MR. TRADER, WOULD YOU LIKE TO CHANGE YOUR ORDER?[†]

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Abstract

Limit order revision and cancellation each accounts for up to one fifth of all order activities. More than 60% of all revisions and cancellations take place within the two best prices in the limit order book and 61% of revisions result in another limit order. Large orders are more likely to be revised than small orders and about 70% of order revisions involve increasing price priority which indicates that non-execution risk is the most common concern. We find that order revisions reduce the costs of using limit orders such as non-execution and free trading option costs. Large market orders and volatility consistently affect order revision and cancellation activity. Bad (good) news is associated with buyers (sellers) cancelling or reducing the price priority of their orders, and sellers (buyers) increases the price priority of their orders.

JEL classification: F10; G14

Keywords: limit orders, free trading option risk, non-execution risk, order cancellation, order revision

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1. Introduction

The best bid and ask price in the limit order book of BHP is $30.55-$30.57. A trader wants to buy 10,000 shares and placed a limit buy order at $30.55. Five minutes later, the order is still outstanding while the best bid and ask price changes to $30.56-$30.58. Should he wait and hope the current limit order will be executed? Should he revise the order price upward to gain higher execution priority or even immediate execution? Should he cancel the order and wait for more information before placing a new order? Making these decisions requires additional information, such as the commitment to trade, timing discretion, reservation price, ability to monitor the market, whether there has been any information announcement since initial order submission, and perception of information advantage. An important observation is that there are more works to be done after submitting a limit order.

Researchers recently begin to pay attention to the after-math of limit order submission. Table 1 summarizes the evidence of limit order cancellation frequencies across stock markets. On the New York Stock Exchange (NYSE, hereafter) more than one-third of all order submissions are cancelled (Ellul et al (2005) and Yeo (2005)).[1] On the Australian Stock Exchange (ASX, hereafter), Liu (2005) finds order revisions and cancellations account for up to 10% and 21%, respectively, of all order submissions. Despite these findings, no existing theoretical or empirical research focus on examining limit order revision and cancellation. Order choice decision models such as Cohen et al (1981), Copeland and Galai (1983), Angel (1994), Glosten (1994), Chakravarty and Holden (1995), Handa and Schwartz (1996), Seppi (1997), Parlour (1998), Foucault (1999), Handa, Schwartz and Tiwari (1999), Wald and Horrigan (2001) and Brown and Holden (2002) are one shot limit order submission models and assume limit orders cannot be revised or cancelled.[2] Nevertheless, these models identify

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[1] Recent observation suggests that as high as 70% of limit orders on the NYSE are cancelled. We thank Li Wei from the NYSE for providing this information.

[2] This focus is adopted for tractability. Only until recently, models of limit order trading began considering order cancellation and revision. Harris (1998) develops a dynamic limit order submission model that considers explicitly the option to revise the order strategy. Hollifield, Miller and Sandas (2004) and Goettler, Parlour and

the key trade off in using limit orders, potential price improvement, non-execution risk, and free trading option risk.

[INSERT TABLE 1 HERE]

When traders decide to submit limit orders they forgo the opportunity to place market orders. Non-execution risk of a limit order refers to the risk that future orders (market and limit orders) and trading activity may shift away from the limit price which results in non-execution, lower execution probability at the original price and increased opportunity cost of using market order. Parlour (1998) predicts that execution probability is positively (negatively) related to the depth of limit order on the opposite (same) side of the book. Coppejans and Domowitz (2002), Ellud et al (2003), Ranaldo (2004) and Liu (2005) find evidence supporting that theory and they also find order cancellations are positively related to non-execution risk.

Free trading option risk (see Copeland and Galai (1983) and Liu (2005))[3] represents the risk that a limit order being picked off, i.e., its execution is triggered by a market order submitted in response to public information arrivals before the limit order trader could revise the limit order. The cost of being picked off is the mis-pricing which is the difference between the price to which the trader would have revised the order and the old limit order price.

After limit order submission, a trader may exert costly effort to monitor the arrival of information and revises or cancels the order such that his exposure to non-execution and free-option trading risk is reduced. Liu (2005) shows that the equilibrium bid-ask spread is characterized by a Nash equilibrium of a monitoring game played by patient traders and newswatchers.

Rajan (2003) recognized the importance of order cancellation but their models assume cancellation occur exogenously at random points in time.

[3] Copeland and Galai (1983) study FTO risk in the context of private information and argue that free trading option risk is equivalent to adverse selection risk. Stoll (1992) distinguish the two and further argued that, in the presence of adverse selection risk, limit orders do not have a positive option value because they have an infinitesimally small maturity. An informed trader with private information will pick off limit orders immediately after they are entered. A much clearer distinction between the two is provided in Stoll (2003). He asserted that free trading option risk arises because of the arrival of adverse public information before the trade, while adverse selection risk arises because of the presence of private information before the trade, which is revealed some time after the trade. We focus on FTO risk in this paper because (i) it is a risk that traders can reduce by monitoring news arrival and (ii) it is difficult to distinguish between the two types of risk empirically.

This paper studies limit order revisions and cancellations in three dimensions. First, we provide a descriptive analysis of limit order revisions and cancellations. Second, we quantify the benefit of these activities in terms of reduction in non-execution and free trading option costs. Third, we test the conjecture that the level of revision and cancellation activities is related to limit order submission risks.

We use the ASX dataset that permits us to track the history of order size and price of all orders in a centralized limit order book market from order submission, to revision, cancellation or execution. We analyse the number of order revision and cancellation at 15-minute intervals because we believe that these decisions are dependent on market conditions and we are interested in their intraday variation. The ability to identify the way an order is revised is important because non-execution risk and free trading option risk lead to specific type of order revisions. Concerns for non-execution risk results in price priority increasing order revisions while concern for free trading option risk results in price priority decreasing order revisions. The empirical literature considers only order cancellations which can be influenced by both types of risk.

Our data shows that order revisions account for a significant proportion of market activity, up to one-fifth of market orders are results of order revisions. Order revisions exhibit a distinct increase in frequency relative to order submission in the last 15 minutes of trading which conforms to Foucault (1999) theoretical result that non-execution risk increases towards the end of a trading day. We find that order revisions are more popular in smaller stocks and limit order traders are patient with about 60 percent of order revisions resulted in another limit order. Limit order traders appear to monitor the market closely since most of the revision and cancellation activities take place at or near the bid-ask quote. Harris (2003) and Liu (2005) note that monitoring the market and managing orders are costly acts. We argue that the benefit of monitoring a large order is higher than that of a small order, and we find evidence that large orders are revised more frequently than small orders. The data also tell us that 72.3 percent of order revisions involve increased price priority and no order size adjustment. Such concentration of activity suggests that reducing non-execution risk is the more frequent reason for order revision.

We measure non-execution cost by calculating the dollar difference in using market orders to fill an order at two points in time, the time of order revision (cancellation) and 15 minutes after the order revision (cancellation). The execution of a limit order is analogous to the execution of an option and the free trading option cost is equivalent to the intrinsic value of the free option. We estimate this cost by computing the difference between the post-execution market price (that reflects the new information) and the price of the executed limit order. We find that traders realize an average positive benefit of 0.41-1.35 cent per share in free trading option cost reduction and 0.98-2.43 cent per share in non-execution cost reduction by revising or cancelling limit orders.

We estimate the relationship between order revision/cancellation frequencies and limit order submission risks using negative binomial count and fractional logistic models. Our regression results show strong association between these variables. While most of the coefficients on proxies of non-execution risk and free trading option risks carry the predicted sign two variables show consistent statistical significant relationship with order revision and cancellation frequencies, lag number of large transactions and return volatility. Specifically large market orders on the opposite side of a limit order signify heightened non-execution risk for the limit order on the same side and heightened free trading risk for limit orders on the opposite side. They trigger priority increase revisions on the same side of the limit order book and priority decrease revisions on the opposite side. Volatility also stands out as an important determinant of all order revision and cancellation activities. Its impact is universally positive indicating that volatility is strongly associated with both non-execution risk and free trading option risk. When we use market sensitive news dummy variables as proxies of limit order submission risks, we find the following patterns that are consistent with our prediction; bad (good) news is associated with buyers (sellers) cancelling or reducing the price priority of their orders, and sellers (buyers) increases the price priority of their orders.

The reminder of this paper is organized as follows. Section 2 presents the institutional background and the dataset used in this empirical study. Section 3 presents and discusses the empirical patterns and behaviors of order cancellation and revision activities. Section 4 examines the determinants of order cancellation revision activities using count regression analysis. Section 5 presents results relating revision/cancellation decision to non-execution cost and free option cost. We conclude in section 6.

2. Institutional details and data

2.1 Institutional details

The ASX operates a centralized electronic limit order book market called SEATS (Stock Exchange Automated Trading System) which is similar to the Toronto CATS and Paris Bourse CAC systems in that there are no designated market makers. Broker-dealers can trade as principals in both the ‘downstairs’ electronic limit order book and the ‘upstairs’ telephone markets but unlike the NYSE specialists or NASDAQ market makers, they do not have any affirmative obligations to maintain price continuity or an orderly market. The ASX charges brokers $0.22 per entered orders and subsequent price or volume revisions or cancellations are free of charge. Typically, brokerage fees are incurred only when a trade is completed. Clients are not responsible for the cost of order submission, which is absorbed by the brokerage firm.

Traders may enter, revise or cancel orders in SEATS from the pre-open phase commencing at 7:00 but the trading system does not match orders until the market opens. SEATS opens stock for trading randomly within alphabetical groups from 10:00. The opening call auction algorithm completes the opening of all stocks by 10:10. Normal continuous trading follows the opening call auction and ends at 16:00. The closing call auction algorithm begins at 16:10 and establishes the closing price of the day.

Investors usually submit market orders and limit orders to SEATS through brokers. Some institutional investors can directly access SEATS via the SEATS Trader Workstation software or a device connected to the SEATS Open Interface. Through the Open Interface market participants enter, revise and withdraw orders electronically using the trading participant's proprietary trading system without using designated trading representatives to re-enter their requests to SEATS. For retail investors, there are online brokers who offer ‘straight-through’ order entry software such that retail investors can also submit, revise and cancel orders almost instantaneously.

While SEATS is a limit order book system and accepts only limit orders, we refer to the subset of limit orders that receive immediate partial or full execution upon submission as market orders. Market orders generate overlapping order books, hence trades. If a market buy order specifies a quantity that exceeds the aggregate quantity of the best ask price, then the order will be executed immediately and partially. The unexecuted portion of the original order remains as a standing limit buy order at that price.

The ASX adopts a price-time priority rule in queuing limit orders. Orders subject to price revisions receive the lowest time priority at the revised price. If a trader increases the volume of an entered order at the same price, the trading system automatically creates a new order which receives the lowest time priority at that price. However, if the volume is decreased, the order retains its time priority.

A crossing trade is one exception to the price-time priority rule. It occurs when a broker by-passes time priority by matching a buy order to a sell order from his client order book. In order to perform a crossing trade, two conditions must be satisfied. First, the broker has an existing quote at the price (best bid or best ask) where the crossing trade is to occur. Second, the best bid and best ask prices must be one tick apart. These two conditions must hold for a minimum of 10 seconds before the broker can legally perform the crossing. Brokers typically enter a single share order at the crossing price and create a one-tick market if one does not already exist. After the crossing trade is completed, the broker deletes the single share order. Crossing trades inflate the number of order submission and cancellation hence we remove all single share order events from our dataset.

2.2 Dataset

We obtain SEATS order flow data from the Securities Industry Research Centre of Asia-Pacific (SIRCA). Our sample contains a complete record of the order flow for twenty large and twenty small stocks on the ASX. We use firm size to proxy different information environments and liquidity conditions. Table 2 lists the sample stocks together with their stock index ranking. The sample period spans 23 trading days from 1st August to 31st August 2000. The dataset records each order and trade including details such as the date, time to the nearest hundredth of second, stock code, price, order volume, order type and an order number. Using the order number and time we track subsequent execution, cancellation or price or quantity revisions.

