders ■ Hypothetical uninformed traders
Table 3
Non-marketable order regression results

This table presents regression results for non-marketable orders using the percentage ex-post cost measure (ex post cost/execution price) as a dependent variable. Limit order aggressiveness for buy orders is the limit price minus the NBBO quote midpoint at the time a trader submits an order, and for sell orders, the NBBO quote midpoint at the time a trader submits an order minus the limit price. See Table 2 for a description of the remaining independent variables.

<table>
<thead>
<tr>
<th>Independent variables</th>
<th>5 minute interval</th>
<th>1 hour interval</th>
<th>End of day interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficient</td>
<td>p-value</td>
<td>Coefficient</td>
</tr>
<tr>
<td>Intercept</td>
<td>0.0693</td>
<td>0.0084</td>
<td>0.1265</td>
</tr>
<tr>
<td>Informed trader dummy</td>
<td>-0.0175</td>
<td>&lt;.0001</td>
<td>-0.0827</td>
</tr>
<tr>
<td>Log trader distance to NYC + 1</td>
<td>0.0013</td>
<td>0.0734</td>
<td>-0.0025</td>
</tr>
<tr>
<td>9:30 – 10:30 a.m. dummy</td>
<td>0.0249</td>
<td>&lt;.0001</td>
<td>0.0256</td>
</tr>
<tr>
<td>10:30 – 11:30 a.m. dummy</td>
<td>0.0056</td>
<td>0.1079</td>
<td>0.0059</td>
</tr>
<tr>
<td>2:00 – 3:00 p.m. dummy</td>
<td>0.0012</td>
<td>0.7444</td>
<td>0.0014</td>
</tr>
<tr>
<td>3:00 – 4:00 p.m. dummy</td>
<td>0.0413</td>
<td>&lt;.0001</td>
<td>0.0410</td>
</tr>
<tr>
<td>Buy dummy</td>
<td>-0.0225</td>
<td>&lt;.0001</td>
<td>-0.0233</td>
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<tr>
<td>Log order share size</td>
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<tr>
<td>Price aggressiveness</td>
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<tr>
<td>Bid-ask spread</td>
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<td>&lt;.0001</td>
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<tr>
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<td>Log volume</td>
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<td>&lt;.0001</td>
<td>0.0012</td>
</tr>
<tr>
<td>Price volatility</td>
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<td>0.5640</td>
<td>0.0121</td>
</tr>
</tbody>
</table>

Other controls - not reported
Trader controls (24)
Stock controls (3)
Time controls (7)

R² | 13.19% | 13.21% | 13.2%
Number of observations | 2,925,668 | 2,925,668 | 2,925,668