MULTIPLE DURATION ANALYSES OF DYNAMIC LIMIT ORDER PLACEMENT STRATEGIES AND AGGRESSIVENESS IN A LOW-LATENCY MARKET ENVIRONMENT

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ABSTRACT

This study examines dynamic order placement strategies in a low-latency environment together with limit orders' aggressiveness by a new approach which utilises survival analysis with a multiple-spell duration model. Two samples are considered, including the period immediately followed Australian Securities Exchange (ASX)'s migration to Integrated Trading System (ITS) and the period subsequent to the launch of ASX Trade. We find the evidence supporting both the 'cost of immediacy hypothesis' and the 'chasing hypothesis' as in Hasbrouck and Saar (2009). Furthermore, several distinctions in the results are found between the samples of ITS period and ASX Trade period as well as between the samples of small-cap stocks and large-cap stocks. The findings of this study are beneficial not only for high-frequency traders in forming dynamic order placement strategies in a low-latency stock market environment, but also for market regulators in helping their attempt to improve regulations for stock exchanges.

Keywords: tick-by-tick data; dynamic order placement strategies; survival analysis; multiple-spell duration; Australian Securities Exchange (ASX).

JEL classification: C35; G15.

1. Introduction

The reductions in latency by stock exchanges around the world, together with innovations in technology, have encouraged more rapid developments of trading algorithms. Algorithmic traders have played an important role in financial markets in the recent years. They have facilitated the trading activities of large institutional as well as individual traders. The Australian Stock Exchange (ASX) is a popular example with its decision to migrate its platform from Stock Exchange Automated Trading System (SEATS) to Integrated Trading System (ITS) in October 2006 which significantly reduced latency in the exchange from 85 to 30 milliseconds. Later, in November 2010, ASX made another move in launching the ASX Trade which lowered market latency even further.

The existing literature on order placement activities has largely overlooked the option to cancel or revise prevailing limit orders. Order revisions and cancellations constitute an important area of study in market microstructure since a significant number of limit orders on the ASX, the NYSE, or the London Securities and Derivatives Exchange are amended or cancelled following their submission (see, for example, Coppejans and Domowitz, 2002; Yeo, 2006; Fong and Liu, 2010). In addition, with the speedy developments of trading technology, not only the number but also the frequency of order revisions and cancellations has also increased rapidly. Hasbrouck and Saar (2009) find that 'fleeting orders'[1] on INET account for 36% of limit order submissions in 2004. This value is twice the rate calculated in 1999. Hendershott et al. (2011) also reveal that the orders-to-trades ratio, which indicates the intensity of order cancellations, rose significantly in 2003 following a structural change in the NYSE towards market automation.

[1] 'Fleeting orders' are defined by Hasbrouck and Saar (2009) as the limit orders which are cancelled within two seconds of being submitted into the order book.

The rapid improvements in technology and market latency have resulted in an arms race of algorithmic and high-frequency trading, which contributed to the stock market flash crash in May 2010. Hasbrouck and Saar (2009), amongst a number of other researchers, have identified strategic orders that are submitted and removed from the market very quickly. 'Fleeting orders' are an example of such strategic orders. Their research paper, however, only studies order cancellations using a single duration model. Therefore, one of the most important contributions of this study is the application of an empirical model that provides a more comprehensive study of limit order placement strategies and their aggressiveness by examining all order events, including limit order cancellation and order revisions, as well as aggressive and defensive revisions. A multiple duration model is employed for the purpose of this study to take into account duration dependence since limit order cancellation and revision are single events from a sequence of multiple events. The research is conducted for the period immediately followed ASX's migration to ITS as well as the period subsequent to the launch of ASX Trade.

The results of this study suggest that the response of dynamic limit order placement strategies tend to changes in the conditions of the stock market. Traders respond to a lower quality of the market by intensifying their activities of order cancellation and order revisions, including aggressive and defensive revisions. In particular, the probability of occurrence of order cancellation and revision activities is found to be higher when there is a higher level of short term volatility and a lower level of liquidity, as well as when there are more fleeting orders in the exchange. Our results also indicate that a higher initial aggressiveness of submitted limit orders leads to a higher hazard rate of order cancellation and a lower hazard rate of order revision. Moreover, the evidence seems to imply that traders have a higher tendency to cancel their limit order and submit a more aggressive one, or to revise their limit order with a more aggressive price when the same-side quote moves adversely away from the initial price. By following such strategies, traders in fact ‘chase the market’ to gain better execution opportunities. This result is indeed consistent with the ‘chasing hypothesis’ discussed in the research of Hasbrouck and Saar (2009). In addition, the ASX Trade period reveals that when the opposite quotes become cheaper, traders are more eager to cancel their existing limit orders to opt for market orders with an immediate execution. This evidence is significant because it provides a strong support for the 'cost of immediacy hypothesis’. Furthermore, the empirical results seem to suggest that submitting an aggressive limit order for a small-cap stock generally has a statistically less significant effect on the hazard rates of order cancellation and order revisions, including aggressive and defensive revisions, than for a large-cap stock.

The rest of this study proceeds as the followings. Section 2 introduces the low-latency stock market environment and discusses related studies in the current literature regarding this area of research. Section 3 presents the limit order data used for the purpose of this study. Section 4 describes the empirical methodology employed including the constructions of explanatory variables. Section 5 presents a discussion of the empirical results and explains why the study findings are interesting and important. Finally, Section 6 concludes the study.

2. The Low-Latency Stock Market Environment

In the recent periods, real time market and news monitoring have become increasingly feasible. This is attributable to the technology developments that allow financial markets around the world to improve trading latency significantly. Latency can be understood as the required time to realise an event which occurs in the market, produce an analysis, and have the securities exchange take action upon that accordingly. Exchanges around the world have made large investments towards improving their platforms with an effort to lower the communication time with investors in handling their orders. Traders have also been offered the option to place their trading computers close to the exchanges in order to cut the transmission times to as low as under a millisecond. Investments in technology have been conducted not only by exchanges, but also by traders themselves in an attempt to respond to information and to trade upon it quicker. Therefore, the low-latency stock market environment has been characterised by an increased speed of not only absorbing the arriving information, but also taking actions upon such news.

Due to the fundamental volatility of many types of financial securities and their rapidly changing prices in the market, it is highly significant for traders to improve their speed of trading. Being able to trade faster than other traders is a very important advantage since it can create potential profit opportunities by enabling a prompt response to the arriving news of the market. This observation creates an arms race in which traders utilise technology innovations and position their trading computers closer to the exchange location with an effort to gain access to the market quicker. As a result, it can be observed in the financial markets today that there are intensive activities in the low-latency market environment. Hasbrouck and Saar (2013) provide an interesting research on the low-latency trading activities which involve automated traders who act in response to each other in the millisecond environment. They find that an increase in the level of low-latency activities actually improves traditional market quality measures.

There is a significant amount of trading that has been carried out by machines (also known as algorithmic trading) to reduce the labour effort devoted to monitoring activities. Human traders are likely to have a more comparative advantage over machines in more complex situations. However, machines have the advantage of responding more quickly to the arrival of information, working out an optimal solution quicker based on a number of input parameters. Besides, machines have virtually unlimited information processing capacity and therefore can be very useful and preferable to human trading in many circumstances. With better access to markets and information via electronic connections, algorithmic trading has led to a significant reduction in monitoring cost. This also helps reducing the submission risks for limit orders. On the other hand, as mentioned above, these advantages of automated trading also give rise to algorithmic arms race between competing trading firms. There have been a growing number of empirical studies in the literature regarding the examination of the speed of trading in financial markets. Some examples include Hendershott and Moulton (2011) and Riordan and Storkenmaier (2012) who investigate technology innovations of securities markets that lead to a reduction in latency. The studies, however, find controversial evidence regarding the effects of such innovations on the quality of the market.

In regards to algorithmic trading, there are a number of studies on high-frequency trading (HFT) which exists in various markets and trading platforms around the world. Some popular examples include: Jovanovic and Menkveld (2016) examine the Euronext and Chi-X exchanges; Chaboud et al. (2014) investigate the inter-dealer foreign exchange market; and Kirilenko et al. (2017) conduct a study on HFT in the futures market. In addition, various research papers study HFT in the Deutsche Boerse (see, for example, Gsell, 2008; Gsell and Gomber, 2009; Prix et al., 2007) and a number of other studies investigate the impacts of HFT on various aspects of the U.S. markets (see, for example, Hendershott et al., 2011; Hendershott and Riordan, 2013). Riordan and Storkenmaier (2012) is another interesting study which finds that a reduction in latency on the Xetra system of the Deutsche Boerse is associated with improved liquidity. On the other hand, Hendershott and Moulton (2011) examine NYSE's Hybrid Market[2] and conclude that a reduced latency causes a lower level of liquidity, but helps improve informational efficiency.

The recent literature on high-frequency trading strives for establishing facts on algorithmic activities and for an evaluation of the impacts of these activities on financial markets. Cespa and Foucault (2008) and Easley et al. (2010) construct theoretical models which allow for a delay in observing information from the market by some traders. Pagnotta and Philippon (2018) study speed as one important element which differentiates one securities exchange from another. Moallemi and Saglam (2013) examine the various placement strategies for a sell limit order in an attempt to find an optimal strategy when there are random arrivals of buy limit orders[3]. Meanwhile, Gsell (2008) investigates algorithmic trading activities on the German Xetra system and demonstrates that a large proportion of such traders are not liquidity suppliers. These traders send orders to demand for liquidity instead. However their orders are not as large as the orders submitted by regular traders.

Other related studies in this field apply various modelling techniques in studying the effects of information latency on liquidity, the cost of capital, as well as the efficiency of prices. They have, nevertheless, arrived at mixed conclusions regarding the true impacts. For instance, Boulatov and Dierker (2007) take a perspective from the securities exchanges and examine information latency using a theoretical model. The research finds that selling data on a real-time basis is beneficial in improving information efficiency for prices, but it is also harmful for market liquidity. On the other hand, Boehmer et al. (2014) report that greater intensity of algorithmic trading even though raises short-term volatility, it actually improves

[2] The Hybrid Market of the NYSE was introduced in 2006. The trading platform enhances automatic execution of orders and lowers the time it takes to execute a market order in the NYSE to under a second compared to ten seconds previously.

[3] In Moallemi and Saglam (2013), a pegging strategy is applied for the sell limit order. However, tracking errors could occur because latency may cause a delay in the monitoring process, and this is very costly for the trader.

liquidity as well as informational efficiency[4]. They also conclude that a higher level of algorithmic trading is associated with a decline in equity capital in the following year, mainly driven by an increase in repurchase activity. Besides, Gsell and Gomber (2008) find strong supports for pegging strategies on the German Xetra, while Prix et al. (2007) show some regular patterns of algorithmic traders in their trading activities. Hendershott and Riordan (2013) uncover that trades executed by algorithms place a greater effect on prices than those which are not executed by algorithms. As a result, they find that algorithmic traders have a larger contribution towards price discovery[5].

Furthermore, algorithmic trading has been observed not only in the stock market but also in the inter-dealer foreign exchange market. Chaboud et al. (2014) study such market and conclude that trading activities by algorithms do not cause an increase in volatility of exchange rates. Hendershott et al. (2011) construct a measure of normalised message count, which can be used as a proxy for algorithmic trading, and show that an increase in algorithmic activities affects liquidity only for large stocks[6]. The presence of algorithmic traders helps the large stocks in term of price discovery, also lowers the quoted spread, the effective spread, as well as the quoted depth of the large stocks. Conversely, Hasbrouck and Saar (2013) indicate an enhancement in all market quality measures for both small and large stocks, including improvements in their quoted depth and short-term volatility.