[INSERT TABLE 2 HERE]

3. A descriptive analysis of limit order revision/cancellation activity

3.1 Intraday distribution

We refer to order submissions, revisions, and cancellations collectively as order events. There are 188,305 (47,738) buy order events in large (small) stocks during the sample period. The corresponding numbers for sell order events are 187,363 and 47,698. Figure 1 illustrates the intraday seasonality of order event and trade counts. We plot the number of limit order submissions (ENTER), cancellations (DELET), revisions (AMEND) and trades (TRADE) within each 15-minutes interval during the trading hours for large and small stocks (Figures 1(a) and 1(b)). We also plot the intraday distribution of the order events and trades within their own group (Figure 1(c)) where each data point is a percentage and these percentages sum to 1 over a trading day. One objective in examining the intraday pattern is to identify any differential behaviour in order revisions and cancellations from order submissions.

The intraday frequencies of all order events and trades exhibit strong U-shaped patterns. The U-shaped patterns of order cancellations and order revisions are broadly consistent with Atiken, Brown and Walter (1995), who present an intraday U-shaped pattern in the number of limit order cancellations and one-tick price revisions based on two years order flow data for 267 stocks listed on the Australian Stock Exchange.

Foucault (1999) demonstrates theoretically that non-execution risk increases when the end of trading day approaches. The general increase in the proportion of all order events towards the end of day across stock groups (see Figure 1c) is consistent with this theory however this is not necessarily due to increased non-execution risk. A more specific support for Foucault (1999) is the disproportionate (relative to order submissions) increase in order revisions and cancellations at the last interval because we expect these activities to be responses to increased non-execution risk. In addition, the fact that the most pronounced spike at the last interval being order revisions further strengthens the case of non-execution risk driving the end of day activities. Order revisions are commitments to trade but cancellations are not.

Recent empirical work by Ellul et al's (2003) also show that order cancellation activity increases towards the end of the trading hours. Biais et al (1995) documented evidence that cancellation activity tends to be concentrated in the afternoon, while new order submission activity tends to be concentrated in the morning. Coppejans and Domowitz (2002) find that cancellation rate increases towards the last hour of trading and they also find that there is an asymmetry in the time-varying pattern in the rate of successive buy order cancellations and sell order cancellations but they do not offer an economic explanation for this result. There are, however, no published studies that distinguish and contrast order revisions and cancellations.

The order event frequency of our small stock sample is about one-fifth of that of the large stocks. The only observable difference in intraday limit order activity patterns of the large and small stocks is the degree of curvature of the U-shaped. There is a more notable drop in the percentage of order events from 12:30 to 14:00 (Figure 1(c)) in the large stock sample than in the small stock sample. This pattern may be attributable to the closure of the Exchange Traded Option market during this time period[4].

[INSERT FIGURE 1 HERE]

3.2 Order events and limit order aggressiveness

We define six levels of limit order aggressiveness based on the information at the time of an order event. They are:

1. *Aggressive* refers to a submitted or revised order resulting in a limit buy (sell) order with the buy (sell) price and quantity that exceeds those at the prevailing best ask (bid) quote. The whole or part of this order would be immediately executed upon submission during trading hours.

[4] While large stocks tend to have a liquid options market, which is an important source of information for price discovery. The absence of the derivative market during the lunch hour reduce information flow, hence fewer order submissions, cancellations and revisions.

2. *Large Market* refers to a submitted or revised order resulting in a limit buy (sell) order with the buy (sell) price at the prevailing ask (bid) price and quantity that exceeds the prevailing ask (bid) quote. The whole or part of this order would be immediately executed upon submission during trading hours.

3. *Small Market* refers to a submitted or revised order resulting in a limit buy (sell) order with the buy (sell) price at the prevailing ask (bid) price and quantity that is equal to or less than the prevailing ask (bid) quote. This order would be fully executed upon submission during trading hours.

4. *Price Improve* refers to a submitted or revised order resulting in a limit order with a price inside the best bid and ask price. This order would not be immediately executed.

5. *At Quote* refers to a submitted or revised order resulting in, or a cancelled order being, a limit buy (sell) order at a limit price that is equal to the best bid (ask) price. This order would not be immediately executed.

6. *Outside Quote* refers to a submitted or revised order resulting in, or a cancelled order being, a limit buy (sell) order at a limit price that is lower (higher) than the prevailing best bid (ask) price. This order would not be immediately executed.

Examination of the aggressiveness of order events allows us to make some inference about distribution of trader demand and supply of immediacy and traders' dynamic strategies to seek execution and avoid exposure to information risk. Table 3 Panel A presents the distribution of order events within an order aggressiveness category. These percentages sum to 1 down the column. The last column in the panel shows that 72.3-73.5 percent of buy order events across all order aggressiveness categories are order submissions. Order submissions account for 80.7-87.1 percent of market (column 1-3) orders and the remaining market orders are resulted from order revisions. A lesser majority (53.1-64.9 percent) of order events *At Quotes* or *Outside Quotes* are also order submissions with the remaining activities approximately equally shared by order revisions and cancellations. We note that order revisions consistently account for more (0.89-2.4 percent) of the market orders in small stocks. This subtle shift in distribution across stock group may be due to the lower liquidity and free trading option risk in small stocks which result in traders to prefer submit-revise limit orders to the alternative of submit-cancel-resubmit limit orders.

The statistics for the sell orders are largely the same as that of the buy orders hence we do not report them separately. However, there are two interesting observations about sell orders in small stocks. Order revisions account for a higher fraction of *Aggressive* and *Large Market* sell orders in small stocks, 22.5% and 22.2% respectively. There is also a lower percentage of sell order cancellation (18.2%) relative to the buy orders in small stocks. Again, lower liquidity encourages traders to submit, monitor and revise limit orders.

Table 3 Panel B shows the distribution of a particular type of order event across aggressiveness categories. Order submissions divides evenly between market orders (column 1-3) and limit orders (column 4-6). Market order usage in large stocks is 3.45% higher than that in small stocks, which is attributable to higher usage of *Large Market* orders and lower usage of *At Quote* limit orders in large stocks. Across all limit order submissions, approximately one half of them are *At Quote* limit orders, a third of them are *Outside Quote* limit orders and the remaining minority (about 13%) are *Price Improve* limit orders.

The majority (61%) of revised orders result in another limit order. We observe that 30.9% to 32.2% of limit order revisions are revised to match the prevailing quote and 37.9%-39% of limit order revisions resulted in market (type 1 to 3) orders. Less than 9% of orders are *Price Improve* orders. This revision pattern shows that instead of undercutting the prevailing quote to gain a better chance of execution, it is common for traders to revise order to seek immediate execution by crossing the bid-ask spread.

Order revisions resulting in limit orders outside the prevailing quote account for 23% and 20.2% of all order revisions in large and small stocks, respectively. Harris (1998) presents a dynamic order submission model and argues traders revise their orders outside the quote for two reasons. First, they have distant deadline to transact, they want more price improvement and they are prepared to utilize the option to revise. Second, when there is a high adverse execution risk traders maintain a high limit order spread, i.e. they place orders outside the prevailing best offer prices. Harris also postulates that high adverse execution risk caused by public information arrival can be reduced by monitoring the information flow intensely. Liu (2005) shows theoretically that when the labor cost of monitoring is too high, or when traders are unable to monitor due to exogenous reasons, they tend to revise limit order price to outside the best quote.

Limit order cancellations contribute 9.6-10.6% of all order events (Panel A column Total). Cancellation at quotes accounts for almost half of the total number across the limit order book. This cancellation distribution suggests that traders who cancel their orders are likely to be closely monitoring the market. The patterns of the sell-side order activity are the same as those of the buy-side hence we do not report them separately. However, we notice that buy cancellation occurs more frequently than sell cancellation for both large and small stocks, by 1%-2.6%. This subtle asymmetry may indicate more monitoring effort by buyers than that by sellers. Limit order buyers may be more reactive than seller to avoid being picked off when prices change against them. These statistics are available on request from the authors.

[INSERT TABLE 3 HERE]

Table 4 shows the distribution of revised and cancelled orders across the limit order book just prior to the act of revision and cancellation. A limit order at the best price step revised to a market order would be grouped into the 1st price step in Table 4 but *Small Market* in Table 3. A limit order at the 2nd price step cancelled would appear under the category of *Outside-Quote* in Table 3 and as a 2nd price step cancelled order in Table 4[5]. Statistics for the seven price steps are presented here, the first 6 best prices and the rest of the book. We observe that order revision and cancellation frequencies are highly positively related to their original order price priority. The first bid and ask price step accounts for 33.6% to 47.2% of revision activities across the entire limit order book. The corresponding numbers for order cancellation is 38% and 49%. This high concentration of order revision and cancellation activity at the top end of the limit order queue suggests that impatient limit order traders submit orders at the top of the queue and then revise their orders to reduce non-execution cost. They monitor the market closely.

[INSERT TABLE 4 HERE]

[5] While the reference price used to classify an order event change for an order revision after the act of revision, the reference price does not change for an order cancellation. For instance, we can describe an order being revised from $1.10 to $1.15. Table 3 uses the price $1.15 while Table 4 uses the price $1.10. However, we describe a cancelled order only by reference to one price, say $1.10.

3.3 Order size and limit order revision/cancellation activity

A trader who revises an order is likely to continue monitoring the market and monitoring is costly, therefore we expect the payoff to order revision to be proportional to order size. We expect larger orders to be revised more frequently. In contrast, a trader demonstrate no commitment to trade after canceling an order, therefore the prediction of a positive relationship between order size and order revision does not extend to order cancellations. We argue that if order cancellations are more likely in volatile market condition and traders submit small orders to test the market liquidity and sometimes cancel them under such market condition, we should observe higher frequency of order cancellation in small orders than in large orders.

Table 5 examines the relationship between order revision and cancellation frequency and original order size. We assign revised and cancelled orders into size quartiles where the cutoffs are determined by ranking the dollar value of submitted orders on a stock-by-stock basis. A revise or cancelled order with an order size within the top (bottom) quartile is designated large (small) order. A revise or cancelled order with an order size within the middle two quartiles is designated a medium order. The first two columns in Table 5 present the distribution of order revisions and cancellations across size quartiles. These percentages sum to 100. If revising and canceling orders are size independent decisions, we should observe 25% of activities in small and large orders and 50% in medium orders. However, there are more revisions in large orders and more cancellations in small orders relative to the null. This result supports our hypotheses based on monitoring costs, volatility and liquidity arguments.

We also measure the percentage of orders of a given size group being cancelled or revised. Column 3 and 4 in Table 5 contains these statistics. An order may experience revision, cancellation, and execution during its life in the limit order book, therefore these percentages do not sum to 1 and they are not additive. These numbers show a consistent picture, order revision is more likely in larger orders and order cancellations are more likely in smaller orders. The relatively low frequency of cancellations in the medium size orders in large stocks reflects the liquidity and relative ease to fill a medium order in large stocks.

[INSERT TABLE 5 HERE]

3.4 Revisions in price priority and order size

Table 6 describes what type of order characteristics, i.e. price priority and order size, traders revise. The majority (68.8% to 72.3%) of revisions involve increasing price priority alone. This suggests that the most common motive to revise orders is to reduce non-execution risk. The frequency of order size increases is higher than the frequency of order size decreases across all price priority change categories. This observation suggests that traders avoid revealing the full size of their orders by first placing a fraction of their orders and then sequentially increase order size possibly after they are partially executed. Although this approach may reduce the chance of execution since the subsequent submissions lose the time priority, they avoid the risk of having their entire order exposed and picked of by the more informed traders.

[INSERT TABLE 6 HERE]

4 Can limit order revisions and cancellations reduce non-execution cost and free trading option cost?

The purpose of order revisions and cancellation is to reduce non-execution and free trading option costs in using limit orders. We assess the performance of order revisions and cancellations by considering the change in market conditions 15 minutes after the act.

