Order Cancelations across Investor Groups: Evidence from an Emerging Order-Driven Market

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Abstract

Employing comprehensive limit-order data that unambiguously identify investor groups, this paper examines the order-cancelation behavior across investor groups in the Taiwan Stock Exchange. Evidence shows that, first, facing trade-offs between the monitoring cost and limit-order risks, such as non-execution and free-trade-option risks, differences exist across investor groups. Foreign investors closely monitoring the market cancel their limit orders most actively, while individual investors with the highest monitoring cost do so least actively. Second, during the worst year of the global financial tsunami, 2008, the levels of order cancelations and their sensitivities to the limit-order risks, particularly by institutional investors, significantly rose.

Keywords: non-execution risk, free-trade-option risk, monitoring cost, order cancelations

1. Introduction

The purpose of this paper is twofold. First, it studies the activity of order cancelations and their determinants in the Taiwan Stock Exchange (TSE), a pure order-driven market. Employing order-level data, this paper, different from prior studies, distinguishes itself by emphasizing behavior differences across investor groups, including foreign investors, domestic institutions, and individual investors. Second, this paper analyzes the order-cancelation dynamics during a sample period from 2007 to 2008, known as the years of the global financial tsunami.[1]

In a pure order-driven market without interference from market makers, traders who submit, revise, and cancel limit orders act directly as liquidity providers. Even in a hybrid market like the NYSE, limit orders accounting for more than half of trading activities still serve as an essential source of liquidity (Chakrabarty *et al.*, 2006). Chung *et al.* (1999) observe that in the NYSE about 75% of all quotes have at least one side of the quotes posted by limit orders. Given the crucial role of limit orders, numerous studies have investigated the relevant issues on intraday liquidity, but most of them (e.g., Lee *et al.*, 2004; Ranaldo, 2004; Menkhoff *et al.*, 2010) focus on order submission behavior. It was not until recently that researchers began to pay attention to the role of order cancelations and revisions in liquidity provision. For example, Ellul *et al.* (2007) and Yeo (2005) observe that in the NYSE more than one-third of limit orders are canceled. Hasbrouck and Saar (2009) state that 93% of limit orders submitted through NASDAQ INET are canceled, and 36.69% of those are fleeting orders canceled within two seconds after submission in their exploration of latent liquidity. Foster and Liu (2008) and Coppejans and Domowitz (2002) find that traders frequently cancel limit orders in derivative markets as well.

The placement of a (non-marketable) limit buy (sell) order, offering other traders an opportunity to sell (buy) shares at a pre-specified price, is equivalent to writing a free put (call) option to the market (Copeland and Galai, 1983).[2] The exercise price of the put (call) is equal to the limit buy (sell) price. Adverse price changes may stale the limit order and make the associated free-trade option (FTO) in-the-money. The uncertainty that the stale order is picked off by informed traders is called the FTO risk. On the other hand, when the prevailing

[1] For more descriptions about the global financial tsunami and its impacts on investor behavior, please see Shefrin and Statman (2011) and Barberis (2011).

[2] For the definitions of marketable and non-marketable limit orders, please see Sections 5.1.1 and 5.1.2.

bid-ask midpoint moves away from the limit price, executions become less possible. The opportunity cost of an unfilled limit order is recognized as the non-execution (NE) risk.

Responding to possible variations in the FTO and the NE risks, traders can either price-protect themselves by submitting limit orders at prices far from the best quotes, or closely monitor the market and cancel/revise their stale limit orders, if necessary (Liu, 2009; Hollifield *et al.* 2004; Goldstein and Kavajecz, 2000; Foucault, 1999).[3] For example, NASDAQ dealers do the latter, when facing professional day traders who closely monitor the market and pick off stale quotes posted by dealers who are slow to adjust (Foucault *et al.*, 2003). Although it is beneficial to actively monitor the market and cancel/revise stale limit orders, since information randomly arrives, the behavior inevitably incurs a nontrivial cost: the monitoring cost. Traders have to exert efforts to find news sources, to interpret information, and to justify its accurateness. Therefore, the smaller the monitoring cost for traders, other things being equal, the more likely they are to monitor the market and actively cancel or revise their limit orders (Fong and Liu, 2010).[4]

Thanks to technological advancements (e.g., on-line trading systems and the Internet) that effectively enhance information transmission and reduce the monitoring cost (Stoll, 2006; Jain, 2005), order cancelations/revisions have substantially increased (Hasbrouck and Saar, 2009; Liu, 2009). Even given the advancements, however, the monitoring cost still exists and varies across investor groups. For example, individual investors cannot constantly monitor the market (Aitken *et al.*, 2007). Especially for those who have dedicated daytime jobs in non-securities-related industries, closely monitoring the market during trading hours is costly and even jeopardizes their professional career.