While it appears that intermediated trading is on the rise with the low-latency traders acting as the intermediaries, it is still inconclusive whether an intensive level of low-latency activities is in fact destructive or beneficial for financial markets. In other words, the existing literature has not satisfactorily provided evidence to answer the question of whether trading

[4] 42 equity markets are examined in Boehmer et al. (2014) to study the impact of trading algorithms intensity on the measures of market quality.
[5] Hendershott and Riordan (2013) study a sample of 30 stocks on the DAX stock exchange.
[6] Hendershott et al. (2011) employ an event study to examine the NYSE event of the auto quoting establishment in 2003. The study investigates algorithmic traders in this market by relying on the rate of information arrival on the NYSE as a measure of combined agency and proprietary algorithmic activities.

activities in the low-latency market environment worsen or improve the quality of financial markets, especially in terms of liquidity and volatility.

3. Limit Order Data

The decision by the ASX to migrate its trading platform from SEATS to ITS substantially reduced the market latency from 85 to 30 milliseconds. Subsequently, the launch of ASX Trade to replace ITS reduced the exchange latency even further. The migrations of the ASX to more advanced platforms brought interesting trading activities in the periods subsequent to the two structural changes.

This study conducts an investigation of dynamic limit order placement activities of the 40 index stocks listed on the ASX over the two sample periods that immediately followed the structural changes. Therefore, the two sample periods of year 2007 and year 2011 are chosen for this research. They are the two recent periods that the market began to have the characteristics of a low-latency trading environment. The data for each sample period contains 20 large and 20 small stocks, ranked by market capitalisation. Large-capitalisation stocks are the top 20 common stocks that are traded on the ASX200 index. For the purpose of this study, small-capitalisation stocks are chosen as the 20 common stocks ranked 111th to 130th on the ASX200 index.

The ASX had employed a fully computerised SEATS from 1987. In October 2006, the exchange introduced the ITS to replace SEATS. ITS is a fully-electronic trading system used for efficient and quick transactions. While it provided several operational improvements over SEATS, it did not change the ASX's market structure or trading rules. Therefore year 2007 is chosen as the sample period for this research as it was the year which immediately followed the inception of ITS. In November 2010, ASX Trade was launched to replace ITS. ASX Trade is an ultra-low latency trading platform. It is powered by NASDAQ OMX's

Genium INET platform, providing one of the fastest integrated equities and derivative platforms in the world. As a result, year 2011 is also chosen as a sample period for this research as it was the year that immediately followed the launch of ASX Trade. In each sample period, the month of August is chosen as the month of interest for study as most preliminary end-of-year earnings reports are released in August and more trading activities are expected as a result. The data samples record each order and trade details, including the date, time, stock code, price, transacted volume and order types. The type of order, such as submission, revision, execution, or cancellation is recorded for each order event. The dataset is provided by the Securities Industry Research Centre of Asia-Pacific (SIRCA).

4. Empirical Methodology

4.1. Empirical Model Specification and Approach

This study examines the periods when the ASX experiences low latency and studies the characteristics, effects and levels of aggressiveness of dynamic limit order placement activities in the market. This study contributes to the current literature by extending the existing investigations to examine the multiple events that happen in the entire life of limit orders. This objective is achieved by utilising a survival analysis methodology with a multiple-spell duration model. To the best of our knowledge, this study is the first research to provide an examination of dynamic limit order placement strategies and aggressiveness in a low-latency market environment using a multiple-spell duration model approach.

Subsequent to the submission of a limit order to buy or sell a stock, the limit order can be executed within a short or long period of time depending on a number of factors, including the order's aggressiveness. If the order is not picked up, the trader then has the option to cancel or revise the limit order. The revised order can be left until execution or it may also be revised multiple times following the first revision. Using the order reference number and time, we can track execution, revision and cancellation order events that follow an order submission or that are subsequent to an order revision. Many orders in the sample of study experience more than one event subsequently to their initial submission into the limit order book. In fact, close to 97% of buy orders experience up to 5 events following their submission, and a similar percentage is also observed for sell orders (as shown in *Table A1-Appendix*). As a result, it is more appropriate to employ survival analysis with a multiple-spell duration model since they allow the duration of an event to be dependent, not only on the order characteristics, but also on the preceding events and their durations.

Proportional Hazard (PH) multiple-spell duration model and its special cases are probably the most well-known duration models based on a specification of the hazard function (Van Den Berg, 2001). There are quite a few empirical analyses of PH models with multi-spell duration data in the literature of biomedical science and labour economics. Some examples of the studies which utilise such methodology include Newman and McCullogh (1984) who estimate models for birth intervals using multiple-spell duration data; Ham and Rea (1987) who employ a discrete-time model; and Coleman (1990) who estimates a reduced-form of unemployment duration models. Lillard (1993) and Lillard and Panis (1996) also use a set of multi-spell data to estimate marriage duration models. In addition, Honore (1993) provides a lagged duration dependence specification, where the duration of the first spell enters the hazard of the second spell multiplicatively.

The focus of this study is on limit order revision and limit order cancellation. These order events are considered as the events of interest since they are the choices that traders are presented with and they have to decide upon, following the submission or the revision of a limit order. The two limit order events represent the options that traders have to consider as part of their dynamic limit order placement strategies. As a result, the successive events of limit orders examined in this study include (i) submission-to-cancellation, (ii) submission-to-revision, (iii) revision-to-cancellation, (iv) revision-to-revision. In each of the above transitions, the order event in the left-hand side is said to be in the *origin state* and the order event in the right-hand side is said to be in the *destination state*. The study focuses on two competing events: limit order cancellation and limit order revision. The two events are considered as competing with each other since they represent the limit order decisions that traders have to make to either revise or cancel their submitted or revised orders. If the market moves against their initial expectation or if other better opportunities arise, traders can only decide between one of the two actions at a time, either revising or cancelling the existing limit order.

In addition to the above, it is also more interesting to look deeper into the insight of the decision to revise a limit order. Therefore, two types of limit order revisions can be considered: aggressive revision and defensive revision. An aggressive order revision is defined for a buy limit order as a limit order which has a price revised upward and a volume that at least stays the same or is revised upward. It is defined for a sell limit order as a limit order which has a price revised downward and a volume that at least stays the same or is revised upward. Conversely, a defensive order revision is defined for a buy (sell) limit order as a limit order which has a price revised downward (upward) and a volume that at least stays the same or is revised downward.

The empirical model of a survival analysis with multiple-spell duration is specified as follows. For each series of limit order events of a stock, a sequence $t_i=\{t_i^c\}$ of adjacent periods of time (spells) spent in different states is observed. The duration spent is denoted by t, the particular series of limit order events occur for an individual stock is denoted by the subscript i and the c^{th} spell in a specific state is denoted by the superscript c. This study utilises a multiple-spell duration model specification similar to that employed in Gagliarducci (2005). The *hazard rate*, θ_{kj}, is defined as the intensity of the transition to the *destination* *state* (denoted by j) after a visit in the *origin state* (denoted by k). The function of the *hazard rate*, θ_{kj}, for the series i at its c^{th} spell is expressed as the following:

$$\theta_{kj}\left(t_i^c \middle| X_{ikj};\beta\right) = h_{kj}(t_i^c)\exp(\beta'_{kj}X_{ikj})v_{ikj} \tag{1}$$

where $h_{kj}(t_i^c)$ is a baseline hazard; X_{ikj} is a set of explanatory variables which incorporate both stock market conditions and limit order characteristics that can influence the decisions and strategies for dynamic order placements; and v_{ikj} is a random individual effect to capture the unobserved heterogeneity. The durations or the survival times of limit orders depend on several factors such as limit order price, order size, market depth, market liquidity, etc. It is worth noting that, the individual covariates X_{ikj} in this study are not all fixed to their values at the beginning of each spell. Instead, the explanatory variables are measured at different states and points in time, depending on the objective of each measure. The variables include those that are calculated in the five minutes preceding the order events, those that are taken at the beginning of the spells, as well as those that keep track of the market conditions after the spells have begun. The various measures are utilised in order to capture the characteristics of the low-latency market environment where the limit order placement activities take place as well as capturing their evolvement even after the limit orders have been submitted or revised.

4.2. Constructions of Explanatory Variables

In the low-latency market environment, order revisions or cancellations are parts of dynamic strategies carried out by high-frequency traders following their submissions or revisions of limit orders. In order to examine such strategies, it is important to relate traders' decisions to developments in market conditions and other factors of interest throughout the lives of limit orders. Therefore, a standard duration model is not suitable for the purpose of this study since all of the explanatory variables in the standard analysis are constructed at the points of limit order submission or revision (i.e. at the beginning of the order spells). As a result, this study utilises time-varying covariates and incorporates them in the multiple duration model to analyse dynamic limit order placement strategies and aggressiveness in a low-latency market environment.

Price aggressiveness is an important factor that characterises dynamic order placement strategies. Liu (2009) proposes that traders revise their limit orders to deal with the free-option risk which has a positive relation with price aggressiveness. Hence, it is important to include the measure of the limit order's price aggressiveness in the analysis of order placement strategies.

The definition of price aggressiveness ($p^{Relative}$) [7] for a buy limit order is as the following:

$$p^{\mathrm{Re}lative}{}_{i,t} = \frac{LimitOrder\ \mathrm{Pr}ice_{i,t=0} - BestBid\ \mathrm{Pr}ice_{i,t=0}}{BestBid\ \mathrm{Pr}ice_{i,t=0}} \tag{2}$$

The definition of price aggressiveness ($p^{Relative}$) for a sell limit order is as the following:

$$p^{\mathrm{Re}lative}{}_{i,t} = \frac{BestBid\ \mathrm{Pr}ice_{i,t=0} - LimitOrder\ \mathrm{Pr}ice_{i,t=0}}{BestBid\ \mathrm{Pr}ice_{i,t=0}} \tag{3}$$

In addition, the intensity of order cancellation is found in Hasbrouck and Saar (2009) to be positively related to the changes in quotes on the same side of the submitted limit order. This positive relation is interpreted as evidence suggesting that traders cancel stale orders and resubmit more aggressive ones in an attempt to chase the market. On the other hand, the order cancellation intensity is also found to be negatively related to the changes in quotes on the opposite side of the submitted limit order. This negative relation is regarded as evidence of traders exploiting more favourable opposite quotes by cancelling limit orders to opt for

[7] This measure is consistent with that employed in Hasbrouck and Saar (2009) for examining the limit order's price aggressiveness at the time of order submission.

market orders. Accordingly, this study also follows Hasbrouck and Saar (2009) to include two time-variant variables, namely Δq^{Same} (change in the same-side quotes) and $\Delta q^{Opposing}$ (change in the opposite side quotes) in the survival analysis.