We define the non-execution cost reduction for a limit buy revision or cancellation as

$$\boldsymbol{NE_{LB}} = A_{\tau+15} - A_{\tau}, \tag{5}$$

where $A_{\tau+15}$ is the best ask price 15 minutes after the order is revised/cancelled at time τ. For all revisions and cancellations occurred in the interval between 15:45 and 16:00, $A_{\tau+h}$ is the closing best ask price, which is the ask price after the closing auction. If the order size of the revised or cancelled limit buy exceeds the book depth at the best ask price, we compute the depth-weighted average price, i.e. the average price paid if the order is replaced with an *Aggressive* buy order. For a limit sell order revision or cancellation, the non-execution cost reduction is:

$$\boldsymbol{NE_{LS}} = B_{\tau} - B_{\tau+15}, \tag{6}$$

where $B_{\tau+15}$ is the best bid price 15 minutes after the order is revised or cancelled at time τ. $B_{\tau+15}$ is the closing best bid if revision or cancellation occurs in the last interval of the trading day. Again, if the order size of the limit sell exceeds the book depth at the best bid price, we compute the depth-weighted average price, i.e. the average price received if the order is replaced with an *Aggressive* sell order.

This measure of non-execution cost reduction compares the cost of using a market order to fill the limit order at the time of revision or cancellation to the cost that would have prevailed 15-minutes after the time of revision or cancellation. The higher the subsequent cost, the more the benefit in revising. It is similar to the metric used in Harris and Hasbrouck (1996). Note that non-execution cost is relevant for price priority increasing order revisions and order cancellations.

Free trading option cost motivates price priority decreasing order revisions and order cancellations. For each limit buy order revision and cancellation, we compute the free trading option cost reduction based on the intrinsic value of the option. For limit buy order revision or cancellation, the post-revision/cancellation free option cost reduction is:

$$\boldsymbol{FTO_{LB}} = \max[0, b_\tau - A_{\tau+h}], \quad (7)$$

where b_τ is the limit buy price revised/cancelled at time τ. For limit sell order cancellation or revision, the post-revision/cancellation free option cost reduction is:

$$\boldsymbol{FTO_{LS}} = \max[0, B_{\tau+h} - a_\tau], \quad (8)$$

where a_τ is the limit sell price revised or cancelled at at time τ. Note that this cost measure is reasonable as it has a value of zero unless the opposing best quote surpasses the limit price. In essence, this metric compares the cost of using a market order 15 minutes later to fill the order to the cost of transacting at the limit order price from which the order is revised or cancelled. The presumption is that had the revision or cancellation did not take place the limit order would have been executed.

We report the average values of non-execution cost reductions and free trading option cost reduction in Table 7. In line with our expectation, the non-execution cost reduction is positive (and statistically significant different from zero) for priority increase order revisions. On average, buyers and sellers would have realized, respectively, 1.41 and 0.98 cent[6]

[6] Minimum tick size on the ASX is 1 cent.

improvement of execution price by revising to market orders at the time of revision rather than doing so 15 minutes later. Traders who decrease the price priority of their trades also demonstrate good judgement. Our measure indicates that buyers and sellers would have realized, respectively, 0.99 and 1.35 cent reduction in free trading option cost.

Our non-execution cost reduction measure and the free trading option cost savings for cancelled orders are positive for both buy and sell limit orders. Had these cancelled orders been resubmitted 15 minutes after cancellation as market orders, they would have benefited from an average price improvement of 0.41 cent. Had these cancelled orders been resubmitted as market orders immediately after cancellation, they would have benefited from an average price improvement of 1.13-2.43 cent.

[INSERT TABLE 7 HERE]

5. What affects the level of limit order cancellation and limit order revision activity?

5.1 Hypotheses

The analysis above explores the distribution of limit order revision and cancellation activity and their relationship to non-execution and free trading option cost reduction. This section review the literature to develop some proxies for non-execution risk and free trading option risk to explain the intraday variation in order revision and cancellation activities.

The state of limit order book provides some cues of non-execution risk. Parlour (1998) find in her limit order book model that when the opposite side of the book is thin, execution probability of limit orders is low. Investors will try to reduce non-execution risk by first canceling their orders and then resubmitting at more aggressive prices. When the same side of the book is thick, traders cancel their limit orders because their orders receive lower execution probability. Their orders are crowded out by competing limit orders on the same side of the book. Biais et al (1995) found evidence that cancellations on the bid (ask) side are more frequent after large sales (purchases)[7] and after market buy (sell) orders arrive. Ranaldo

[7] On the Paris Bourse, traders often use market orders to check if there are hidden orders at the best quotes. Traders use hidden (limit) orders when they specify a partial display of their orders to other traders. While only a fraction of the order quantity is publicly visible on the screen, the remaining fraction becomes visible when the

(2004) also presents empirical evidence that supports Parlour (1998). He examines order and transaction data from the Swiss Stock Exchange and finds that that traders tend to cancel their orders when the market depth on its own (opposite) side increases (decreases). Liu (2005) used the number of order cancellations and revisions as a proxy for cancellation and revision activity and Coppejans and Domowitz (2002) used an Autogressive Conditional Duration (ACD) model to analyze stock index futures data on the London Securities and Derivatives Exchange. Both studies find results supporting Parlour (1998).

Ranaldo (2004) finds and argues that when the bid-ask spread is wide, passive orders are canceled and resubmitted inside the spread to increase the chance of execution. Ellul et al (2003) studies 148 of the most actively traded NYSE stocks and find evidence that order cancellation activity is intense when the bid-ask spread is wide. Coppejans and Domowitz (2002) also find similar results. Liu (2005) developed a game model that offers a different perspective of the empirical relationship between spread and order cancellations. While Ranaldo, Ellul et al, and Coppejans and Domowitz assume free trading option risk is irrelevant in cancellation activity, Liu emphasizes the relevance of free trading option risk to cancellation and revision decisions. He predicts that, in the presence of an uncertain arrival date of public information which might cause the option value to be in-the-money, limit order traders post a higher (lower) ask (bid) if the cost of monitoring exceeds the net gain from limit order trading. That is, if monitoring cost is sufficiently low, traders cancel and revise their orders more frequently. They receive a greater scope to narrow the spread due to competition in supplying liquidity. As a result, bid-ask spread should be negatively related to the rate of limit order cancellations and revisions. Liu tested his model and he found weak evidence supporting this claim. Non-execution risk seems to be the dominating factor in the order cancellation and revision decisions.

Price volatility is positively related to free trading option risk and non-execution risk. The first relation is straightforward. High price volatility increases the execution probability of limit orders and thus associates with higher free option risk (Copeland and Galai, 1983, Stoll, 1992, Harris, 1998, Foucault, 1999 and Wald and Horrigan, 2001). While higher fill rate implies lower non-execution risk when trading a volatile stock (Cho and Nelling, 2000,

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order is filled. If there is no hidden order subsequent to the trader’s submission of a market order, the unfilled portion will be converted to a limit order at that price level. To avoid free trading option risk, traders tend to cancel the converted order.

Ahn et al, 2001, Hasbrouck and Saar, 2002, Lo et al, 2002, Bae et al, 2003,[8] Ellul et al, 2003), high volatility could also increase the opportunity cost of unfilled orders (Wald and Horrigan, 2001). Smith (2000) finds that the impact of volatility on the order choice decision is mixed because of the countervailing effects on execution probability and the opportunity cost of non-execution.

If the trader expects the stock to trend downward, then the limit buy price should be lower. Harris's (1998) numerical exercise of dynamic order submission showed that an optimal strategy under such condition is to revise the limit buy orders away from the original position when the mid-quote return is negative.

Finally, free trading option risk and non-execution risk are higher with the arrival of new public information. When a piece of bad (good) news is released by the firm, outstanding limit buy (sell) orders become in-the-money if the news drive the stock value below (above) the limit price (Stoll, 1992, 2003). Using large option trade as proxy for a public information event, Berkman finds that limit orders for options on the European Options Exchange (EOE) tend to be picked off after adverse changes in the underlying stock price surrounding a large option trade.[9] Instead of canceling or revising limit orders of options when there is an adverse change in the underlying stock price, limit orders are picked off as investors tend to buy calls and sell puts after a rise in the stock price, and tend to sell calls and buy puts after a fall in the stock price. Berkman and Jarnecic (1999) and Hollifield et al (2004) use market index as proxy for a public information event and they show that that FTO risk arises when the market index moves against the limit order. Liu and Sawyer (2003) examine FTO costs conditional on 163 earnings announcements with ex post stock prices that are adverse to various hypothetical limit order strategies. They find that FTO cost increases when the adversity of news increases because it is positively related to the intrinsic value of the FTO. Meanwhile, outstanding limit sell (buy) orders suffer from a lower chance of execution as the news drives the stock price away from the limit price. To reduce both risks,

[8] Note that Bae et al (2003) separated price volatility into transitory volatility and informational volatility. They showed that a rise in transitory volatility encourages traders to submit limit orders (lower non-execution risk), while informational volatility appears to have no effect on the order placement decision.
[9] In the EOE, an instruction to cancel a public limit order for options requires several minutes to execute. This inability to cancel promptly increases the FTO value.

traders can cancel and revise their limit orders before the information is fully impounded into the price.[10]

In summary, we have two hypotheses that link revision/cancellation activity with limit order submission risks:

H1 (free trading option risk):

H1.1 *Buy (sell) order cancellation activity increases (i) after a large sale (purchase), (ii) when midquote price is exhibiting a downward (upward) trend, (iii) when the stock price volatility is high, (iv) when the spread is tight, and (v) after a bad (good) news announcement.*

H1.2 *Buy (sell) priority decrease revision activity increases (i) after a large sale (purchase), (ii) when midquote price is exhibiting a downward (upward) trend, (iii) when the stock price volatility is high, (iv) when the spread is tight, (v) when the buy (sell) side of the book is thin and when the sell (buy) side of the book is thick, and (vi) after a bad (good) news announcement.*

H2 (non-execution risk):

H2.1 *Buy (sell) order cancellation activity increases (i) after a large purchase (sale), (ii) when midquote price is exhibiting a upward (downward) trend; (iii) when the stock price volatility is high, (iv) when the spread is wide, (v) when the opposite (same) side of the book is thin (thick), and (vi) after a good (bad) news announcement.*

H2.2 *Buy (sell) priority increase revision activity increases (i) after a large purchase (sale), (ii) when midquote price is exhibiting a upward (downward) trend; (iii) when the stock price volatility is high, (iv) when the spread is wide, (v) when the buy (sell) side of the book is thick and when the sell (buy) side of the book is thin, and (vi) after a good (bad) news announcement.*

5.2 Variable construction

[10] In most markets, the ability to cancel or revise is greatly enhanced when trading halt is placed by the Exchange following the news release. However, trading halts cannot perfectly protect limit order submitters because there are other relevant news announcements that are not made by the company. For example, announcements pertaining to competing firms could have a substantial impact on share values if investors arbitrage between substitute stocks. It is impossible for the stock exchange to identify and filter information from every source and halt trading before picking off activities intensify. It is also impossible for the exchange to forecast the potential price impact of each piece of information because investors may under-react or over-react depending on many other factors.

In order to test hypotheses H1 and H2, we use the number of price priority increase and decrease order revisions and order cancellations as a proxy for the level of activity. Order count is a better measure of the number of traders who are monitoring the information flow than a volume based measure. When a large volume is canceled or revised, the latter measure cannot distinguish the case of a few large orders being revised or canceled from the case of a large number of small orders being revised or canceled. We also construct the following variables to test the hypotheses:

1. *Number of large sales* (***LARGESALE***$_{t-1}$) *and purchases* (***LARGEBUY***$_{t-1}$) *in the previous interval*. For each interval, we count the number of market orders or aggressive limit orders with order size that belongs to the largest quartile trade size in that interval. We use order counts instead of trade counts because submission of an aggressive limit order can fill a number of contra-side limit orders.