Compared to individual investors, institutional investors tend to be full-time traders and are considered informed (Chakravarty, 2001; Anand *et al.*, 2005; Kaniel and Liu, 2006). Institutional investors can effectively gather and interpret information by closely monitoring the market. As news arrives, given their lower monitoring cost, their behavior is expected to

[3] Hollifield *et al.* (2004) build a structural model of an order-driven market that captures the trade-offs among the order price, the order execution probability, and the winner's curse.

[4] Aside for being an activity for traders managing their limit-order risks, order cancelations can possibly be regarded as strategic behavior of traders engaging in price manipulation (Kuk *et al.*, 2010; Eom, Lee and Park, 2013). Yeo (2005) posits that order cancelations may result from an undercutting strategy in which limit order traders can undercut one another by improving the quotes. If successful, trades take place; if not, the traders may cancel their orders and either engage in further undercutting by resubmitting these orders or leave the market.

be more responsive to market changes than individual investors' (Lee *et al.*, 1991; Menkhoff *et al.*, 2010).[5] In this paper we study order submission across investor groups.

This paper contributes to the literature in the three ways. Firstly, our data unambiguously classify each limit order into different investor groups. Taking advantage of the data's richness, we distinguish order cancelations across investor groups, including foreign investors, domestic institutions, and individual investors along the following dimensions. (1) How are their monitoring costs different? (2) How do the limit-order risks separately affect their order cancelations? To our knowledge, this is the first study applying such comprehensive order-level data to examine these issues across investor groups. Secondly, over our sample period 2007-2008, the years of the global financial tsunami, this paper illustrating the dynamics of order cancelations helps economists understand the impacts of a financial crisis on the behavior across investor groups. Thirdly, we point out deficiencies of the FTO and the NE risk measures initially developed by Liu and Sawyer (2003); then, we propose a revision and show its empirical improvement by using our data.

Our conclusions on order cancelations across investor groups previously unexplored are as follows. First, significant differences exist in response to the FTO and NE risks across investor groups. The intraday pattern of order cancelations, along with the proportion of limit orders submitted before the open, supports that individual investors have the highest monitoring cost. Second, not only do foreign investors cancel their limit orders most frequently, but their order cancelations are also the most sensitive to the FTO and the NE risks, while individual investors cancel their limit orders least frequently. Third, the sensitivities of order cancelations by foreign investors and domestic institutions to those risks more than doubled from 2007 to 2008, as the financial crisis got worse.

The remainder of this paper proceeds as follows. Section 2 briefly describes the institutional background of the TSE. Section 3 introduces the employed data and some preliminary evidence. Section 4 develops several hypotheses capturing the detailed purposes of this paper. We introduce the research design covering the employed variables and methodology in Section 5. Section 6 reports the empirical results, verifies our hypotheses, and discusses the implications. Finally, we conclude this paper in Section 7.

[5] Aitken *et al.* (2007) suggest that active traders, such as institutional investors, expend resources in monitoring the market and the status of their limit orders whereas passive traders do not. Hence, the FTO risk is relevant to some institutional investors and to all individual investors.

2. Institutional background

All listed securities on the TSE are traded by auto-matching via a Fully Automated Securities Trading (FAST) system. It is centralized and order-driven, and its trading mechanism is similar to the electronic limit-order system in Hong Kong (e.g., Ahn, Bae and Chan, 2001), except that the FAST is purely a call market system. Trading operates from 9:00 am to 1:30 pm, Monday through Friday. There are no designated market makers and liquidity is provided by limit order traders. Orders can be keyed in 30 minutes prior to the open during which neither submitted orders are executed nor information regarding the limit order book is disseminated. After the open, information (including the best five bid and ask prices, and the number of shares demanded or offered at each of these five prices) is disseminated to the public on a real-time basis.