The definitions of the variables for a buy limit order are as follows:

$$\Delta q^{same}{}_{i,t} = \frac{BestBid\ \mathrm{Pr}ice_{i,t} - BestBid\ \mathrm{Pr}ice_{i,t=0}}{BestBid\ \mathrm{Pr}ice_{i,t=0}} \tag{4}$$

$$\Delta q^{opposing}{}_{i,t} = \frac{BestOffer\ \mathrm{Pr}ice_{i,t} - BestOffer\ \mathrm{Pr}ice_{i,t=0}}{BestOffer\ \mathrm{Pr}ice_{i,t=0}} \tag{5}$$

The definitions of the variables for a sell limit order are as follows:

$$\Delta q^{same}{}_{i,t} = \frac{BestOffer\ \mathrm{Pr}ice_{i,t=0} - BestOffer\ \mathrm{Pr}ice_{i,t}}{BestOffer\ \mathrm{Pr}ice_{i,t=0}} \tag{6}$$

$$\Delta q^{opposing}{}_{i,t} = \frac{BestBid\ \mathrm{Pr}ice_{i,t=0} - BestBid\ \mathrm{Pr}ice_{i,t}}{BestBid\ \mathrm{Pr}ice_{i,t=0}} \tag{7}$$

The empirical model in this study also includes *Order Size* as an explanatory variable since it has been documented in the literature that the size of limit orders matters in revision and cancellation decisions. For example, Fong and Liu (2010) find that traders tend to revise large orders more than small orders due to fixed costs of monitoring. The *Order Size* variable is constructed as the following:

$$OrderSize_{i,t} = Log(OrderVolume_{i,t} \times LimitOrder\ \mathrm{Pr}ice_{i,t}) \tag{8}$$

Another interesting phenomenon that is observed in the low-latency market environment is the large amount of rapid cancellations of limit orders (see, for example, Hasbrouck and Saar, 2009). It is important to understand whether limit orders that are cancelled very quickly are in fact different from the traditional limit orders, where the traditional ones are assumed to be limit orders that stay patiently in the order book and wait for incoming orders to execute. This study defines a limit order that is cancelled within two seconds or less as a “fleeting order”. Similar to Hasbrouck and Saar (2009), the explanatory variable *Fleeting Orders* is constructed as the log of the maximum of either one or the number of fleeting orders in the 5 minutes preceding the order spell.

Finally, in order to study the effects of market conditions on the limit order placement strategies of traders, it is necessary to incorporate the measures of market qualities in the empirical model. Therefore, the explanatory variables *Market Depth*, *Volatility*, and *Spreads* are also included to account for the prevailing market conditions prior to the submission of the limit order. The variables are defined as the followings:

The first market condition variable, *Volatility*, measures short term volatility that the stock experiences and is computed as the difference between the highest and the lowest mid-point of the quoted bid/ask spreads in the 5 minutes preceding each order spell. A lower (higher) value of *Volatility* indicates that the market is less (more) volatile and hence a higher (lower) quality market.

$$Volatility_{i,t} = MaxMQ_{i,t} - MinMQ_{i,t} \tag{9}$$

The second market condition variable, *Spreads*, measures the liquidity level currently existing in the market. This is computed as the time-weighted average of the quoted bid/ask spreads in the 5 minutes preceding the order spell. A lower (higher) value of *Spreads* indicates that the market is more (less) liquid and hence a higher (lower) quality market.

$$Spreads_i = \sum_{j=1}^{n} tw_j (QuoAsk_{i,j} - QuoBid_{i,j}) \tag{10}$$

The final market condition variable, *Market Depth*, measures the depth of the limit order book. This is another measure of market liquidity and it is computed as the time-weighted average of the number of shares of a stock in the limit order book in the 5 minutes preceding the order spell. A higher (lower) value of *Market Depth* indicates that the market is more (less) liquid and hence a higher (lower) quality market.

$$\text{Market Depth}_i = \sum_{j=1}^{n} tw_j (LOBAsk_{i,j} + LOBBid_{i,j}) \tag{11}$$

5. Empirical Results and Discussions

5.1. Hypotheses for the Existence of 'Fleeting Orders'

There are two relevant hypotheses that explain why many limit orders are cancelled very quickly following their submissions into the system. The first hypothesis refers to fleeting orders as a part of a dynamic trading strategy that traders employ when they observe a reduction in the cost of immediate execution. This hypothesis is called the 'cost of immediacy hypothesis' which describes the trade-off a market participant faces when market conditions change (see, for example, Cohen et al., 1981). When the spread is shortened, the cost of immediate execution decreases, there is a tendency to cancel submitted limit orders in favour of market orders for an immediate execution. This hypothesis also implies that trader of the original limit order is not a patient liquidity provider because the trader cancels the limit order to opt for a market order to avoid the opportunity cost of waiting. This strategy actually combines elements of both supplying of and demanding for liquidity.

The second hypothesis is called the 'chasing hypothesis'. It proposes that, when prices move away from the original limit price, traders tend to 'chase the market' by cancelling the existing limit order to opt for a different limit order with a different price. It means that if traders want to improve the probability of execution, they would cancel their submitted limit order in favour of a more aggressive limit order. The dynamic strategy of utilising 'fleeting orders' indicates a certain level of urgency in the trader's hope to have the orders executed. It creates a third category of limit orders where the order lies between an impatient market order (which requires to be executed immediately at a higher cost), and a traditional limit order (which patiently waits for the preferred price to arrive). Trading strategies employed by high-frequency arbitrage traders may also attempt to earn market-making profits by chasing the market prices. They do so by submitting limit prices close to the prevailing market price. As a result, when the market prices move away from the original position, these traders also chase the new levels by cancelling their existing orders and submitting the new limit orders.

By examining the interaction of the probability of order cancellation (as well as order revision) with movements in the same-side and opposite-side quotes, it is possible to find evidence in support of (or against) the 'chasing hypothesis' and the 'cost of immediacy hypothesis'. For example, when the subsequent bid improves the order price, if a higher intensity is observed for cancellation activities of buy limit orders, then that shows consistent evidence with the 'chasing hypothesis'.

5.2. Integrated Trading System (ITS): The Full Sample under Study

The decision by ASX to migrate its trading platform from SEATS to ITS in October 2006 significantly reduced the market latency from 85 to 30 milliseconds and created a low-latency environment with a higher level of intensive trading activities. The first two tables of this section report the empirical results for the study of dynamic order placement strategies using a multiple duration approach in the period that followed ASX's migration to ITS. The results for the pooled sample of buy limit orders are presented in *Table 1*, while the results for the pooled sample of sell limit orders are presented in *Table 2*. Each table of results is divided into two sections associated with two *origin states*, which are order submission and order revision. The coefficient estimates and their significance levels are then reported for each variable in each type of *destination states*, including order cancellation, order revision, aggressive revision and defensive revision. The standard errors are also included in the parentheses.

Table 1 shows some interesting findings for dynamic limit order placement strategies in the pooled sample of buy limit orders in the ITS period. For limit orders originating from submission, the coefficient estimate of the initial aggressiveness measure, $p^{Relative}$, is found to be significantly positive for the destination state of order cancellation and significantly negative for the destination state of order revision. The estimates suggest that a higher initial aggressiveness of the submitted limit order tends to result in a higher hazard rate of order cancellation and a lower hazard rate of order revision. When a trader submits a limit order at an aggressive price, it indicates that the trader has a need for early execution of the order. For such limit orders, timing is important as they lie between the conventional limit orders which are patient and the market orders which require immediate execution.

[Insert Table 1 here]

Therefore, when the market conditions change (e.g. liquidity is improved, spread is shortened), traders will have a tendency to cancel limit order and opt for market orders for an immediate execution. The intuition is consistent with the 'cost of immediacy hypothesis' and is evident in the estimation results, which suggest a higher probability of cancellation and a lower probability of revision for submitted limit orders with higher initial aggressiveness. On the other hand, when considering limit orders that originate from revision, the coefficient estimates of $p^{Relative}$ are positive and statistically significant for both destination states of order cancellation and order revision. The higher initial aggressiveness is, therefore, associated with a higher hazard rate for both cancellation and revision in this case. This positive relationship implies that after an aggressively submitted order is revised, there is a higher probability that it will be cancelled or it will continue to be revised if the stock market becomes more turbulent and moves away from the limit order's anticipated price range.

Following the initial revisions, traders will continue to 'chase the market' by cancelling their existing order to submit another limit order; or they can simply revise the existing order with a more aggressive price. This result is, in fact, consistent with the 'chasing hypothesis' as described in the above section. The coefficient estimates of $p^{Relative}$ in *Table 2* for the sample of sell limit orders are generally not as statistically significant as those found in *Table 1* for the sample of buy limit orders. This outcome could be caused by the fact that the stock market was experiencing a bullish run in the period under study in this section. As a result, aggressive buy limit orders were a more dominating force in the stock market than aggressive sell limit orders.

The coefficient estimates of *Order Size* in both *Table 1* and *Table 2* show opposite effects which are all statistically significant for limit orders originating from submission compared to limit orders arising from revision in both samples of buy and sell limit orders. The size of the limit order is found to be positively (negatively) related to cancellation intensity and negatively (positively) related to revision intensity when the original state is an order submission (revision). This evidence supports the monitoring hypothesis of Liu (2009), which suggests that a limit order with a larger size tends to be monitored more closely than those with a smaller size. Specifically, a larger limit order could be associated with a larger opportunity cost. When the large limit order is submitted for the first time, it is more likely that early execution is preferred to minimise the waiting cost. Therefore, if better opportunity arrives, there is a higher tendency to cancel the limit order to opt for a market order for an immediate execution.

[Insert Table 2 here]

On the other hand, when the larger order enters the origin state of revision, its waiting cost may not be as high as the one in submission state. As a result, the large limit order no longer requires urgent execution. Instead, the patient limit order will be monitored more closely and it will be revised, either more aggressively or more defensively, depending on the changes in the market conditions.

The results reported in *Table 1* and *Table 2* indicate how market conditions affect dynamic limit order placement strategies. In both samples of buy and sell limit orders, the coefficient estimates of *Spreads* and *Volatility* are all positive and statistically significant, while the estimates for *Market Depth* are mostly negative and statistically significant. The coefficient estimates for *Fleeting Orders* are also significantly positive for both samples of buy and sell limit orders. When more fleeting orders appear in the market, they cause an increase in market turbulence. The results indicate that when the stock market experiences a higher level of short term volatility and a lower level of liquidity (larger spreads, lower depth), there is also a higher probability of order cancellation and revision activities. The effects are also found to be consistent when considering aggressive and defensive revisions. The lower quality market conditions stimulate limit order placement activities and as a response to such market conditions, traders intensify their actions for limit order cancellation and revision, including aggressive and defensive revisions.

The findings of this section lend some support to the current literature. Ranaldo (2004) studies the order aggressiveness in limit order book markets and finds evidence for a higher level of aggressive trading activities when the spread is widened, when volatility is heightened, when the same side book is thicker or when the opposite side book is thinner. Similarly, Menkhoff et al. (2010) investigate the activities of limit order submission under asymmetric information and find that informed traders are more sensitive to changes in volatility, spreads, depth, and momentum.

Further evidence of the ‘chasing hypothesis’ is also found in the pooled sample of sell limit orders in this ITS period. The coefficient estimates of Δq^{Same} in *Table 2* are mostly positive and statistically significant. This result implies that when the best same-side quote moves adversely away from the initial best price, traders have a higher tendency to cancel their limit order and submit a more aggressive one; or they revise their limit order with a more aggressive price. By doing either way, the traders in fact 'chase the market' to gain better execution opportunities. This result is consistent with the 'chasing hypothesis' discussed by Hasbrouck and Saar (2009). Their study also finds evidence in favour of the 'cost of immediacy hypothesis' in the effects of the opposite quotes. The parameter estimates of $\Delta q^{Opposing}$ in this period are, however, mostly positive and significant for both samples of buy and sell limit orders. It implies that when the opposite quotes become cheaper, there is no evidence that traders are more motivated to cancel their existing limit orders in favour of market orders for executions against the more favourable bid (offer) quotes.