2. *Abnormal changes in buy-side quote depth* (***BIDDEPTHΔ***$_{t-1}$) *and sell-side quote depth* (***ASKDEPTHΔ***$_{t-1}$) *in the previous interval*. To derive a measure of quote depth change, first, we compute the buy/sell-side quote depth (quantity outstanding) for each 15-minute interval based on the average of 15 minute-by-minute snapshot of the limit order book. Then, for each intraday interval (1 to 24), we compute the normal level of buy/sell-side quote depth based on an average value across 23 trading days due to the intraday pattern of the quote depth. The abnormal change is based on the difference of the natural logarithm of quote depth and the natural logarithm of the normal quote depth level.

3. *Average bid-ask spread in the previous interval* (***SPREAD***$_{t-1}$). The bid-ask spread value is generated based on the average of the based on a 15 minute-by-minute snapshot in the 15-minutes interval.

4. *Price volatility in the previous interval* (***VOLATILITY***$_{t-1}$). Stock price volatility is computed based on the standard deviation of the 1-minute snapshot of the midquote price in the 15-minutes interval.

5. *Midquote return in the previous interval* (***RETURN*** $_{t-1}$). We compute the midquote return based on the logarithm of the midquote change recorded at the beginning and at the end of the interval.

6. *Good news and bad news announcement dummies* (***GOODNEWS*** $_t$; ***BADNEWS*** $_t$).

GOODNEWS $_t$ = 1 if sign($RETURN_t + RETURN_{t+1}$) × NEWS $_t$ > 0, and 0 otherwise;

BADNEWS $_t$ = 1 if sign($RETURN_t + RETURN_{t+1}$) × NEWS $_t$ < 0, and 0 otherwise,

where NEWS $_t$ is a dummy variable that takes the value of 1 if there is any market sensitive announcement made by the company during the interval. The exact timing of the announcement is recorded in the Signal G Database, which is provided by SIRCA.

7. *Time-of-the-day dummies*. We control for the U-shaped time-of-the-day pattern in order cancellation and revisions by including 23 dummy variables. The use of the dummy variable captures the seasonality pattern that appears in both dependent variables and independent variables.

Table 8 summarizes the prediction of the coefficients of the multivariate model of different limit order revision and cancellation variables. We report the summary statistics and correlation coefficient of the variables in Table 9.

[INSERT TABLE 8 AND 9 HERE]

5.2 Econometric Issues

5.2.1 Negative Binomial Count Model

We test hypotheses H1 and H2 using the number of cancellations and revisions in each 15-minute interval as proxy for their respective activity. There are 552 intervals (24 intervals per day × 23 trading days) for each stock and we have two sets of panel data consisting 20 stocks each (large and small stocks). The standard way to estimating event counts is the Poisson count regression technique.[11] Let y_{it} refers to the number of event counts in the time interval $[t-1, t]$ for stock i and it follows a Poisson distribution with parameter λ_{it}. Assuming that the event counts are i.i.d. across time intervals, the density function of the conditional expected number of event counts is given by

$$f(y_{it} \mid \mathbf{x}_{it}) = \frac{\exp(-\lambda_{it})(\lambda_{it})^{y_{it}}}{y_{it}!},\ t = 1, 2, \ldots, T,\ i = 1, 2, \ldots, M,$$

where $\mathbf{x}_{it}$ is the $(N \times 1)$ covariates and parameter $\boldsymbol{\beta}'$ is a $1 \times K$ vector. The expected number of count events is

$$\mathrm{E}[y_{it} \mid \mathbf{x}_{it}] = \lambda_t = \exp(\boldsymbol{\beta}'\mathbf{x}_{it}).$$

Due to the property of the Poisson, the conditional variance equals its conditional mean:

$$var[y_{it} \mid \mathbf{x}_{it}] = \exp(\boldsymbol{\beta}'\mathbf{x}_{it}) = \lambda_{it}.$$

This gives rise to the equidisperson property, which is very restrictive because events count under investigation may have a high proportion of zeros. In our data, the length of the time interval is relatively short (15 minutes) and we expect that there is a large number of intervals consist of no cancellation or revision, particularly for smaller stocks. In such case equidisperson property may be violated, as the conditional variance would most likely exceed the conditional mean. To accommodate this overdispersion in the data, the Poisson model can be extended to the negative binomial (NB) model. Suppose, the probability function for y_{it} is

$$f(y_{it} \mid \mathbf{x}_{it}) = \frac{\exp(-\theta_{it})(\theta_{it})^{y_{it}}}{y_{it}!},\ t = 1, 2, \ldots, T,\ i = 1, 2, \ldots, M,$$

where $\theta_{it} = \exp(\boldsymbol{\beta}'\mathbf{x}_{it} + \varepsilon_{it}) = \exp(\boldsymbol{\beta}'\mathbf{x}_{it})\exp(\varepsilon_{it}) = \lambda_{it}v_{it}$. Unlike the standard Poisson model, θ_t is not a constant because it includes a multiplicative random term ε_{it} that captures (possibly unobserved) omitted exogenous variables. To obtain an explicit probability function v_{it} is assumed to be i.i.d. and $v_{it} \sim Gamma(\alpha^{-1}, \alpha^{-1})$. The marginal distribution of y_{it} is obtained by integrating v_{it} and the probability function is given by:

$$f(y_{it} \mid \mathbf{x}_{it}, \alpha) = \frac{\Gamma(y_{it} + \alpha^{-1})}{\Gamma(y_{it} + 1)\Gamma(\alpha^{-1})} \left(\frac{\alpha^{-1}}{\lambda_{it} + \alpha^{-1}} \right)^{\alpha^{-1}} \left(\frac{\lambda_{it}}{\lambda_{it} + \alpha^{-1}} \right)^{y_{it}},\ t = 1, 2, \ldots, T,\ i = 1, 2, \ldots, M,$$

[11] Cameron and Trivedi (1998) and Winkelmann (1997) provide an excellent survey of the literature on count regression models.

for $\alpha > 0$. This Poisson-Gamma mixture is known as the negative binomial distribution (Greenwood and Yule, 1920).[12] The conditional mean and the conditional variance of y_t are:

$$E[y_{it} \mid \mathbf{x}_{it}, \alpha] = \exp(\boldsymbol{\beta}'\mathbf{x}_{it}) = \lambda_{it},$$

$$var[y_{it} \mid \mathbf{x}_{it}, \alpha] = \exp(\boldsymbol{\beta}'\mathbf{x}_{it})(1 + \alpha \exp(\boldsymbol{\beta}'\mathbf{x}_{it})) = \lambda_{it}(1 + \alpha\lambda_{it}).$$

The additional parameter α yields the dispersion factor $(1 + \alpha\lambda_{it})$, which captures the overdispersion in the data. The first order conditions of the log-likelihood function yield the maximum likelihood estimators. If the density is correctly specified, these estimators are consistent for $\boldsymbol{\beta}$ and α under the usual regularity conditions. The asymptotic variance-covariance matrix of the estimators is derived based on the inverse of the negative of the (expected) Hessian matrix. Even if the density function is incorrectly specified, we can still obtain the (pseudo) ML estimators, which are consistent so long as the mean function is correctly specified and the model belongs to the linear exponential family (see Gourieroux, Monfort and Trognon, 1984). Since the negative binomial model belongs to the linear exponential family, we can obtain the robust heteroskedastic consistent variance-covariance matrix of estimators.

5.2.2 Fractional logistic model

Due to heterogeneity across stocks, we also consider scaling the count events by the number of order appeared on the same side of the book. The denominator of the scaled value is computed based on first, averaging 15 minute-by-minute snapshots of the number of out-standing limit order within the interval and second, averaging the value across 23 trading days. This method helps to alleviate any heterogeneity across stocks and intraday pattern.

Since the scaled value is bounded by construction between 0 and 1, ordinary least squares is likely to produce highly biased estimates when there are many observations lying at the boundaries or near them (in our case, we have a large number of intervals containing zero cancellation and revision). One alternative is to employ the log-odd transformation on the scaled values and modeled it as a linear function of the regressors. This may not be appropriate in our case because by construction, log-odds ratio is suitable only when the dependent variable is strictly within the (0,1) bounds. A better alternative is the fractional

[12] For a complete derivation, see Cameron and Trivedi (1998) and Johnson and Kotz (1969).

estimation method introduced by Papke and Wooldbridge's (1996). The method combines the generalized linear models (GLM) literature from statistics and the quasi-likelihood literature from econometrics to obtain robust method for estimation and inference with fractional variables. Papke and Wooldbridge proposed a non-linear function for estimating the expected value of fractional variables z_{it}, conditional on a vector of covariates $\mathbf{x}_{it}$:

$$E(z_{it} \mid \mathbf{x}_{it}) = G(\boldsymbol{\beta}'\mathbf{x}_{it}).$$

In here, $G(\cdot)$, the *link* function, is chosen to be a cumulative distribution function such that the predicted values of z_{it} lie in the interval (0, 1), thus $0 \leq G(\cdot) \leq 1$. In the GLM literature, $G(\cdot)$ is chosen to be a logistic function:

$$E(z_{it} \mid \mathbf{x}_{it}) = G(\boldsymbol{\beta}'\mathbf{x}_{it}) \equiv \frac{\exp(\boldsymbol{\beta}'\mathbf{x}_{it})}{1+\exp(\boldsymbol{\beta}'\mathbf{x}_{it})}. \quad (1)$$

Note that equation (1) is well defined even if z_{it} takes on 0 or 1 with positive probability. The quasi-maximum likelihood estimator (QMLE) of $\boldsymbol{\beta}$ can be obtained by maximizing the following Bernoulli log-likelihood function:

$$\max_{\hat{\boldsymbol{\beta}}} \sum_{i=1}^{M}\sum_{t=1}^{T} l_{it}(\hat{\boldsymbol{\beta}}) \equiv \sum_{i=1}^{M}\sum_{t=1}^{T} z_{it} \ln(G(\hat{\boldsymbol{\beta}}'\mathbf{x}_{it})) + (1-z_{it})\ln(G(\hat{\boldsymbol{\beta}}'\mathbf{x}_{it})).$$

We obtain the asymptotically robust variance based on Papke and Wooldbridge (1996, pp. 622-623). Let $g(z) \equiv \mathrm{d}G(z)/\mathrm{d}z$, $\hat{G}_{it} \equiv G(\hat{\boldsymbol{\beta}}'\mathbf{x}_{it}) \equiv \hat{y}_{it}$ and $\hat{g}_{it} \equiv g(\hat{\boldsymbol{\beta}}'\mathbf{x}_{it})$. Then the estimated information matrix is:

$$\hat{\mathbf{A}} \equiv \sum_{i=1}^{M}\sum_{t=1}^{T} \frac{\hat{g}_{it}\mathbf{x}_{it}'\mathbf{x}_{it}}{[\hat{G}_{it}(1-\hat{G}_{it})]}.$$

To obtain a valid estimate of the asymptotic variable of $\hat{\boldsymbol{\beta}}$, we need the outer product of the score. Let $\hat{u}_{it} \equiv y_{it} - G(\hat{\boldsymbol{\beta}}'\mathbf{x}_{it})$ be the residuals and define:

$$\hat{\mathbf{B}} \equiv \sum_{i=1}^{M}\sum_{t=1}^{T} \frac{\hat{u}_{it}^2\hat{g}_{it}^2\mathbf{x}_{it}'\mathbf{x}_{it}}{[\hat{G}_{it}(1-\hat{G}_{it})]^2},$$

The estimated variance of $\hat{\boldsymbol{\beta}}$ is obtained based on the following sandwich form:

$$\hat{\mathbf{A}}^{-1}\hat{\mathbf{B}}\hat{\mathbf{A}}^{-1} \quad (2)$$

The standard errors of $\hat{\boldsymbol{\beta}}$ can be obtained by taking the square root of the diagonal elements of equation (2).