Moreover, *Table 1* and *Table 2* suggest that the time a limit order spends in the prior spells also has a negative impact on the probability of transition in the subsequent spell. The coefficient estimates for *Lagged Duration* are found to be negative and statistically significant across the two samples of buy and sell limit orders for both spell types, including revision-to-cancellation and revision-to-revision. This observation is in fact consistent with findings in the literature of labour economics. Studies, such as Van Ours (2004), conclude that if the subsidised job lasts too long, workers start reducing their job search intensity. As a direct comparison, the longer a limit order stays in the limit order book, the more discouraging it is for traders to search for better order placement strategies. Traders can either be extremely patient or they do not have a need for early execution. As a result, they may choose to set a limit price that is far away from the best quotes. This strategy, in turn, makes the limit order stay idle in the limit order book for an extended amount of time without being picked up or amended. Therefore, if the limit order has a longer duration in the previous spells, there is a lower probability that it will be revised or cancelled in the subsequent spell.

Negative duration dependence is also found in a number of multiple-spell duration analyses in the literature of economics (see, for example, Booth et al., 2002[8]; De Graaf-Zijl et

[8] Booth et al. (2002) study the effect of the number of temporary contracts held in the past on current wages.

al., 2011[9]). It is also interesting to observe that, even though coefficient estimates of *Lagged Duration* for aggressive revision are significantly negative, they are positive and significant for defensive revision. This result can be explained by an observation that the longer the limit order stays in the order book, the more likely it will continue staying there. Consequently, it is unlikely that the order will be revised more aggressively. In fact, if traders intend to amend such limit orders, it is more likely that they will take a defensive move.

Finally, the unobserved heterogeneity variable, *Unobhet*, is also included in the empirical model to represent the factors that could have an effect on the hazard rate of transitions for the limit order spells. These factors, however, are not observed and cannot be quantified. The coefficient estimates of *Unobhet* are positive and statistically significant across the two samples of buy and sell limit orders. They suggest a positive impact that the unobserved factors have on the probability of limit orders' transitions. Examples of such factors could include traders' preferences and trading objectives.

5.3. Integrated Trading System (ITS): Large Stocks vs Small Stocks

Survival analyses using the multiple-spell duration model are performed separately for large-cap and small-cap stocks in both samples of buy and sell limit orders in the ITS period. *Table 3* and *Table 4* show the empirical results for the low-latency multiple duration analysis of buy and sell limit orders, respectively, for the sample of large-capitalisation stocks. Similarly, *Table 5* and *Table 6* show the empirical results for the low-latency multiple duration analysis of buy and sell limit orders, respectively, for the sample of small-capitalisation stocks.

[Insert Tables 3-6 here]

[9] De Graaf-Zijl et al. (2011) examine a multi-spell data for the labour market and conclude that temporary employment is a necessary path for a transition to a permanent job.

The results for both large-cap and small-cap stocks are generally consistent with the pooled sample and the parameter estimates can be interpreted in a similar way as discussed in the above section. Nevertheless, there are a couple of distinctions between the samples that represent the large-cap and small-cap stocks. Evidence of the 'cost of immediacy hypothesis' is found in the sample of large-cap stocks, as consistent with the pooled sample. However, in the sample of small-cap stocks, there is no evidence found that a higher initial aggressiveness leads to an increase in limit order cancellations to opt for market orders due to the 'cost of immediacy'. The coefficient estimate of $p^{Relative}$ is not statistically significant in the sample of buy limit orders and it is significantly negative in the sample of sell limit orders of small-cap stocks. Besides, submitting an aggressive limit order generally has a statistically insignificant effect on the hazard rate of limit order revisions, including aggressive and defensive revisions, in both samples of buy and sell limit orders of small-cap stocks.

The effects of market conditions on the intensity of order placement activities for both large and small stocks are generally consistent with the pooled sample in this period. Specifically, when market quality declines due to higher turbulence, higher short term volatility and lower liquidity, traders respond by intensifying their order activities, including order cancellation and order revision. This effect is shown by the significantly positive coefficient estimates of *Fleeting Orders*, *Spreads* and *Volatility*; as well as by the mostly negative and significant coefficient estimates of *Market Depth*. There is, however, one exception in the case of small-cap stocks where the parameter estimates for *Spreads* are generally negative and statistically significant for buy and sell limit orders that originate from submission. It indicates that, in this period, traders of small-cap stocks do not respond to changes in the spreads in the same way as they do for the large-cap stocks. In other words, traders submitting limit orders to buy or sell small-cap stocks concern more about the stock market with a lower level of liquidity caused by a reduced level of depth than one caused by the widening of spreads.

Furthermore, there is another noticeable distinction in the sample of small-cap stocks compared to the sample of large-cap stocks or the pooled sample in this ITS period. The coefficient estimates of duration dependence variable, *Lagged Duration*, in the sample of large-cap stocks are consistent with the pooled sample, i.e. they are negative and significant for all destination states, except for defensive revision. The sample of small-cap stocks, however, show significantly negative estimates only for the destination state of cancellation. The rest of the destination states reveal significantly positive coefficient estimates of *Lagged Duration*. In other words, all destination states of revisions, including aggressive and defensive revisions, experience positive and significant duration dependence in the both samples of buy and sell limit orders for the small-cap stocks. These results seem to suggest that revision activities of small-cap stocks are more intense at the low-latency level than large-cap stocks. Traders of smaller stocks can be more patient since the cost of waiting for them is not as high as the larger stocks. Therefore, spending a longer time in the previous spells does not prevent traders of small-cap stocks intensifying their revision activities (both aggressive and defensive). This intensity of revision activities for small stocks could also be a part of dynamic order placement strategies conducted by high-frequency traders who utilise the benefit of a low-latency market environment.

5.4. The Pooled Sample of Buy and Sell Limit Orders in the ASX Trade Period

In November 2010, ASX launched its new trading platform, called the ASX Trade. This structural change with new technological improvements helped reduce the market latency even further. The results of survival analyses utilising a multiple-spell duration model are presented in *Table 7* and *Table 8* for the pooled sample of buy and sell limit orders, respectively. Each result table is, again, divided into two sections associated with the *origin states* of order submission and order revision. The parameter estimates and their levels of significance are then reported for each variable in the model for each *destination state*. The *destination states* include order cancellation, order revision, aggressive revision and defensive revision. The standard errors are also included in the parentheses.

[Insert Tables 7 and 8 here]

One of the most noticeable distinctions between the two sample periods of ITS and ASX Trade is the effect of initial aggressiveness level on the hazard rate of order revision. For buy limit orders of the ASX Trade sample period, *Table 7* shows a positive and significant coefficient estimate of $p^{Relative}$ for order revision originating from submission. The same estimate is, however, found to be significantly negative in the ITS period, as seen in *Table 1*. Similarly, for sell limit orders of the ASX Trade sample period, *Table 8* shows a significantly negative coefficient estimate of $p^{Relative}$ for order revision originating from submission. *Table 2*, however, finds the same estimate to be positive and statistically significant in the ITS period. The results indicate that in the ASX Trade period, a higher level of initial aggressiveness tends to increase (decrease) the probability of revision following the submission of the order for buy (sell) limit orders. The effects of initial aggressiveness are also more statistically significant in this period than the previous period of ITS, especially for the revision-to-revision order spells in the sample of sell limit orders. The evidence seems to suggest that the decision to submit a more aggressive limit order in this period has a more significant impact on the intensity of cancellation and revision activities conducted by traders. This effect could partially be contributed by the fact that ASX Trade significantly reduced the market latency even further than ITS.

Another distinction of the ASX Trade period can be found in the effects of changes in the opposite quotes. Specifically, *Table 7* shows that the coefficient estimate of $\Delta q^{Opposing}$ is negative and statistically significant for destination state of order cancellation which originates from submission of buy limit orders. It indicates that when the opposite quotes become cheaper, traders are more motivated to cancel their existing limit orders in favour of market orders for an immediate execution. This finding is in fact consistent with the 'cost of immediacy hypothesis' discussed in Hasbrouck and Saar (2009). Evidence consistent with this hypothesis can be found if there is an increase in the probability of rapid cancellation of limit orders when the opposite side of the best bid or offer approaches the limit price after the order is placed in the book.

Unlike the previous period of ITS, this ASX Trade sample period shows a coefficient estimate of Δq^{Same} that is negative and statistically significant for order cancellation originating from submission of sell limit orders (as evident in *Table 8*). Hasbrouck and Saar (2009) show that when the market moves away from traders' submitted limit orders, they would 'chase the market' by cancelling stale orders and resubmitting more aggressive ones. Their study, however, is based on a stock market where traders cannot revise their limit orders. In this research of the ASX Trade, even though traders reduce their cancellation activities when the best same-side quote moves adversely away from the initial best price (i.e. a higher value of Δq^{Same}), they at the same time increase their activities in limit order revision. This action is evident in the sample of sell limit orders (*Table 8*) where the coefficient estimate of Δq^{Same} is significantly positive for order revision originating from submission. Traders, therefore, respond to the changes in same-side quotes by revising their limit orders with more aggressive ones in order to gain better execution opportunities. The combined effect is, indeed, still consistent with the 'chasing hypothesis' discussed in Hasbrouck and Saar (2009).

Finally, the rest of the results in this period are generally consistent with the prior period. Specifically, most of the quality measures of the stock market in the period of ASX Trade appear to have consistent effects with the ITS period on the intensity of order cancellation and order revision activities. Particularly, traders in this period also respond to a drop in market quality by increasing their order placement activities. *Table 7* and *Table 8* show generally positive and significant estimates for the coefficients of *Volatility* and *Fleeting Orders*. The coefficient estimates of *Market Depth* are also mostly negative and statistically significant as found in the previous period. Nevertheless, a number of limit order spells in this ASX Trade period experience mixed effects when *Spreads* is considered as a measure for market quality. The parameter estimates for *Spreads* are positive and statistically significant in most cases. They are, however, significantly negative in some other cases (e.g. for order spell type submission-to-cancellation in the sample of buy limit orders and for order spell type revision-to-revision in the sample of sell limit orders). This observation tends to suggest that even though traders of ASX Trade period also act upon a higher turbulence, a higher short term volatility and a lower liquidity level in the same way as the prior period, they do not respond to the changes of the quoted spreads in the same way as previously. The results, in fact, lend some support for the study conducted by Liu (2009) which finds that traders cancel or revise their limit orders to eliminate the 'free-option risk' in volatile periods.

5.5. The Samples of Large Stocks and Small Stocks in the ASX Trade Period

For completeness, survival analyses utilising the multiple-spell duration model are also conducted separately for both samples of large-cap and small-cap stocks for both buy and sell limit orders in the ASX Trade period. *Table 9* and *Table 10* show the empirical results for the low-latency multiple duration analysis of buy and sell limit orders, respectively, for the large-cap stocks. Similarly, *Table 11* and *Table 12* show the empirical results for the low-latency multiple duration analysis of buy and sell limit orders, respectively, for the small-cap stocks.

[Insert Tables 9-12 here]

The results for both samples of large-cap and small-cap stocks are mostly consistent with the full sample of ASX Trade period and the coefficient estimates can be explained in a similar way as in *Section 4*. There are, however, a couple of differences that are worth noting when compare between the two samples of large-cap and small-cap stocks. The first distinction can be observed in the effects of initial aggressiveness. The coefficient estimates of $p^{Relative}$ for the large-cap stocks are consistent with the pooled sample and they are statistically significant for most types of order spells in both samples of buy and sell limit orders. On the other hand, the estimates of $p^{Relative}$ for the small-cap stocks are statistically less significant in both samples shown in *Table 11* and *Table 12*. In fact, they are mostly insignificant for limit order spells originating from order submission. This result implies that submitting an aggressive limit order for a smaller stock generally has a statistically less significant effect on the hazard rates of order cancellation and order revisions, including aggressive and defensive revisions, than for a larger stock in this period of ASX Trade.