5.3 Estimation Results

5.3.1 Determinants of limit order cancellation and revision activities

For all market variables (*LARGESALE*, *LARGEBUY*, *BIDDEPTH*Δ, *ASKDEPTH*Δ, *SPREAD*, *VOLATILITY*, *RETURN*), we use lagged values in the regression to avoid the endogeneity issue. Our sample comprises of 23 15-minute intervals per day, starting from 10:15-10:30 to 3:45-4:00. We use the interval 10:00-10:15 only for the purpose of obtaining the lagged value. Count regression results are reported in Table 10. For convenience, estimated coefficients of intraday dummies are suppressed. Wald test statistics (obtained by dividing the estimated α by its standard error) of the negative binomial model (second last row of each panel) shows that there is a strong evidence of overdispersion in both cancellation count and revision count data, as they are all significant at the 1% level.[13] Pearson R^2 for each model is reported at the last row.[14] The negative binomial model is fitting both cancellation count and priority-increased revision count relatively well, particularly for large stocks.

Estimation results contained in Table 10 reveal strong association between revision/cancellation activities and limit order submission risks. Most coefficients of $BIDDEPTH\Delta_{t-1}$, $ASKDEPTH\Delta_{t-1}$, $LARGEBUY_{t-1}$ and $LARGESELL_{t-1}$, are significant at the 1% level, indicating that when the number of large sell (buy) orders in the previous interval increases, free option risk for limit buy (sell) increases, and thus buy (sell) cancellation, LBC_t, and limit buy (sell) priority-decreased revision activities, $LBRD_t$, increase. When the number of large sell (buy) orders in the previous interval increases, non-execution risk for limit sell (buy) increases, and thus sell (buy) cancellation, LSC_t, and sell (buy) priority-increased revision activities increase, $LSRU_t$. Results are similar for small stocks.

The sign of all lagged abnormal change of book depth ($BIDDEPTH\Delta_{t-1}$ and $ASKDEPTH\Delta_{t-1}$) coefficients are consistent with our prediction. However we only found strong statistical support of the relation between cancellation and non-execution risk; if the book is thick, existing orders are more likely being crowded out by orders with better price as

[13] LM test and LR tests of overdispersion are not reported, as they should produce similar results.
[14] Pearson R^2 was developed by Cameron and Windmeijer (1996) and it is computed based on Pearson residuals.

they receive a lower chance of execution (Parlour, 1998). For the order revision, there is strong statistical evidence that when there is a strong buying (selling) interest, indicated by an increase in bid (ask) depth, the level of limit sell priority-increased (-decreased) revision activity decreases (increases). For other types of revision, evidence is weak. Results on fractional logistic model are even weaker, though the sign of all coefficients coincide with our prediction. This might due to the fact that when the book depth is positively serially correlated, the impact of $BIDDEPTH\Delta_{t-1}$ and $ASKDEPTH\Delta_{t-1}$ on the scaled number of revision/cancellation counts are washed out as the all dependent variables are scaled by the contemporaneous same-side book depth.

The lagged spread coefficient is negative for all regressions and most of them are statistically significant at the 5% level. This result contradicts to the finding of the existing literature that generally assumes free option risk is irrelevant. Although the result in Table 10 supports the relevance of free trading option risk, there is no clear pattern when the scaled value of revision/cancellation activity is used. Arguably, the result in Table 10 is driven by the negative relation between order activities and spread when larger stocks have higher liquidity, greater order activities and narrower spread. After controlling for the heterogeneity across stocks by using the scaled count (Table 11), there is no systematic pattern on the *SPREAD* coefficients due to countervailing sign predicted by our hypotheses on free trading option risk and non-execution risk.

Lagged intra-interval price volatility level is positively and strongly related to all cancellation and revision counts. There are two inferences we can draw from this. First, traders fear being picked off when they observe a large price swing. They either withdraw their orders or relocate their orders away from the market price. Second, high price volatility increases the opportunity cost of unfilled orders and therefore the level of priority-increased revision activity increases. Even though in general high price volatility increases the fill rate, it appears that when traders observe a high level of price volatility, it raises the uncertainty of the direction of price change.

We have confounding results for lagged price trend (intra-interval stock return). This is not surprising for cancellation activity because of the countervailing relation with free option risk and non-execution risk. But based on the coefficient estimates, it appears that price trend and non-execution risk is more strongly related, particularly for large stocks where five of the six coefficients are of the predicted sign. The relation is less clear for small stocks where only three of the six coefficients are of the predicted sign, perhaps due to illiquidity. Regression results on small stocks improve slightly when the fractional logistic model is used.

[INSERT TABLE 10 HERE]

[INSERT TABLE 11 HERE]

As an robustness test, we replace market variables with news dummy variables as proxy for limit order submission risks and we find evidence that is broadly consistent with the prediction; when bad (good) news arrives buyers (sellers) revise limit order price to reduce their price priority or withdraw their orders from the book, and sellers (buyers) revise limit order price to increase price priority. For large stocks, we find evidence in support of the free option risk argument as the coefficients of bad (good) news announcement dummy are positively and statistically significant for priority-decreased buy (sell) revision and buy cancellation count regression. We find strong empirical support of the non-execution risk argument as the coefficients of good (bad) news announcement dummy for priority-increased buy (sell) revision and buy (sell) cancellation count regression are positive and statistically significant. For small stocks, we find evidence in support of the positive relation between non-execution risk and priority-increased revision/cancellation activity but evidence on free trading option risk is weak as the coefficients of $BADNEWS_t$ on $LBRD_t$ and LBC_t, and $GOODNEWS_t$ on LSC_t are positive but not statistically significant. There are two reasons for this result. First, small stocks release less public information than large stocks and they receive little financial press coverage. Hence limit order traders of small stocks face a lower risk of being picked off as most newswatchers choose to monitor and trade large stocks. Second, small stocks have a lower level of liquidity and hence limit order traders' primary concern is to position their orders so as to gain a better chance of execution.[15]

[INSERT TABLE 12 HERE]

[15] We also check if market sensitive news announcement made by other firms within the same industry affect cancellation and revision activity. We do not find any evidence supporting this association (not reported).

In summary, we find strong empirical support on the relation between order revision/cancellation activity and limit order submission risk. Results are similar when the count events are scaled the count events by the number of order appeared on the same side of the book to account for the heterogeneity across stocks.

Some might argue that the negative binomial model may be inappropriate if the count data exhibit serial correlation and this could be true for microstructure data. We check the serial correlation of the cancellation and revision count. Table 13 reports the correlation coefficient with and without the covariates. Note that the correlation coefficients 'without the covariates' are derived based on Pearson residuals:

$$z_{i,t} = \frac{y_{i,t} - \hat{\lambda}_{i,t}}{\sqrt{\hat{\omega}_{i,t}}},$$

which are obtained after deseasonalizing the event count data using 23 intraday dummies on negative binomial count model. $\hat{\omega}_{i,t}$ is the estimated variance. The estimated correlation $\hat{\rho}_{i,k}$ against *k* lag is given by:

$$\hat{\rho}_{i,k} = \frac{\sum_{t=k+1}^{T} z_{i,t} z_{i,t-k}}{\sum_{t=1}^{T} z_{i,t}^2}.$$

We report the median values of $\hat{\rho}_{i,1}$ and $\hat{\rho}_{i,2}$, and the associated Ljung-Box Q-statistics for the sample of large stocks and small stocks in Table 13. For large stocks, the statistics indicate that order cancellations and priority-increased revision activities are clustered. These clustering patterns imply that less-informed traders who monitor the book follows what others do when informed traders cancel or reposition their orders. For small stocks, we do not find a similar pattern, possibly due to lack of order activity or lack of information arrival that reduces the incentive for traders to monitor the book. The strong positive serial correlation for large stocks rejects the theory that predicts a negative serial correlation on cancellation activity when the limit order book follows a long run cycle of exhausting and replenishing liquidity (Ellul et al, 2003). Their theory is irrelevant here because the length of the interval under investigation is considered short.

After we include all proxies of order submission risks, there is a notable reduction in both $\hat{\rho}_{i,1}$ and $\hat{\rho}_{i,2}$, particularly order cancellation or large stocks. However, most of them remain statistically different from zero. While it is tempted to consider time series count model (such as Integer-valued ARMA models) developed recently, we choose not to use such model for two reasons. First, because of the contemporaneous relation between event counts and other independent variables, the explanatory power of those variables might be reduced and hence create difficulty in interpreting the result. Second, there is no added value for knowing the serial correlation of revision/cancellation activity from a decision-making point of view, as public traders cannot study the serial correlation other than observing the order flow or the snapshot of the limit order book. We suspect that the positive serial correlation is in part caused by the information assimilation process and they should be captured in the independent variables. We leave the investigation of this issue for future research.

[INSERT TABLE 13 HERE]

6. Conclusion

Limit order allow traders to gain better price but expose traders to non-execution and free trading option risks. Traders can reduce their exposure to these risks by monitoring news arrival and limit order book activity and revise or cancel their order accordingly. While the limit order literature often ignore limit order revisions and cancellations for data or tractability reasons, these activities are common. Order revisions result in up to one fifth of market and limit order activities and order cancellation account another one fifth of limit order activities. More than 60% of all revisions and cancellations taking place within the two best prices in the limit order book, indicating that these traders monitor the market closely. We find that traders revising limit orders are patient, 61% of limit order revisions result in another limit order. We present evidence to support the conjecture that monitoring is costly: large orders are more likely to be revised than small orders. Our result also suggests that non-execution risk is the most common reason for order revision; about 70% of order revisions involve increasing price priority and no change in order size.

We provide evidence that order revisions and cancellations reduce non-execution cost and free trading option cost. These savings are substantial. They are up to 2.43 cent per share in non-execution cost and 1.35 cent per share in free trading option cost.

Our regression result shows that order revision and cancellation frequencies are closely related to non-execution and free option trading risks. While most of the regression coefficients have the predicted sign, two market variables stand out from the rest. The coefficients on large market orders and volatility are consistently statistically significant. These variables appear to be good proxies of non-execution risk and free option trading risk. When market variables are replaced with market sensitive news dummy variables as proxies of limit order submission risks, our regression results are largely consistent with the prediction; Bad (good) news is associated with buyers (sellers) cancelling or reducing the price priority of their orders, and sellers (buyers) increases the price priority of their orders.

While this study represents an effort to understand the dynamics in using limit orders, more works remains to be done. One interesting avenue of future research is to study dynamic limit order strategies by tracking and studying the revision history of limit orders.

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APPENDIX

Table 1: Percentage of orders cancelled and revised in extant empirical studies

This table reports the percentage of orders cancelled and revised reported in existing empirical studies. Forth (Fifth) column show the frequency of total, buy and sell limit order cancellation (revision) relative to the frequency of total, buy and sell order submission, respectively. Total, buy and sell order submission include the submission of limit orders, market orders and marketable limit order submission. In order to provide a cross-study comparison, adjustments are made to include market orders and marketable limit order submission. Order revisions include price and quantity revision. We exclude studies that do not specifically compute the number of order cancellations. For example, Griffith et al (2000, pp.82-83) and Lo et al (2002, pp. 38-39) only reported the percentage of limit orders unfilled, which can be attributed to expiration of the order, rather than deliberate cancellation.