Moreover, another interesting distinction is found in the sample of large-cap stocks. Unlike the sample of small-cap stocks or the pooled sample, the coefficient estimate of Δq^{Same} is positive and statistically significant for order cancellation originating from order submission of large-cap stocks in the sample of sell limit orders (as shown in *Table 10*). The variable Δq^{Same} measures the change in the same-side quotes and as it increases, the hazard rate of order cancellation also rises. The result reveals that when the same-side quote moves adversely away from the initial price, traders is more encouraged to cancel their limit order and submit a more aggressive one. Besides, the coefficient estimates of Δq^{Same} are also found to be significantly positive for order revision and aggressive revision which originate from order submission of large-cap stocks in the sample of sell limit orders. Therefore, in this period of ASX Trade, traders seem to revise their limit orders to sell large-cap stocks more intensively and aggressively in order to chase the market if it moves away from them. The evidence found for the sample of large-cap stocks, in deed, lends a strong support for the 'chasing hypothesis' discussed in Hasbrouck and Saar (2009).

There is no clear evidence that traders of small-cap stocks also 'chase the market' in this sample period. Nevertheless, the sample of small-cap stocks also shows a similar finding to the pooled sample and the sample of large-cap stocks in the effects of the opposite quotes. Particularly, the coefficient estimate of $\Delta q^{Opposing}$ is negative and statistically significant for order cancellation originating from limit order submission of small-cap stocks (as evident in the sample of buy limit orders in *Table 11*). The result signifies that when the opposite quotes become cheaper, traders of small-cap stocks have a tendency to increase the intensity of cancelling their buy limit orders to opt for market orders for executions against the more favourable quotes. The sample of buy limit orders for small-cap stocks, again, shows some evidence for the presence of the 'cost of immediacy hypothesis' in this period of ASX Trade.

Finally, the relationship between the market quality measures and the intensity of order cancellation and revision activities for both large-cap and small-cap stocks are generally consistent with the pooled sample in this period. This result is shown by the consistent signs and significance levels of the parameter estimates of *Spreads*, *Volatility*, *Market Depth* as well as *Fleeting Orders*. High-frequency traders utilise the ultra-low latency in the stock market in the period of ASX Trade to form dynamic order placement strategies. Their strategies involve combinations of multiple responses to the changes in market conditions by conducting a number of limit order cancellation as well as revision activities, including aggressive and defensive revisions.

6. Conclusion

Dynamic limit order placement activities, their effects and determinants have been a controversial topic in market microstructure over the past decade. In the current environment, it is even more difficult to determine the effects of those activities, especially when stock exchanges around the world are racing to reduce their market latency. The ASX is a recent example where the stock market migrated its trading platform from SEATS to ITS in October 2006 and significantly reduced the exchange latency. Later in November 2010, ASX again launched the ASX Trade platform to replace ITS, which lowered the market latency even further.

Limit order revision and cancellation activities have been documented in recent studies to play an important role in forming dynamic order placement strategies. However determinants and effects of these activities have not been adequately accounted for by the existing theoretical and empirical research in the literature of market microstructure. In this study, dynamic order placement strategies in a low-latency environment together with limit orders' aggressiveness are examined by a new approach which utilises survival analysis with a multiple-spell duration model. The two samples undertaken in this study include the period immediately followed ASX's migration to ITS and the period subsequent to the launch of ASX Trade.

The study finds evidence in support for both the 'cost of immediacy hypothesis' and the 'chasing hypothesis', which is consistent with the study by Hasbrouck and Saar (2009). The results of this study suggest that a higher initial aggressiveness of the submitted limit order leads to a higher hazard rate of order cancellation and a lower hazard rate of order revision. Thus, when the market conditions improve (e.g. liquidity increases, spread is shortened), traders will have a tendency to cancel limit order and opt for market orders for an immediate execution. This tendency is, indeed, justified by the 'cost of immediacy hypothesis'. Moreover, the study also finds that when the best same-side quote moves adversely away from the initial best price, traders have a higher tendency to cancel their limit order and submit a more aggressive one; or they revise their limit order with a more aggressive price. By conducting such activities, traders in fact ‘chase the market’ to gain better execution opportunities. This result is consistent with the ‘chasing hypothesis’.

One of the distinctions found between the samples of ITS period and ASX Trade period is the effect of changes in the opposite quotes. The sample of buy limit orders in the ASX Trade period shows significant evidence consistent with 'cost of immediacy hypothesis’. Specifically, when the opposite quotes become cheaper, traders are more motivated to cancel their existing limit orders in favour of market orders for an immediate execution. The sample of small-cap stocks also experiences some differences in the effects on the hazard rates of order cancellation and revisions, as compared to the sample of large-cap stocks. For example, submitting an aggressive limit order for a smaller stock generally has a statistically less significant effect on the hazard rates of order cancellation and order revisions, including aggressive and defensive revisions, than for a larger stock.

The results in this study demonstrate the effects of market conditions on dynamic limit order placement strategies. The lower quality of the market stimulates limit order placement activities and traders respond to such market conditions by intensifying their activities of order cancellation and order revisions, including aggressive and defensive revisions. In particular, the probability of occurrence for order cancellation and revision activities is found to be higher when there is a higher level of short term volatility and a lower level of liquidity, as well as when there are more fleeting orders appear in the market.

This study contributes to the existing literature by enhancing the current understanding of dynamic order placement strategies in a low-latency environment. The findings are not only beneficial for market participants, but they also have important policy implications which will hopefully help market regulators in their attempt to improve regulations for stock exchanges.

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Table 1: Low-Latency Multiple Duration Analysis of Buy Limit Orders in the Pooled Sample of ITS Period

	Submission				**Revision**			
	Cancellation	*Revision*	*Aggressive Revision*	*Defensive Revision*	*Cancellation*	*Revision*	*Aggressive Revision*	*Defensive Revision*
$p^{Relative}$	0.130***	-0.029***	-0.093***	0.044**	0.150***	0.020***	-0.001	0.034***
	(0.007)	(0.008)	(0.010)	(0.021)	(0.013)	(0.005)	(0.007)	(0.009)
Δq^{Same}	-0.191***	0.007	0.072***	-0.122***	-0.151***	-0.059***	-0.035***	-0.124***
	(0.007)	(0.008)	(0.009)	(0.021)	(0.013)	(0.005)	(0.006)	(0.009)
$\Delta q^{Opposing}$	0.156***	0.852***	1.445***	-0.071	0.111***	0.489***	0.546***	0.776***
	(0.023)	(0.031)	(0.036)	(0.046)	(0.022)	(0.011)	(0.015)	(0.010)
Order Size	0.170***	-0.029***	-0.134***	0.328***	-0.393***	0.308***	0.229***	1.148***
	(0.004)	(0.004)	(0.004)	(0.014)	(0.009)	(0.003)	(0.003)	(0.006)
Fleeting Orders	0.720***	0.377***	0.274***	0.318***	0.527***	0.295***	0.295***	0.249***
	(0.004)	(0.004)	(0.005)	(0.014)	(0.008)	(0.003)	(0.003)	(0.005)
Spreads	0.024***	0.019***	0.014***	0.059***	0.010	0.004	0.002	-0.012
	(0.005)	(0.004)	(0.005)	(0.014)	(0.009)	(0.003)	(0.004)	(0.008)
Volatility	0.078***	0.098***	0.104***	0.038**	0.141***	0.049***	0.074***	-0.191***
	(0.005)	(0.005)	(0.005)	(0.015)	(0.009)	(0.003)	(0.004)	(0.008)
Market Depth	-0.089***	-0.235***	-0.338***	-0.254***	0.382***	-0.117***	-0.304***	-0.225***
	(0.004)	(0.004)	(0.005)	(0.013)	(0.009)	(0.003)	(0.004)	(0.006)
Lagged Duration					-0.011***	-0.001***	-0.001***	0.004***
					(<.001)	(<.001)	(<.001)	(<.001)
Constant	-0.681***	-1.274***	-1.592***	-4.011***	-2.683***	0.198***	-0.029***	-0.776***
	(0.006)	(0.005)	(0.006)	(0.018)	(0.013)	(0.004)	(0.004)	(0.008)
Unobhet	1.644***	1.450***	1.617***	3.252***	2.315***	0.256***	0.329***	0.770***
	(0.003)	(0.004)	(0.005)	(0.015)	(0.014)	(0.003)	(0.004)	(0.006)

Standard errors are reported in the parentheses. ***, **, * denote statistical significance at the 1, 5 and 10 percent level respectively.

Table 2: Low-Latency Multiple Duration Analysis of Sell Limit Orders in the Pooled Sample of ITS Period

	Submission				Revision			
	Cancellation	*Revision*	*Aggressive Revision*	*Defensive Revision*	*Cancellation*	*Revision*	*Aggressive Revision*	*Defensive Revision*
$p^{Relative}$	0.001	4.550***	2.774**	2.341***	-0.009**	0.182	0.082	0.783*
	(0.003)	(1.270)	(1.316)	(1.846)	(0.004)	(0.158)	(0.185)	(0.432)
Δq^{Same}	0.290***	1.295***	1.918***	-0.336***	-0.007	0.788***	1.251***	2.410***
	(0.018)	(0.027)	(0.033)	(0.053)	(0.004)	(0.012)	(0.017)	(0.032)
$\Delta q^{Opposing}$	0.097***	0.086***	0.082***	0.057***	0.039***	0.071***	0.074***	0.081***
	(0.004)	(0.004)	(0.005)	(0.012)	(0.008)	(0.003)	(0.003)	(0.006)
Order Size	0.046***	-0.016***	-0.118***	0.298***	-0.407***	0.316***	0.245***	1.146***
	(0.004)	(0.004)	(0.005)	(0.014)	(0.009)	(0.003)	(0.003)	(0.006)
Fleeting Orders	0.702***	0.481***	0.342***	0.422***	0.617***	0.293***	0.293***	0.199***
	(0.004)	(0.004)	(0.005)	(0.013)	(0.008)	(0.003)	(0.003)	(0.005)
Spreads	0.062***	0.036***	0.035***	0.020	0.050***	0.003	0.001	0.010
	(0.004)	(0.005)	(0.005)	(0.016)	(0.009)	(0.003)	(0.004)	(0.008)
Volatility	0.099***	0.098***	0.117***	0.014	0.065***	0.064***	0.095***	-0.221***
	(0.004)	(0.005)	(0.005)	(0.016)	(0.009)	(0.003)	(0.004)	(0.008)
Market Depth	-0.208***	-0.278***	-0.330***	-0.264***	0.244***	-0.108***	-0.263***	-0.184***
	(0.004)	(0.004)	(0.005)	(0.012)	(0.009)	(0.003)	(0.004)	(0.006)
Lagged Duration					-0.014***	-0.001***	-0.001***	0.004***
					(<.001)	(<.001)	(<.001)	(<.001)
Constant	-0.629***	-1.287***	-1.725***	-3.924***	-2.322***	0.226***	-0.014***	-0.831***
	(0.006)	(0.006)	(0.007)	(0.018)	(0.013)	(0.004)	(0.005)	(0.008)
Unobhet	1.499***	1.380***	1.547***	3.183***	2.445***	0.262***	0.365***	0.684***
	(0.003)	(0.004)	(0.005)	(0.017)	(0.012)	(0.003)	(0.004)	(0.006)

Standard errors are reported in the parentheses. ***, **, * denote statistical significance at the 1, 5 and 10 percent level respectively.

Table 3: Low-Latency Multiple Duration Analysis of Buy Limit Orders of Large-Cap Stocks in the ITS Sample Period

	Submission				Revision			
	Cancellation	*Revision*	*Aggressive Revision*	*Defensive Revision*	*Cancellation*	*Revision*	*Aggressive Revision*	*Defensive Revision*
$p^{Relative}$	0.159***	-0.021**	-0.081***	-0.003	0.175***	0.024***	0.001	0.029***
	(0.008)	(0.009)	(0.012)	(0.026)	(0.015)	(0.006)	(0.007)	(0.010)
Δq^{Same}	-0.222***	-0.007	0.056***	-0.097***	-0.182***	-0.064***	-0.040***	-0.117***
	(0.008)	(0.008)	(0.011)	(0.024)	(0.014)	(0.005)	(0.007)	(0.010)
$\Delta q^{Opposing}$	0.074***	0.826***	1.694***	-0.011	0.102***	0.836***	0.755***	1.138***
	(0.028)	(0.053)	(0.058)	(0.018)	(0.027)	(0.019)	(0.025)	(0.013)
Order Size	0.240***	-0.114***	-0.236***	0.266***	-0.347***	0.256***	0.165***	1.205***
	(0.005)	(0.004)	(0.005)	(0.015)	(0.009)	(0.003)	(0.003)	(0.007)
Fleeting Orders	0.682***	0.277***	0.162***	0.241***	0.512***	0.230***	0.228***	0.194***
	(0.005)	(0.004)	(0.005)	(0.014)	(0.009)	(0.003)	(0.003)	(0.006)
Spreads	0.032***	0.006	-0.002	0.054***	0.008	-0.005	-0.007*	-0.027***
	(0.005)	(0.005)	(0.006)	(0.015)	(0.010)	(0.003)	(0.004)	(0.009)
Volatility	0.130***	0.071***	0.068***	0.024	0.144***	0.051***	0.073***	-0.149***
	(0.005)	(0.005)	(0.006)	(0.017)	(0.010)	(0.003)	(0.004)	(0.009)
Market Depth	-0.039***	-0.233***	-0.340***	-0.254***	0.416***	-0.091***	-0.276***	-0.191***
	(0.005)	(0.004)	(0.005)	(0.014)	(0.009)	(0.003)	(0.004)	(0.006)
Lagged Duration					-0.012***	-0.001***	-0.001***	0.003***
					(<.001)	(<.001)	(<.001)	(<.001)
Constant	-0.604***	-1.023***	-1.310***	-3.809***	-2.636***	0.300***	0.083***	-0.703***
	(0.007)	(0.006)	(0.007)	(0.019)	(0.014)	(0.004)	(0.005)	(0.008)
Unobhet	1.816***	1.377***	1.529***	3.117***	2.305***	0.177***	0.233***	0.696***
	(0.004)	(0.004)	(0.005)	(0.016)	(0.016)	(0.003)	(0.004)	(0.006)

Standard errors are reported in the parentheses. ***, **, * denote statistical significance at the 1, 5 and 10 percent level respectively.

Table 4: Low-Latency Multiple Duration Analysis of Sell Limit Orders of Large-Cap Stocks in the ITS Sample Period

	Submission				Revision			
	Cancellation	*Revision*	*Aggressive Revision*	*Defensive Revision*	*Cancellation*	*Revision*	*Aggressive Revision*	*Defensive Revision*
$p^{Relative}$	0.001	1.048**	0.418**	1.559***	-0.009*	0.164	0.031	0.994*
	(0.003)	(0.505)	(0.207)	(0.976)	(0.005)	(0.177)	(0.204)	(0.522)
Δq^{Same}	0.425***	2.057***	2.812***	-0.223***	-0.008*	1.396***	1.936***	4.612***
	(0.028)	(0.045)	(0.051)	(0.044)	(0.005)	(0.019)	(0.027)	(0.048)
$\Delta q^{Opposing}$	0.102***	0.095***	0.093***	0.054***	0.046***	0.077***	0.080***	0.078***
	(0.005)	(0.005)	(0.005)	(0.013)	(0.008)	(0.003)	(0.003)	(0.007)
Order Size	0.102***	-0.119***	-0.234***	0.229***	-0.319***	0.271***	0.186***	1.193***
	(0.005)	(0.004)	(0.005)	(0.014)	(0.009)	(0.003)	(0.003)	(0.007)
Fleeting Orders	0.675***	0.373***	0.220***	0.310***	0.592***	0.239***	0.234***	0.149***
	(0.004)	(0.004)	(0.005)	(0.014)	(0.008)	(0.003)	(0.003)	(0.006)
Spreads	0.075***	0.027***	0.024***	0.011	0.052***	-0.002	-0.005	0.004
	(0.005)	(0.005)	(0.006)	(0.018)	(0.010)	(0.003)	(0.004)	(0.009)
Volatility	0.148***	0.069***	0.077***	-0.003	0.084***	0.061***	0.090***	-0.199***
	(0.005)	(0.005)	(0.006)	(0.017)	(0.010)	(0.003)	(0.004)	(0.009)
Market Depth	-0.182***	-0.283***	-0.341***	-0.254***	0.270***	-0.093***	-0.252***	-0.152***
	(0.005)	(0.004)	(0.005)	(0.013)	(0.010)	(0.003)	(0.004)	(0.006)
Lagged Duration					-0.014***	-0.001***	-0.001***	0.003***
					(<.001)	(<.001)	(<.001)	(<.001)
Constant	-0.586***	-1.037***	-1.457***	-3.693***	-2.355***	0.312***	0.085***	-0.767***
	(0.007)	(0.006)	(0.007)	(0.020)	(0.014)	(0.004)	(0.005)	(0.008)
Unobhet	1.666***	1.261***	1.411***	2.989***	2.404***	0.186***	0.275***	0.589***
	(0.004)	(0.005)	(0.006)	(0.019)	(0.014)	(0.003)	(0.004)	(0.006)

Standard errors are reported in the parentheses. ***, **, * denote statistical significance at the 1, 5 and 10 percent level respectively.

Table 5: Low-Latency Multiple Duration Analysis of Buy Limit Orders of Small-Cap Stocks in the ITS Sample Period

	Submission				**Revision**			
	Cancellation	*Revision*	*Aggressive Revision*	*Defensive Revision*	*Cancellation*	*Revision*	*Aggressive Revision*	*Defensive Revision*
$p^{Relative}$	0.001	-0.026*	-0.075***	0.148***	0.019	0.008	0.007	-0.015
	(0.011)	(0.015)	(0.018)	(0.037)	(0.027)	(0.011)	(0.014)	(0.019)
Δq^{Same}	-0.052***	0.011	0.056***	-0.211***	0.008	-0.055***	-0.045***	-0.086***
	(0.010)	(0.013)	(0.016)	(0.052)	(0.023)	(0.010)	(0.012)	(0.019)
$\Delta q^{Opposing}$	0.109***	0.471***	0.669***	-0.315***	0.089***	0.187***	0.296***	0.561***
	(0.012)	(0.013)	(0.016)	(0.054)	(0.018)	(0.008)	(0.010)	(0.017)
Order Size	0.192***	-0.236***	-0.326***	0.047	-0.752***	0.432***	0.367***	1.527***
	(0.008)	(0.009)	(0.010)	(0.035)	(0.022)	(0.008)	(0.010)	(0.020)
Fleeting Orders	0.885***	0.442***	0.320***	0.341***	0.435***	0.522***	0.547***	0.571***
	(0.009)	(0.013)	(0.015)	(0.047)	(0.025)	(0.008)	(0.010)	(0.015)
Spreads	-0.034***	0.003	-0.003	0.068*	0.019	0.021***	0.014	0.032**
	(0.008)	(0.011)	(0.012)	(0.037)	(0.024)	(0.008)	(0.010)	(0.014)
Volatility	0.111***	0.036***	0.057***	-0.021	0.020	-0.006	0.006	-0.055***
	(0.008)	(0.011)	(0.012)	(0.040)	(0.022)	(0.008)	(0.010)	(0.014)
Market Depth	-0.460***	-0.322***	-0.299***	-0.475***	-0.008	-0.445***	-0.530***	-0.594***
	(0.007)	(0.009)	(0.011)	(0.035)	(0.020)	(0.007)	(0.010)	(0.015)
Lagged Duration					-0.007***	0.002***	0.003***	0.005***
					(<.001)	(<.001)	(<.001)	(<.001)
Constant	-0.862***	-2.354***	-2.859***	-4.390***	-2.921***	-0.280***	-0.674***	-1.142***
	(0.009)	(0.011)	(0.013)	(0.046)	(0.030)	(0.010)	(0.012)	(0.020)
Unobhet	1.173***	1.333***	1.455***	3.858***	2.299***	0.478***	0.590***	0.998***
	(0.006)	(0.012)	(0.015)	(0.043)	(0.031)	(0.007)	(0.010)	(0.012)

Standard errors are reported in the parentheses. ***, **, * denote statistical significance at the 1, 5 and 10 percent level respectively.

Table 6: Low-Latency Multiple Duration Analysis of Sell Limit Orders of Small-Cap Stocks in the ITS Sample Period

	Submission				Revision			
	Cancellation	*Revision*	*Aggressive Revision*	*Defensive Revision*	*Cancellation*	*Revision*	*Aggressive Revision*	*Defensive Revision*
$p^{Relative}$	-0.011**	-0.004	-0.006	-0.002	-0.013**	-0.141	-0.011	0.017
	(0.005)	(0.014)	(0.015)	(0.074)	(0.005)	(0.175)	(0.033)	(0.014)
Δq^{Same}	-0.012	0.562***	0.815***	-0.579***	0.061***	0.259***	0.522***	0.375***
	(0.008)	(0.013)	(0.016)	(0.047)	(0.010)	(0.008)	(0.011)	(0.016)
$\Delta q^{Opposing}$	0.074***	0.032***	0.037***	0.065**	-0.001	0.052***	0.054***	0.061***
	(0.007)	(0.010)	(0.012)	(0.033)	(0.010)	(0.007)	(0.010)	(0.016)
Order Size	0.127***	-0.136***	-0.286***	-0.078**	-0.327***	0.418***	0.355***	1.377***
	(0.008)	(0.009)	(0.011)	(0.036)	(0.015)	(0.008)	(0.010)	(0.020)
Fleeting Orders	0.859***	0.596***	0.386***	0.576***	0.423***	0.465***	0.462***	0.514***
	(0.008)	(0.012)	(0.015)	(0.042)	(0.015)	(0.008)	(0.010)	(0.015)
Spreads	-0.001	-0.049***	-0.067***	0.032	-0.001	0.023***	0.016	0.023
	(0.007)	(0.011)	(0.014)	(0.042)	(0.012)	(0.008)	(0.010)	(0.017)
Volatility	0.121***	0.091***	0.109***	-0.037	0.076***	0.092***	0.103***	0.068***
	(0.007)	(0.011)	(0.013)	(0.040)	(0.012)	(0.008)	(0.010)	(0.016)
Market Depth	-0.385***	-0.429***	-0.388***	-0.726***	-0.106***	-0.404***	-0.529***	-0.501***
	(0.007)	(0.010)	(0.012)	(0.038)	(0.013)	(0.008)	(0.010)	(0.016)
Lagged Duration					-0.008***	0.002***	0.004***	0.005***
					(<.001)	(<.001)	(<.001)	(<.001)
Constant	-0.702***	-2.314***	-2.975***	-4.455***	-2.701***	-0.247***	-0.680***	-1.171***
	(0.009)	(0.012)	(0.014)	(0.046)	(0.019)	(0.011)	(0.013)	(0.021)
Unobhet	1.104***	1.393***	1.476***	3.851***	0.409***	0.477***	0.589***	1.003***
	(0.006)	(0.012)	(0.015)	(0.045)	(0.134)	(0.008)	(0.010)	(0.013)

Standard errors are reported in the parentheses. ***, **, * denote statistical significance at the 1, 5 and 10 percent level respectively.