Studies (Reference)	Order Flow Data		% orders canceled	% orders revised
Biais et al (1995) (Table 2)	40 Paris Bourse listed stocks that appeared in CAC 40 index for 19 trading days between 29 Oct and 26 Nov 1991.	Total	10.73	NA
		Buy	12.14	NA
		Sell	9.64	NA
Coppejans and Domowitz (2002) (Table 1)	Stock index futures contracts traded on the London Securities and Derivatives Exchange for the period between 31 Jul 1995 and 23 Feb 1996.	Total	61.21§	NA
		Buy	61.92	NA
		Sell	60.51	NA
Ranaldo (2004) (Table 2)	15 stocks listed on the Swiss Stock Exchange for the period between Mar and Apr 1997.	Total	6.79†	NA
		Buy	6.63	NA
		Sell	6.98	NA
Ellul et al (2005) (Table 2)	148 stocks traded on the NYSE with orders entered into the SuperDot system during the week of 30 Apr to 4 May 2001.	Total	32.54	NA
		Buy	-	NA
		Sell	-	NA
Liu (2005)	23 out of top 30 largest stocks listed on the Australian Stock Exchange in the year 1999.	Total	10.18	20.63
		Buy	9.74	19.47
		Sell	10.69	22.00
Yeo (2005) (Table 1 and 2)	148 stocks traded on the NYSE with orders entered into the SuperDot system on 11 Apr 2001.	Total	22.25	NA
		Buy	28.93§§	NA
		Sell	27.29§§	NA

§ The relative frequency value is based on the daily average number of limit order cancellations and the daily average number of order submissions. The number of order submission is based on sum of the number of limit order submissions and the number of trades.
§§ The value is based on the percentage of orders that are partially unfilled, as those orders are either expired or cancelled.
† The number of order submissions excludes orders submitted behind the spread.

Table 2: Sample stocks

This table lists the sample stocks. Largeitalization stocks are the top 20 common stocks traded on the ASX and smallitalization stocks are bottom 20 common stocks ranked out of top 130 stocks based on (All Ordinaries) index ranking at the end of the August 2000.

ASX code	Stock name
Panel A: Largeitalization stocks	
TLS	Telstra Corporation Limited
NCP	News Corporation Limited
NAB	National Australia Bank Limited
CBA	Commonwealth Bank Of Australia
BHP	BHP Billiton Limited
WBC	Westpac Banking Corporation
ANZ	Australia And New Zealand Banking Group Limited
AMP	AMP Limited
CWO	Cable & Wireless Optus Limited
RIO	Rio Tinto Limited
BIL	Brambles Industries Limited
LLC	Lend Lease Corporation Limited
PBL	Publishing & Broadcasting Limited
WPL	Woodside Petroleum Limited
CML	Coles Myer Limited
WOW	Woolworths Limited
WSF	Westfield Holdings Limited
WFT	Westfield Trust
SGB	St George Bank Limited
CSL	CSL Limited
Panel B: Smallitalization stocks	
APN	APN News & Media Limited
HLY	Hills Motorway Group
LHG	Lihir Gold Limited
RMD	Resmed Inc
SGW	Sons Of Gwalia Limited
QRL	QCT Resources Limited
PBB	Pacifica Group Limited
APF	Advance Property
SNX	Securenet Limited
OEC	Orbital Engine Corporation Limited
ECP	Ecorp Limited
VRL	Village Roadshow Limited
ARL	Austrim Nylex Limited
JUP	Jupiters Limited.
OML	Orogen Minerals Limited
ASH	Ashton Mining Limited
SPT	Spotless Group Limited
CAA	Capral Aluminium Limited
KYC	Keycorp Limited
PMP	PMP Limited

Table 3: The Aggressiveness of New Orders, Order Revisions and Order Deletion

This table presents the frequency of limit order submission, cancellations and revisions across six level of order aggressiveness. The sample is based on the order flow data of 20 large and 20 small stocks by market capitalization in the All Ordinaries Index. The sample period spans 23 trading days in the month of August 2000. *Aggressive* refers to a submitted or revised order resulting in a limit buy (sell) order with the buy (sell) price and quantity that exceeds those at the prevailing best ask (bid) quote. The whole or part of this order may be immediately executed upon submission during trading hours. *Large Market* refers to a submitted or revised order resulting in a limit buy (sell) order with the buy (sell) price at the prevailing ask (bid) price and quantity that exceeds the prevailing ask (bid) quote. The whole or part of this order may be immediately executed upon submission during trading hours. *Small Market* refers to a submitted or revised order resulting in a limit buy (sell) order with the buy (sell) price at the prevailing ask (bid) price and with quantity that is equal to or less than the prevailing ask (bid) quote. This order would be fully executed upon submission during trading hours. *Price Improve* refers to a submitted or revised order resulting in a limit order with a price inside the best bid and ask price. This order would not be immediately executed. *At Quote* refers to a submitted or revised order resulting in, or a cancelled order being, a limit buy (sell) order at a limit price that is equal to the best bid (ask) price. This order would not be immediately executed. *Outside Quote* refers to a submitted or revised order resulting in, or a cancelled order being, a limit buy (sell) order at a limit price that is lower (higher) than the prevailing best bid (ask) price. This order would not be immediately executed.

Aggressiveness	*Aggressive*	*Large Market*	*Small Market*	*Price Improve*	*At Quote*	*Outside Quote*	*Total*
Panel A Buy Orders % Across Order Type							
Large Stocks							
Submission	86.6	82.7	87.1	83.3	64.8	53.1	73.5
Revision	13.41	17.31	12.9	16.7	19.1	20.1	16.9
Cancellation	-	-	-	-	16.2	26.9	9.6
Small Stocks							
Submission	85.7	80.7	84.9	80.9	64.9	55.8	72.3
Revision	14.3	19.3	15.1	19.1	18.1	17.2	17.1
Cancellation	-	-	-	-	17.0	27.0	10.6
Panel B Buy Orders % Across Aggressiveness							
Large Stocks							
Submission	1.0	14.3	37.4	9.2	24.1	14.0	100
Revision	0.7	13.0	24.2	8.1	30.9	23.0	100
Cancellation	-	-	-	-	46.0	54.0	100
Small Stocks							
Submission	0.8	9.4	38.4	8.5	27.3	15.5	100
Revision	0.6	9.5	28.9	8.6	32.2	20.2	100
Cancellation	-	-	-	-	48.9	51.1	100

[§] No limit order is cancelled under the category of *Price Improve* because when limit order is cancelled after it is placed inside the spread, it will be immediately recognized as the best quote, which belongs to the category of *At Quote*.

Table 4: Original price location of revised and cancelled orders in the limit order book

This table presents original price location of revised and cancelled orders in the limit order book. *Revisions* refer to the frequency of limit order revisions. *Cancellations* refer to the frequency of limit order cancellations. % is the relative frequency of limit order revisions/ cancellations. *Price Step* refers to position of limit orders in the queue. "1st" refers to the number of orders revised or cancelled if the original limit buy (sell) price is the best bid (ask) of buy (sell) order. "2nd"refers to the number of orders revised or cancelled if the original limit buy (sell) price is at the next price step to the best bid (ask). Note that the difference between consecutive price steps can be more than the minimum tick size as it depends on how well the order book is filled.

	Buy Orders		**Sell Orders**	
Price Step	*% of Revisions*	*% of Cancellations*	*% of Revisions*	*% of Cancellations*
Panel A: Large stocks				
>6th	9.6	13.6	13.7	11.2
6th	2.4	2.5	2.4	2.3
5th	4.0	3.9	3.9	3.8
4th	7.2	6.0	6.5	5.6
3rd	13.5	10.2	12.7	10.2
2nd	28.7	17.9	27.2	17.9
1st	34.7	46.0	33.6	49.0
Panel B: Small stocks				
>6th	7.9	24.57	13.56	15.6
6th	2.0	3.6	3.16	3.2
5th	3.0	3.5	3.97	4.3
4th	4.6	5.8	6.95	5.5
3rd	10.1	8.8	11.14	11.3
2nd	25.2	15.7	24.77	18.0
1st	47.2	38.0	36.46	42.1

Table 5: Percentage of order cancellations and revisions across order size

This table presents the percentage of entered orders being cancelled and revised across order size quartiles.

	Percentage of Order Events		Percentage of Submissions	
	Revisions	Cancellations	Revisions	Cancellations
Large Stocks				
Small Orders	19.2	40.0	16.6	19.7
Medium Orders	51.9	33.7	23.9	8.8
Large Orders	28.9	26.3	28.1	14.6
Small Stocks				
Small Orders	24.5	36.3	20.0	18.4
Medium Orders	45.8	44.2	22.8	13.6
Large Orders	29.6	19.5	33.1	13.5

Table 6: Distribution of upward and downward price/quantity revision

This table presents the frequency distribution of upward and downward price/quantity revision of limit orders. For large stocks, the number of limit buy and sell order revisions are 31731 and 29960, respectively. For small stocks, the number of limit buy and sell order revisions are 6358 and 6492, respectively. *Priority increased* (*Priority decreased*) refers to number of limit price revisions that lead to an increase (decrease) in priority of execution. For example, an increase in limit buy price would lead to an increase in priority but an increase in limit sell price would lead to a decrease in priority. *Increased* (*Decrease*) refers to the number of orders that increase (decrease) in order size.

	Buy Orders			Sell Orders		
	Order Size Decreased	No change	Order Size Increased	Order Size Decreased	No change	Order Size Increased
Panel A: Large stocks						
Priority Decreased	0.1	5.7	0.7	0.1	6	0.7
No change	5.4	-	8.5	5.5	-	9
Priority Increased	2.1	72.3	5.1	1.4	72	4.7
Panel B: Small stocks						
Priority Decreased	0.1	6	0.8	0.1	7	0.6
No change	6	-	10.5	5.8	-	9.1
Priority Increased	3.5	68.8	4.2	1.2	72	3.9

Table 7: Average non-execution cost and free option cost reduction

This table presents the average values of post-revision/cancellation imputed free option cost and opportunity cost. Imputed opportunity cost is computed based on equations (5) and (6), respectively for each limit buy and sell revision/cancellation. Imputed free option cost is computed based on equations (7) and (8), respectively for each limit buy and sell revision/cancellation. Intrinsic value of the option is based on the prevailing opposing quote 15 minutes following the event. Standard errors are given in parentheses.

Panel A: Limit buy order	Non-execution cost reduction: $A_{\tau+15} - A_{\tau}$	Free trading option cost reduction: max[0, $b_{\tau} - A_{\tau+15}$],
Revision		
Priority Increased (upward price revision)	0.0141 (0.0011)	-
Priority Decreased (downward price revision)	-	0.0099 (0.0031)
Cancellation	0.0243 (0.0013)	0.0041 (0.0005)

Panel B: Limit sell order	Non-execution cost reduction: $B_{\tau} - B_{\tau+15}$	Free trading option cost reduction: max[0, $B_{\tau+15} - a_{\tau}$],
Revision		
Priority Increased (downward price revision)	0.0098 (0.0009)	-
Priority Decreased (upward price revision)	-	0.0135 (0.0043)
Cancellation	0.0113 (0.0009)	0.0041 (0.0004)

Table 8: A summary of the predicted sign of the estimated coefficient for each variable

This table summarizes the predicted sign of the estimated coefficient for each variable, which relates to free trading option risk (FTO) and non-execution risk (NE). The dependent variable under investigation is the number of limit buy order priority increase revision (*LBRU*), limit buy order priority decrease revision (*LBRD*) and limit buy order cancellations (*LBC*), limit sell order priority increase revision (*LSRU*), limit sell order priority decrease revision (*LSRD*) and limit sell order cancellations (*LSC*) in each 15-minutes interval. *LARGEBUY* and *LARGESELL* are the number of respective large buy and sell orders in the previous interval. We consider a market order as a large order if its order size belongs to the largest quartile trade size in that interval. *BIDDEPTHΔ* and *ASKDEPPTHΔ* are the average abnormal changes in buy-side quote depth and sell-side quote depth, respectively. *SPREAD* is the bid-ask spread based on an average value of a minute-by-minute snapshot of the spread in the previous interval. *VOLATILITY* is the standard deviation of the stock price in the previous hour. The standard deviation is computed based on each 15-minute snapshot of the stock price. *RETURN* is average log return of the stock price in the previous interval. *GOODNEWS* is a dummy variable that takes the value of 1 if sign($RETURN_t$ + $RETURN_{t+1}$) × NEWS > 0, where NEWS is the news announcement dummy. *BADNEWS* is a dummy variable that takes the value of 1 if sign($RETURN_t$ + $RETURN_{t+1}$) × NEWS < 0.