Table 7: ASX Trade Period and Low-Latency Multiple Duration Analysis of Buy Limit Orders in the Pooled Sample

	Submission				**Revision**			
	Cancellation	*Revision*	*Aggressive Revision*	*Defensive Revision*	*Cancellation*	*Revision*	*Aggressive Revision*	*Defensive Revision*
$p^{Relative}$	0.082***	0.027***	-0.019***	0.085***	0.087***	0.030***	0.030***	-0.001
	(0.002)	(0.004)	(0.006)	(0.018)	(0.005)	(0.003)	(0.005)	(0.003)
Δq^{Same}	-0.115***	-0.084***	-0.006	-0.297***	-0.074***	-0.102***	-0.093***	-0.068***
	(0.002)	(0.004)	(0.005)	(0.020)	(0.004)	(0.003)	(0.005)	(0.003)
$\Delta q^{Opposing}$	-0.019***	0.231***	0.796***	-0.760***	0.040***	-0.132***	-0.018**	0.103***
	(0.003)	(0.010)	(0.011)	(0.052)	(0.010)	(0.009)	(0.008)	(0.006)
Order Size	0.156***	-0.192***	-0.607***	0.305***	-0.611***	1.084***	1.471***	0.830***
	(0.002)	(0.003)	(0.004)	(0.015)	(0.005)	(0.003)	(0.004)	(0.003)
Fleeting Orders	0.357***	0.875***	0.769***	1.389***	0.750***	0.434***	0.528***	0.266***
	(0.001)	(0.002)	(0.003)	(0.009)	(0.003)	(0.002)	(0.003)	(0.002)
Spreads	-0.012***	0.026***	0.014***	-0.006	0.023***	0.012***	-0.043***	-0.023***
	(0.002)	(0.004)	(0.004)	(0.016)	(0.005)	(0.002)	(0.004)	(0.002)
Volatility	0.048***	0.088***	0.147***	0.211***	-0.040***	0.209***	0.269***	0.099***
	(0.002)	(0.003)	(0.004)	(0.015)	(0.005)	(0.003)	(0.004)	(0.002)
Market Depth	-0.017***	-0.053***	-0.083***	0.023*	0.084***	-0.134***	-0.255***	-0.229***
	(0.002)	(0.003)	(0.004)	(0.014)	(0.004)	(0.002)	(0.005)	(0.005)
Lagged Duration					-0.057***	-0.011***	-0.009***	-0.001***
					(<.001)	(<.001)	(<.001)	(<.001)
Constant	-0.094***	-2.965***	-3.893***	-5.671***	-2.212***	2.477***	1.259***	-1.132***
	(0.005)	(0.009)	(0.011)	(0.040)	(0.015)	(0.009)	(0.015)	(0.007)
Unobhet	0.862***	1.932***	2.107***	4.778***	2.079***	1.278***	1.513***	-1.006***
	(0.002)	(0.003)	(0.004)	(0.007)	(0.005)	(0.001)	(0.002)	(0.017)

Standard errors are reported in the parentheses. ***, **, * denote statistical significance at the 1, 5 and 10 percent level respectively.

Table 8: ASX Trade Period and Low-Latency Multiple Duration Analysis of Sell Limit Orders in the Pooled Sample

	Submission				**Revision**			
	Cancellation	*Revision*	*Aggressive Revision*	*Defensive Revision*	*Cancellation*	*Revision*	*Aggressive Revision*	*Defensive Revision*
$p^{Relative}$	0.002	-0.004**	-0.375***	1.039***	-0.661***	-0.741***	-0.766***	0.863***
	(0.002)	(0.002)	(0.073)	(0.209)	(0.006)	(0.008)	(0.018)	(0.012)
Δq^{Same}	-0.735***	0.308***	1.217***	-1.478***	0.110***	0.053***	0.504***	1.397***
	(0.003)	(0.005)	(0.013)	(0.064)	(0.003)	(0.008)	(0.010)	(0.016)
$\Delta q^{Opposing}$	0.067***	0.065***	0.114***	0.156***	0.018***	0.111***	0.118***	0.132***
	(0.002)	(0.002)	(0.004)	(0.013)	(0.002)	(0.002)	(0.004)	(0.005)
Order Size	0.018***	-0.325***	-0.764***	0.194***	-0.336***	1.315***	1.495***	2.380***
	(0.002)	(0.002)	(0.004)	(0.015)	(0.002)	(0.003)	(0.004)	(0.006)
Fleeting Orders	0.366***	0.528***	0.792***	1.392***	0.386***	0.083***	0.583***	0.329***
	(0.001)	(0.001)	(0.002)	(0.009)	(0.002)	(0.002)	(0.003)	(0.004)
Spreads	0.013***	0.027***	0.045***	0.099***	0.022***	-0.042***	-0.003	0.013***
	(0.002)	(0.002)	(0.004)	(0.015)	(0.002)	(0.003)	(0.004)	(0.005)
Volatility	0.064***	0.047***	0.134***	0.137***	0.014***	0.202***	0.211***	0.171***
	(0.002)	(0.002)	(0.004)	(0.015)	(0.002)	(0.003)	(0.004)	(0.005)
Market Depth	-0.029***	-0.046***	-0.070***	-0.120***	0.028***	0.123***	-0.268***	-0.355***
	(0.002)	(0.002)	(0.004)	(0.014)	(0.002)	(0.003)	(0.005)	(0.007)
Lagged Duration					-0.054***	-0.015***	-0.011***	-0.008***
					(<.001)	(<.001)	(<.001)	(<.001)
Constant	0.020***	-2.836***	-3.755***	-5.551***	-2.427***	4.462***	0.932***	2.519***
	(0.005)	(0.005)	(0.010)	(0.042)	(0.009)	(0.008)	(0.015)	(0.021)
Unobhet	0.555***	0.302***	1.928***	4.711***	-0.229***	1.378***	1.482***	1.875***
	(0.002)	(0.008)	(0.004)	(0.007)	(0.012)	(0.001)	(0.002)	(0.002)

Standard errors are reported in the parentheses. ***, **, * denote statistical significance at the 1, 5 and 10 percent level respectively.

Table 9: ASX Trade Period and Low-Latency Multiple Duration Analysis of Buy Limit Orders of Large-Cap Stocks

	Submission				Revision			
	Cancellation	*Revision*	*Aggressive Revision*	*Defensive Revision*	*Cancellation*	*Revision*	*Aggressive Revision*	*Defensive Revision*
$p^{Relative}$	0.097***	0.033***	-0.016**	0.035	0.089***	0.030***	-0.003	0.012***
	(0.003)	(0.005)	(0.007)	(0.022)	(0.005)	(0.003)	(0.006)	(0.002)
Δq^{Same}	-0.130***	-0.100***	-0.020***	-0.282***	-0.074***	-0.104***	-0.075***	-0.064***
	(0.003)	(0.004)	(0.006)	(0.023)	(0.005)	(0.003)	(0.005)	(0.002)
$\Delta q^{Opposing}$	-0.009***	0.055***	1.306***	-0.770***	0.003	-0.242***	-0.494***	0.295***
	(0.003)	(0.011)	(0.021)	(0.126)	(0.005)	(0.017)	(0.024)	(0.009)
Order Size	0.177***	-0.155***	-0.605***	0.382***	-0.484***	1.062***	1.478***	0.495***
	(0.002)	(0.003)	(0.004)	(0.017)	(0.005)	(0.003)	(0.004)	(0.002)
Fleeting Orders	0.445***	0.816***	0.639***	1.373***	0.765***	0.459***	0.480***	0.270***
	(0.002)	(0.003)	(0.004)	(0.014)	(0.004)	(0.002)	(0.004)	(0.002)
Spreads	-0.008***	0.025***	0.005	-0.010	0.023***	0.015***	-0.044***	-0.002
	(0.003)	(0.004)	(0.005)	(0.018)	(0.006)	(0.002)	(0.004)	(0.002)
Volatility	0.046***	0.084***	0.159***	0.218***	-0.053***	0.218***	0.275***	0.072***
	(0.003)	(0.004)	(0.005)	(0.017)	(0.005)	(0.003)	(0.004)	(0.002)
Market Depth	-0.009***	-0.099***	-0.157***	-0.022	0.077***	-0.124***	-0.257***	-0.087***
	(0.002)	(0.004)	(0.005)	(0.016)	(0.004)	(0.002)	(0.005)	(0.002)
Lagged Duration					-0.073***	-0.013***	-0.012***	-0.002***
					(0.001)	(<.001)	(<.001)	(<.001)
Constant	-0.410***	-2.648***	-3.332***	-5.383***	-2.323***	2.502***	1.746***	-0.593***
	(0.008)	(0.014)	(0.017)	(0.070)	(0.021)	(0.013)	(0.020)	(0.008)
Unobhet	0.960***	1.931***	2.091***	4.796***	2.043***	1.290***	1.534***	-0.777***
	(0.002)	(0.003)	(0.005)	(0.008)	(0.005)	(0.002)	(0.002)	(0.011)

Standard errors are reported in the parentheses. ***, **, * denote statistical significance at the 1, 5 and 10 percent level respectively.

Table 10: ASX Trade Period and Low-Latency Multiple Duration Analysis of Sell Limit Orders of Large-Cap Stocks

	Submission				Revision			
	Cancellation	*Revision*	*Aggressive Revision*	*Defensive Revision*	*Cancellation*	*Revision*	*Aggressive Revision*	*Defensive Revision*
$p^{Relative}$	0.010	-0.027***	-0.435***	0.906***	-0.826***	-0.685***	0.011***	-0.192***
	(0.007)	(0.008)	(0.131)	(0.074)	(0.006)	(0.008)	(0.003)	(0.004)
Δq^{Same}	0.159***	0.480***	2.502***	-2.396***	3.608***	0.067***	0.348***	2.553***
	(0.004)	(0.008)	(0.041)	(0.157)	(0.024)	(0.007)	(0.019)	(0.017)
$\Delta q^{Opposing}$	0.036***	0.067***	0.075***	0.172***	0.079***	0.108***	0.123***	0.119***
	(0.001)	(0.002)	(0.004)	(0.016)	(0.005)	(0.002)	(0.004)	(0.004)
Order Size	0.138***	-0.324***	-0.122***	0.319***	0.130***	1.067***	1.519***	1.351***
	(0.001)	(0.002)	(0.003)	(0.017)	(0.005)	(0.003)	(0.004)	(0.004)
Fleeting Orders	0.201***	0.443***	0.410***	1.280***	0.821***	0.445***	0.467***	0.469***
	(0.001)	(0.002)	(0.003)	(0.014)	(0.004)	(0.002)	(0.004)	(0.004)
Spreads	0.009***	0.024***	0.022***	0.116***	0.031***	-0.015***	-0.004	-0.029***
	(0.002)	(0.002)	(0.004)	(0.018)	(0.005)	(0.003)	(0.004)	(0.004)
Volatility	0.029***	0.048***	0.085***	0.130***	0.002	0.178***	0.210***	0.156***
	(0.001)	(0.002)	(0.003)	(0.017)	(0.005)	(0.003)	(0.004)	(0.004)
Market Depth	-0.066***	-0.061***	-0.131***	-0.144***	-0.058***	-0.127***	-0.234***	-0.164***
	(0.001)	(0.002)	(0.004)	(0.016)	(0.005)	(0.003)	(0.005)	(0.004)
Lagged Duration					-0.027***	-0.015***	-0.013***	-0.011***
					(0.001)	(<.001)	(<.001)	(<.001)
Constant	-0.805***	-2.500***	-2.205***	-4.770***	-1.476***	2.605***	1.777***	2.483***
	(0.005)	(0.008)	(0.013)	(0.071)	(0.020)	(0.012)	(0.020)	(0.019)
Unobhet	-0.858***	0.173***	0.172***	4.750***	0.962***	1.287***	1.515***	1.637***
	(0.007)	(0.009)	(0.009)	(0.008)	(0.004)	(0.002)	(0.002)	(0.002)

Standard errors are reported in the parentheses. ***, **, * denote statistical significance at the 1, 5 and 10 percent level respectively.