Hypotheses/Expected Sign

Order Type	Limit Buy Order				Limit Sell Order			
Theoretical Drivers	FTO		NE		FTO		NE	
Dependent Variables	*LBRD*	*LBC*	*LBC*	*LBRU*	*LSRD*	*LSC*	*LSC*	*LSRU*
Explanatory Variables								
LARGEBUY			+	+	+	+		
LARGESELL	+	+					+	+
BIDDEPTHD	–	–	+	+	+	+	–	–
ASKDEPTHD	+	+	–	–	–	–	+	+
SPREAD	–	–	+	+	–	–	+	+
VOLATILITY	+	+	+/–	+/–	+	+	+/–	+/–
RETURN	–	–	+	+	+	+	–	–
GOODNEWS		+	+	+	+	+	+	
BADNEWS	+	+	+			+	+	+

Table 9: Summary statistics of dependent variables and market variables

This table presents the summary statistics and correlation of dependent and independent variables. The dependent variable under investigation is the number of limit buy order priority increase revision (*LBRU*), limit buy order priority decrease revision (*LBRD*) and limit buy order cancellations (*LBC*), limit sell order priority increase revision (*LSRU*), limit sell order priority decrease revision (*LSRD*) and limit sell order cancellations (*LSC*) in each 15-minutes interval. *LARGEBUY* and *LARGESELL* are the number of respective large buy and sell orders. An order is defined as large if its order size belongs to the largest quartile trade size in that interval. *VOLATILITY* is the standard deviation of the stock price within the interval. The standard deviation is computed based on each 15 minute-by-minute snapshot of the stock price. *RETURN* is stock price return in the interval. *SPREAD* is the bid-ask spread based on an average value of a minute-by-minute snapshot of the spread in the previous interval. *BIDDEPTHΔ* and *ASKDEPPTHΔ* are the average abnormal changes in buy-side quote depth and sell-side quote depth, respectively.

Panel A: Large capitalization stocks

	Dependent variables: order counts						**Independent variables**						
	LBC	*LSC*	*LBRU*	*LBRD*	*LSRU*	*LSRD*	*LARGEBUY*	*LARGESELL*	*RETURN*	*SPREAD*	*VOLATILITY*	*BIDDEPTHΔ*	*ASKDEPTHΔ*
Mean	1.67	1.47	2.24	0.19	2.10	0.19	1.00	0.96	0.00	0.02	0.01	-0.18	-0.22
Median	1.00	1.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.02	0.01	-0.16	-0.19
Std dev.	2.18	2.05	3.03	0.51	2.67	0.51	2.10	1.84	0.01	0.03	0.02	0.59	0.66
Skewness	2.60	2.48	3.14	3.65	2.50	3.39	5.46	3.95	28.81	4.45	7.68	-0.06	-0.22
Kurtosis	12.69	9.76	17.36	18.61	10.13	15.01	56.66	28.93	1507.17	29.84	125.81	0.54	1.20
Min.	0	0	0	0	0	0	0.00	0.00	-0.15	0.01	0.00	-2.80	-3.55
Max.	30	22	40	7	30	6	41.00	33.00	0.26	0.40	0.55	2.12	2.51

Panel B: Small capitalization stocks

	Order counts						Independent variables						
	LBC	*LSC*	*LBRU*	*LBRD*	*LSRU*	*LSRD*	*LARGEBUY*	*LARGESELL*	*RETURN*	*SPREAD*	*VOLATILITY*	*BIDDEPTHΔ*	*ASKDEPTHΔ*
Mean	0.38	0.26	0.44	0.04	0.46	0.05	0.20	0.19	0.00	0.03	0.00	-0.20	-0.13
Median	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	-0.12	-0.11
Std dev.	0.89	0.68	1.03	0.21	1.01	0.24	0.73	0.63	0.00	0.03	0.01	0.70	0.51
Skewness	5.39	4.06	5.11	6.09	4.90	6.33	6.87	6.50	-31.93	3.33	5.59	-1.15	-0.17
Kurtosis	63.05	26.08	49.96	46.73	51.24	55.61	67.74	79.40	1434.62	15.67	50.28	3.38	0.65
Min.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.23	0.01	0.00	-3.87	-2.89
Max.	20.00	11.00	22.00	4.00	23.00	5.00	12.00	15.00	0.11	0.30	0.17	2.16	2.10

Panel C: Correlation of order counts and market variables

	LBC_t	LSC_t	$LBRU_t$	$LBRD_t$	$LSRU_t$	$LSRD_t$
$LARGEBUY_{t-1}$	0.30	0.34	0.28	0.18	0.40	0.10
$LARGESELL_{t-1}$	0.32	0.45	0.32	0.22	0.38	0.17
$BIDDEPTHD_{t-1}$	0.06	0.07	0.06	0.04	0.05	-0.05
$ASKDEPTHD_{t-1}$	0.11	0.25	0.11	0.08	0.25	0.09
$SPREAD_{t-1}$	0.03	0.09	0.03	0.02	0.07	0.07
$VOLATILITY_{t-1}$	0.15	0.23	0.19	0.00	0.21	0.14
$RETURN_{t-1}$	0.08	0.00	0.13	-0.05	0.05	0.13

Table 10: Negative binomial count regression of limit order cancellation and revision on market variables

This table reports the results for the negative binomial model of revision/cancellation counts. The dependent variable under investigation is the number of (i) limit buy order cancellation (*LBC*), (ii) limit sell order cancellation (*LSC*), (iii) limit buy priority increased revision (*LBRU*), (iv) limit buy priority decreased revision (*LBRD*), (iv) limit sell priority increased revision (*LSRU*), (iv) limit sell priority decreased revision (*LSRD*), in each 15-minutes interval *t*. The estimated coefficients for 23 dummy variables are suppressed. Robust z statistics are given in parentheses; * and ** represent significance levels of 5% and 1%, respectively.

Panel A: Large capitalization stocks						
	$LBRD_t$	LBC_t	$LBRU_t$	$LSRD_t$	LSC_t	$LSRU_t$
$LARGEBUY_{t-1}$	-	0.0734	0.0914	0.0675	0.0412	-
	-	(5.36)**	(5.43)**	(4.22)**	(4.60)**	-
$LARGESELL_{t-1}$	0.1149	0.0402	-	-	0.0812	0.1107
	(5.70)**	(3.75)**	-	-	(5.71)**	(5.94)**
$BIDDEPTH\Delta_{t-1}$	-0.0305	0.0852	0.0617	0.0342	-0.0416	-0.1337
	(0.53)	(2.45)*	(1.75)	(0.61)	(1.60)	(4.03)**
$ASKDEPTH\Delta_{t-1}$	0.0137	0.0358	-0.0005	-0.0105	0.0993	0.0561
	(0.20)	(1.17)	(0.01)	(0.15)	(2.88)**	(1.83)
$SPREAD_{t-1}$	-2.8134	-6.3512	-3.8142	-3.9549	-6.6325	-5.2271
	(1.03)	(2.29)*	(2.24)*	(1.08)	(1.98)*	(2.99)**
$VOLATILITY_{t-1}$	11.2183	12.0284	12.6358	9.8056	12.6233	11.2089
	(2.66)**	(3.47)**	(3.14)**	(2.57)*	(3.60)**	(2.85)**
$RETURN_{t-1}$	-2.1006	0.8700	2.5523	-2.4427	-0.0202	-1.5517
	(0.76)	(0.81)	(1.58)	(0.60)	(0.01)	(1.10)
Constant	-2.9386	-0.7843	-0.4831	-2.7089	-1.1604	-0.2503
	(13.11)**	(5.10)**	(2.49)*	(13.19)**	(6.37)**	(1.49)
Log likelihood	-5406.56	-18054.16	-20678.23	-5477.72	-17001.39	-20275.18
Alpha	1.40	0.57	0.70	1.39	0.66	0.65
Wald test	6.72**	9.32**	9.14**	6.73**	8.27**	7.68**
Pearson R^2	0.27	0.62	0.73	0.27	0.62	0.69
Panel B: Small capitalization stocks						
	$LBRD_t$	LBC_t	$LBRU_t$	$LSRD_t$	LSC_t	$LSRU_t$
$LARGEBUY_{t-1}$	-	0.2411	0.2813	0.2646	0.1263	-
	-	(8.10)**	(9.25)**	(4.42)**	(4.10)**	-
$LARGESELL_{t-1}$	0.2469	0.1334	-	-	0.1836	0.2841
	(7.73)**	(3.07)**	-	-	(5.49)**	(7.19)**
$BIDDEPTH\Delta_{t-1}$	-0.1478	0.0342	0.0446	0.0141	-0.0549	-0.0523
	(2.29)*	(0.60)	(0.69)	(0.15)	(0.79)	(1.00)
$ASKDEPTH\Delta_{t-1}$	-0.0352	0.1245	-0.0020	-0.1536	0.1428	0.1186
	(0.33)	(1.66)	(0.03)	(1.92)	(2.57)*	(2.12)*
$SPREAD_{t-1}$	-4.4177	-11.8899	-6.1398	-11.9210	-6.1570	-3.7358
	(0.87)	(3.25)**	(2.77)**	(2.13)*	(2.44)*	(1.41)
$VOLATILITY_{t-1}$	22.0313	23.5466	29.1872	33.6816	25.7793	29.2972
	(4.57)**	(6.39)**	(6.46)**	(6.51)**	(4.41)**	(3.62)**
$RETURN_{t-1}$	-4.6930	-0.5516	-0.7595	-4.3498	5.9084	2.0361
	(1.03)	(0.17)	(0.15)	(0.51)	(0.63)	(0.75)
Constant	-5.0438	-1.3972	-1.8641	-3.3641	-2.4639	-1.4566
	(8.55)**	(5.22)**	(8.50)**	(12.72)**	(9.16)**	(6.69)**
Log likelihood	-1729.03	-8188.73	-8936.62	-1963.11	-6541.34	-9338.92
Alpha	1.37	1.38	1.35	2.57	1.54	1.25
Wald test	3.10**	6.72**	13.72**	3.39**	7.63**	8.61**
Pearson R^2	0.13	0.50	0.56	0.17	0.41	0.53

Table 11: Fractional logistic estimation of the scaled number of limit order cancellation and revision on market variables

This table present the results using the fractional logistic model proposed by Papke and Wooldridge (1996). The dependent variable under investigation is the event count (LBC_t LSC_t $LBRU_t$ $LBRD_t$ $LSRU_t$ and $LSRD_t$) scaled by the average number of outstanding orders within the same interval across 23 trading days. The estimated coefficients for 23 dummy variables are suppressed. Robust z statistics are given in parentheses; * and ** represent significance levels of 5% and 1%, respectively.

Panel A: Largeitalization stocks

	$LBRD_t$	LBC_t	$LBRU_t$	$LSRD_t$	LSC_t	$LSRU_t$
$LARGEBUY_{t-1}$	-	0.0553	0.0602	0.0488	0.0208	-
	-	(3.42)**	(2.94)**	(3.33)**	(2.81)**	-
$LARGESELL_{t-1}$	0.0839	0.0209	-	-	0.0825	0.0590
	(4.94)**	(1.97)*	-	-	(7.00)**	(3.65)**
$BIDDEPTH\Delta_{t-1}$	-0.0462	0.0849	0.0613	-0.1435	-0.0687	-0.0102
	(0.83)	(1.86)	(1.21)	(2.59)**	(1.26)	(0.10)
$ASKDEPTH\Delta_{t-1}$	-0.0718	-0.0040	-0.0374	0.0199	0.0533	-0.0779
	(0.85)	(0.09)	(0.69)	(0.32)	(0.72)	(1.14)
$SPREAD_{t-1}$	1.5981	-1.5910	-0.7313	-2.0002	-1.2299	1.5127
	(0.55)	(0.42)	(0.27)	(0.73)	(0.31)	(0.42)
$VOLATILITY_{t-1}$	5.7530	9.5908	10.1859	12.1326	10.9607	6.9164
	(2.83)**	(2.52)*	(2.68)**	(4.02)**	(3.47)**	(5.12)**
$RETURN_{t-1}$	-0.5883	0.7646	1.6035	-1.3556	0.3146	-0.9718
	(0.23)	(0.60)	(0.72)	(0.83)	(0.15)	(0.21)
Constant	-6.8753	-4.5798	-4.2652	-4.3165	-5.2364	-6.9703
	(27.14)**	(28.43)**	(24.44)**	(31.36)**	(31.67)**	(38.94)**
Log likelihood	-277.86	-1486.19	-1842.56	-1496.79	-1167.35	-228.01

Panel B: Smallitalization stocks

	$LBRD_t$	LBC_t	$LBRU_t$	$LSRD_t$	LSC_t	$LSRU_t$
$LARGEBUY_{t-1}$	-	0.1342	0.1768	0.1263	0.0621	-
	-	(3.01)**	(4.84)**	(3.20)**	(1.27)	-
$LARGESELL_{t-1}$	0.1683	0.1299	-	-	0.1578	0.2136
	(3.88)**	(2.81)**	-	-	(3.93)**	(4.70)**
$BIDDEPTH\Delta_{t-1}$	-0.1445	0.0614	0.0419	0.0113	-0.0265	0.0562
	(1.45)	(0.64)	(0.43)	(0.17)	(0.36)	(0.64)
$ASKDEPTH\Delta_{t-1}$	-0.1242	-0.0865	-0.1018	-0.0367	0.0200	-0.1786
	(0.86)	(0.62)	(1.30)	(0.48)	(0.22)	(1.91)
$SPREAD_{t-1}$	1.4748	-6.2719	-2.3899	1.0827	0.4252	-2.3994
	(0.26)	(1.37)	(0.67)	(0.46)	(0.17)	(0.56)
$VOLATILITY_{t-1}$	25.8469	30.9093	29.9012	30.6228	24.7031	31.4193
	(7.67)**	(6.48)**	(9.19)**	(5.21)**	(5.28)**	(10.42)**
$RETURN_{t-1}$	-6.0645	13.6855	14.7164	-0.1496	14.3010	6.5270
	(1.27)	(2.11)*	(2.66)**	(0.07)	(1.22)	(0.33)
Constant	-9.0291	-5.5250	-5.8641	-5.4122	-6.7858	-7.4248
	(13.25)**	(24.39)**	(17.00)**	(22.73)**	(25.85)**	(24.10)**
Log likelihood	-60.28	-365.68	-475.13	-497.18	-295.73	-71.50

Table 12: Negative binomial count regression of limit order cancellation and revision on news variables

This table reports the results for the negative binomial model of revision/cancellation counts. The dependent variable under investigation is the number of (i) limit buy order cancellation (*LBC*), (ii) limit sell order cancellation (*LSC*), (iii) limit buy priority increased revision (*LBRU*), (iv) limit buy priority decreased revision (*LBRD*), (iv) limit sell priority increased revision (*LSRU*), (iv) limit sell priority decreased revision (*LSRD*), in each 15-minutes interval *t*. GOODNEWS is a dummy variable that takes the value of 1 if sign($RETURN_t$ + $RETURN_{t+1}$) × NEWS > 0, where NEWS is the news announcement dummy. BADNEWS is a dummy variable that takes the value of 1 if sign($RETURN_t$ + $RETURN_{t+1}$) × NEWS < 0. The estimated coefficients for 23 dummy variables are suppressed. Robust z statistics are given in parentheses; * and ** represent significance levels of 5% and 1%, respectively.

Panel A: Large capitalization stocks						
	$LBRD_t$	LBC_t	$LBRU_t$	$LSRD_t$	LSC_t	$LSRU_t$
GOODNEWS_t	0.6013	0.5077	0.2913	0.6120	0.2663	0.7274
	(1.51)	(2.23)*	(2.31)*	(2.19)*	(1.60)	(4.97)**
BADNEWS_t	0.9600	0.5066	0.4042	0.6844	1.1605	0.9496
	(2.63)**	(2.79)**	(1.79)	(1.78)	(3.30)**	(3.60)**
Constant	-2.8848	-0.8529	-0.4730	-2.7378	-1.2446	-0.2796
	(14.30)**	(5.61)**	(2.54)*	(13.85)**	(8.09)**	(1.96)
Log likelihood	-5503.31	-18522.08	-21062.27	-5537.05	-17428.70	-20665.60
Alpha	1.61	0.71	0.81	1.49	0.82	0.77
Wald test	6.60**	8.17**	8.23**	6.64**	7.36**	7.25**
Pearson R^2	0.25	0.61	0.72	0.26	0.62	0.69
Panel B: Small capitalization stocks						
	$LBRD_t$	LBC_t	$LBRU_t$	$LSRD_t$	LSC_t	$LSRU_t$
GOODNEWS_t	0.6279	0.5744	0.5097	1.3437	0.5202	-0.2629
	(1.27)	(2.02)*	(2.28)*	(3.96)**	(1.09)	(0.74)
BADNEWS_t	0.5472	0.2072	0.3648	1.0761	0.5638	0.7923
	(0.62)	(0.46)	(0.78)	(2.88)**	(2.20)*	(3.58)**
Constant	-5.0345	-1.5784	-1.9127	-3.4965	-2.5215	-1.4487
	(9.20)**	(6.51)**	(8.73)**	(11.83)**	(9.67)**	(6.79)**
Log likelihood	-1774.86	-8607.79	-9354.58	-2051.24	-6775.56	-9704.98
Alpha	1.86	1.86	1.76	3.52	1.90	1.63
Wald test	3.03**	5.76**	9.16**	3.84**	7.76**	7.00**
Pearson R^2	0.11	0.46	0.53	0.14	0.39	0.50

Table 13: Autocorrelation of count events before and after the NB regressions

This table reports the median values of the estimated correlation coefficient and the corresponding median values of Ljung-Box Q-statistic (in bracket) of the Pearson residual values extracted from the negative binomial models reported in Table 10. Asterisks represent significance levels of 5%.

Panel A: Limit buy order

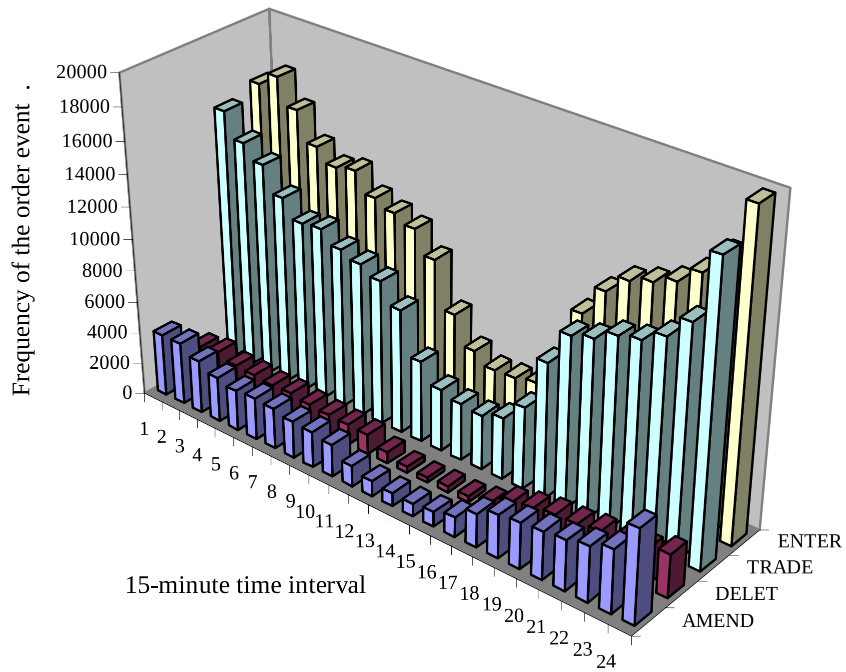
	Without covariates				With covariates			
	Large cap		**Small cap**		**Large cap**		**Small cap**	
	Lag 1	*Lag 2*	*Lag 1*	*Lag 2*	*Lag 1*	*Lag 2*	*Lag 1*	*Lag 2*
Cancellation	0.14	0.10	0.07	0.03	0.11	0.10	0.06	0.03
	(10.69)*	(18.48)*	(2.43)*	(3.81)*	(6.41)*	(13.47)*	(1.72)	(6.48)*
Revision								
increase in priority /	0.15	0.15	0.07	0.06	0.16	0.15	0.07	0.07
upward price revision	(12.41)*	(24.88)*	(2.49)*	(6.17)*	(13.66)*	(23.63)*	(2.85)*	(6.91)*
decrease in priority /	0.05	0.01	0.00	-0.01	0.04	0.02	0.00	-0.01
downward price	(1.62)	(2.84)*	(0.15)	(1.22)	(1.36)	(2.67)*	(0.07)	(0.51)

Panel B: Limit sell order

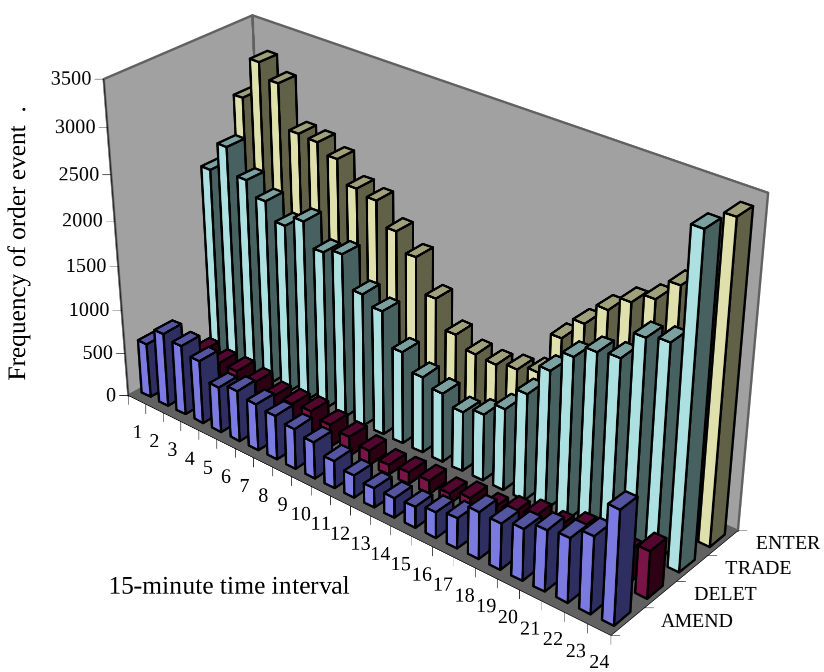
	Without covariates				With covariates			
	Large cap		**Small cap**		**Large cap**		**Small cap**	
	Lag 1	*Lag 2*	*Lag 1*	*Lag 2*	*Lag 1*	*Lag 2*	*Lag 1*	*Lag 2*
Cancellation	0.06	0.12	0.06	0.02	0.09	0.08	0.05	0.04
	(2.26)*	(9.79)*	(2.00)*	(3.76)*	(4.49)*	(10.19)	(1.62)	(2.14)*
Revision								
increase in priority /	0.16	0.14	0.08	0.07	0.16	0.12	0.04	0.04
downward price revision	(15.15)*	(22.69)*	(3.44)*	(7.39)*	(14.39)*	(22.13)*	(0.88)	(4.96)*
decrease in priority /	0.04	0.04	0.04	-0.01	0.03	0.03	0.00	-0.01
upward price	(0.93)	(2.44)*	(0.84)	(1.72)	(0.44)	(2.97)*	(0.14)	(0.66)

Figure 1: Intraday Pattern of the frequency of new order submission (ENTER), execution (TRADE), cancellation (DELET) and revision (AMEND)

(a) Total frequency of order event 20 large stocks



(b) Total frequency of order event 20 small stocks



(c) Percentage distribution of each order event across time