Table 11: ASX Trade Period and Low-Latency Multiple Duration Analysis of Buy Limit Orders of Small-Cap Stocks

	Submission				Revision			
	Cancellation	*Revision*	*Aggressive Revision*	*Defensive Revision*	*Cancellation*	*Revision*	*Aggressive Revision*	*Defensive Revision*
$p^{Relative}$	0.057***	-0.005	-0.016	0.010	0.032**	0.045***	0.144***	0.048***
	(0.004)	(0.009)	(0.012)	(0.015)	(0.014)	(0.008)	(0.013)	(0.008)
Δq^{Same}	-0.087***	-0.025***	0.025***	-0.129***	-0.053***	-0.074***	-0.104***	-0.049***
	(0.004)	(0.007)	(0.009)	(0.015)	(0.012)	(0.007)	(0.011)	(0.009)
$\Delta q^{Opposing}$	-0.052***	0.255***	0.463***	-0.056***	0.137***	-0.071***	0.289***	0.090***
	(0.004)	(0.008)	(0.009)	(0.017)	(0.014)	(0.010)	(0.012)	(0.006)
Order Size	0.103***	-0.478***	-0.667***	-0.051***	-1.348***	0.842***	0.644***	0.737***
	(0.003)	(0.006)	(0.008)	(0.012)	(0.013)	(0.008)	(0.011)	(0.010)
Fleeting Orders	0.292***	0.456***	0.425***	0.500***	0.339***	0.331***	0.216***	0.078***
	(0.003)	(0.005)	(0.007)	(0.010)	(0.012)	(0.006)	(0.008)	(0.006)
Spreads	-0.012***	-0.030***	-0.037***	-0.004	0.032**	-0.055***	-0.029**	-0.013
	(0.004)	(0.007)	(0.010)	(0.013)	(0.014)	(0.008)	(0.012)	(0.010)
Volatility	0.033***	0.177***	0.118***	0.224***	0.150***	0.010	0.052***	-0.013
	(0.004)	(0.007)	(0.009)	(0.013)	(0.013)	(0.008)	(0.011)	(0.008)
Market Depth	-0.004	-0.007	-0.009	-0.003	0.050***	-0.175***	-0.305***	-0.262***
	(0.003)	(0.006)	(0.009)	(0.011)	(0.012)	(0.007)	(0.014)	(0.014)
Lagged Duration					-0.023***	-0.005***	0.003***	0.003***
					(0.001)	(<.001)	(<.001)	(<.001)
Constant	-0.147***	-2.539***	-3.429***	-3.400***	-1.224***	1.600***	-0.218***	-1.501***
	(0.006)	(0.012)	(0.015)	(0.024)	(0.030)	(0.015)	(0.021)	(0.014)
Unobhet	0.633***	1.816***	1.995***	3.100***	2.224***	1.150***	1.182***	-1.155***
	(0.003)	(0.008)	(0.011)	(0.014)	(0.012)	(0.005)	(0.009)	(0.070)

Standard errors are reported in the parentheses. ***, **, * denote statistical significance at the 1, 5 and 10 percent level respectively.

Table 12: ASX Trade Period and Low-Latency Multiple Duration Analysis of Sell Limit Orders of Small-Cap Stocks

	Submission				**Revision**			
	Cancellation	*Revision*	*Aggressive Revision*	*Defensive Revision*	*Cancellation*	*Revision*	*Aggressive Revision*	*Defensive Revision*
$p^{Relative}$	-0.003*	-0.007	-0.012*	-0.005	-1.006***	-1.402***	-1.021***	-0.520***
	(0.002)	(0.006)	(0.007)	(0.018)	(0.016)	(0.018)	(0.013)	(0.030)
Δq^{Same}	0.001	-0.137***	0.110***	-0.318***	0.146***	0.123***	0.649***	0.698***
	(0.002)	(0.006)	(0.006)	(0.019)	(0.006)	(0.014)	(0.012)	(0.019)
$\Delta q^{Opposing}$	0.030***	0.078***	0.054***	0.045***	0.024***	0.071***	0.073***	0.079***
	(0.002)	(0.006)	(0.007)	(0.017)	(0.006)	(0.007)	(0.010)	(0.017)
Order Size	0.020***	-0.521***	-0.592***	-0.234***	-0.395***	1.606***	0.510***	1.393***
	(0.002)	(0.006)	(0.007)	(0.016)	(0.007)	(0.008)	(0.010)	(0.018)
Fleeting Orders	0.167***	0.515***	0.417***	0.458***	0.221***	-0.226***	0.318***	0.222***
	(0.002)	(0.005)	(0.006)	(0.016)	(0.006)	(0.005)	(0.008)	(0.014)
Spreads	0.009***	-0.027***	-0.031***	0.007	-0.007	-0.078***	0.018	0.053***
	(0.002)	(0.007)	(0.008)	(0.019)	(0.007)	(0.008)	(0.011)	(0.020)
Volatility	0.019***	0.103***	0.105***	0.041**	0.045***	-0.065***	0.090***	0.040**
	(0.002)	(0.006)	(0.006)	(0.018)	(0.007)	(0.007)	(0.010)	(0.018)
Market Depth	-0.078***	-0.052***	-0.111***	-0.090***	-0.017**	1.073***	-0.469***	-0.470***
	(0.002)	(0.006)	(0.008)	(0.021)	(0.008)	(0.034)	(0.014)	(0.024)
Lagged Duration					-0.028***	-0.008***	0.004***	0.010***
					(0.001)	(<.001)	(<.001)	(<.001)
Constant	-0.677***	-2.370***	-3.173***	-5.261***	-1.987***	4.516***	-0.917***	-0.648***
	(0.004)	(0.012)	(0.013)	(0.034)	(0.017)	(0.012)	(0.020)	(0.034)
Unobhet	-1.024***	1.374***	1.015***	2.917***	0.538***	1.426***	1.024***	1.818***
	(0.013)	(0.008)	(0.023)	(0.075)	(0.028)	(0.003)	(0.009)	(0.013)

Standard errors are reported in the parentheses. ***, **, * denote statistical significance at the 1, 5 and 10 percent level respectively.

APPENDIX: Table A1: Length and Frequency of Limit Order Events

PANEL A: BUY ORDERS

Order Length	Frequency	Percentage	Cumulative Frequency	Cumulative Percentage
1	5,582	3.67	5,582	3.67
2	94,069	61.77	99,651	65.43
3	27,595	18.12	127,246	83.55
4	11,632	7.64	138,878	91.19
5	5,539	3.64	144,417	94.83
6	2,908	1.91	147,325	96.74
7	1,694	1.11	149,019	97.85
8	1,018	0.67	150,037	98.52
9	646	0.42	150,683	98.94
10	419	0.28	151,102	99.22
11	306	0.20	151,408	99.42
12	217	0.14	151,625	99.56
13	162	0.11	151,787	99.67
14	95	0.06	151,882	99.73
15	88	0.06	151,970	99.79
16	67	0.04	152,037	99.83
17	44	0.03	152,081	99.86
18	39	0.03	152,120	99.89
19	19	0.01	152,139	99.90
20	34	0.02	152,173	99.92
21	15	0.01	152,188	99.93
22	23	0.02	152,211	99.95
23	16	0.01	152,227	99.96
24	11	0.01	152,238	99.97
25	8	0.01	152,246	99.97
26	8	0.01	152,254	99.98
27	3	0.00	152,257	99.98
28	6	0.00	152,263	99.98
29	2	0.00	152,265	99.98
30	6	0.00	152,271	99.99
31	2	0.00	152,273	99.99
32	4	0.00	152,277	99.99
33	2	0.00	152,279	99.99
34	1	0.00	152,280	99.99
35	1	0.00	152,281	99.99
36	1	0.00	152,282	99.99
37	1	0.00	152,283	99.99
38	1	0.00	152,284	100.00
40	1	0.00	152,285	100.00
41	1	0.00	152,286	100.00
42	1	0.00	152,287	100.00
44	1	0.00	152,288	100.00
46	1	0.00	152,289	100.00
50	1	0.00	152,290	100.00
59	1	0.00	152,291	100.00

PANEL B: SELL ORDERS

Order Length	Frequency	Percentage	Cumulative Frequency	Cumulative Percentage
1	6,733	4.40	6,733	4.40
2	94,676	61.94	101,409	66.34
3	26,697	17.47	128,106	83.81
4	11,791	7.71	139,897	91.52
5	5,248	3.43	145,145	94.96
6	2,902	1.90	148,047	96.86
7	1,672	1.09	149,719	97.95
8	1,050	0.69	150,769	98.64
9	623	0.41	151,392	99.04
10	387	0.25	151,779	99.30
11	252	0.16	152,031	99.46
12	182	0.12	152,213	99.58
13	149	0.10	152,362	99.68
14	95	0.06	152,457	99.74
15	84	0.05	152,541	99.80
16	61	0.04	152,602	99.84
17	42	0.03	152,644	99.86
18	40	0.03	152,684	99.89
19	35	0.02	152,719	99.91
20	31	0.02	152,750	99.93
21	19	0.01	152,769	99.94
22	13	0.01	152,782	99.95
23	12	0.01	152,794	99.96
24	9	0.01	152,803	99.97
25	12	0.01	152,815	99.97
26	3	0.00	152,818	99.98
27	3	0.00	152,821	99.98
29	6	0.00	152,827	99.98
30	6	0.00	152,833	99.99
31	2	0.00	152,835	99.99
32	2	0.00	152,837	99.99
34	1	0.00	152,838	99.99
35	1	0.00	152,839	99.99
36	1	0.00	152,840	99.99
37	3	0.00	152,843	99.99
38	1	0.00	152,844	99.99
39	1	0.00	152,845	99.99
40	1	0.00	152,846	99.99
41	2	0.00	152,848	100.00
42	1	0.00	152,849	100.00
52	1	0.00	152,850	100.00
55	1	0.00	152,851	100.00
66	1	0.00	152,852	100.00
75	1	0.00	152,853	100.00
100	1	0.00	152,854	100.00