All orders must be priced at submission. Neither market nor hidden orders are allowed. Trades periodically take place for each stock about every 15 seconds. Limit orders are prioritized first by price and then by submission time. The execution price, determined by a single-price auction, is the one maximizing trading volume. Unfilled orders automatically expire at the end of each trading day.

Note that the FAST, unlike most systems worldwide, does not directly execute order revisions. Instead, it responds to an order revision by sequentially executing, first, an order cancelation and, then, an order resubmission at the revised price and quantity. Afterwards, the FAST generates two separate records. Since the data do not contain valid cross-reference numbers between order cancelations and resubmissions for us to exactly identify order revisions, we study only order cancelations in this paper.

3. Data and preliminary evidence

3.1 The data and sample

This paper employs the Order and Quote Files, compiled by the TSE, from 1/2007 to 12/2008, for a total of 496 trading days. The data contain the intraday information on all submitted limit orders and quotes. The quote data, illustrating the dynamics of the limit order book for each stock, contain the time stamp as well as bid (ask) information at 15-second intervals, including the number of shares waiting to execute at the best bid (ask) and at each

of the four consecutive lower (higher) ticks. For each order, the order data include the time stamp (to the nearest one hundredth of a second), stock code, a buy-sell indicator, order size, limit price, and investor type.

The investor type classifies each limit order into one of five groups: foreign investors, mutual funds, securities dealers, individual investors, and corporate institutions. Mutual funds are solely composed of domestic mutual fund firms, while foreign investors cover a wide variety of foreign institutions, including foreign (investment) banks, insurance companies, mutual funds, pension funds, and so on. Corporate institutions consist of all domestic institutions other than mutual funds and securities dealers. For brevity, we aggregate mutual funds, securities dealers, and corporate institutions into one group of domestic institutions.

In most of the following discussions, we use data over 15-minute intervals for each stock over each trading day from 9:00 am to 1:30 pm, totaling eighteen successive 15-minute intervals. The selected sample consists of the largest 50% of common stocks, for a total of 375 firms, based on the daily average market capitalization over the sample period. The concern over firm sizes is that some small-cap stocks are not even traded by institutional investors, making it difficult to study their order cancelation behavior.

3.2 Preliminary evidence

Table 1 presents the summary statistics for the sample stocks. The quoted spread is the difference between the best ask and bid at the market close, while the relative spread is the quoted spread relative to the bid-ask midpoint. As indicated, the characteristics of the selected stocks are widely spread. For example, the covered market capitalization ranges from NT$3.74 billion to NT$1.586 trillion. Applying the bid-ask spread to measure liquidity, the most liquid and illiquid stocks have relative spreads of 0.042% and 0.297%, respectively. Stock prices and trading volumes demonstrate large swings as well.

Figure 1 chronologically plots the cancelation ratios, in volume and in the number of canceled orders, over the sample period. Note that, no matter which measure we apply, both the mean and the volatility of the cancelation ratio increase, starting from the second half of 2007, which is about when the financial tsunami erupted. According to the annual reports published by the TSE (http://www.twse.com.tw/en/statistics/statistics.php?tm=07), in 2008 the Taiwan composite stock index fell by 46%, while the average daily turnover fell by 15%, suggesting that a contagion of fear discouraged trading activities. If a trader still insisted on

trading during the financial tsunami period, he was likely to be extra cautious about the risks and tended to monitor the market closely and frequently canceled his orders.

Market capitalization and investment preferences could jointly matter for the monitoring cost and limit-order risks. Large-cap firms with high levels of transparency are often frequently traded, lowering the monitoring cost for traders (Liu, 2009). Moreover, Hasbrouck and Saar (2001) argue that the execution rates for limit orders increase with market capitalization, so limit orders for large-cap firms have smaller NE risks. Since institutions prefer large-cap stocks (Falenstein, 1996; Gompers and Metrick, 2001; Frieder and Subrahmanyam, 2005),[6] in the following we shall partition the full sample into two sub-samples, large- and small-cap firms, based on the average daily market capitalization over the sample period, to examine the order cancelations across investor groups.

Table 2 summarizing order submissions and cancelations across investor groups reports the average daily numbers of submitted (canceled) orders by each investor group to the numbers of all submitted (canceled) orders and their order sizes. In terms of submitted orders, individual investors are clearly the dominating traders. For large-cap stocks, the daily submitted orders by individual investors make up about 80% of orders, while for small-cap stocks, their share even soars to more than 90%. Among institutional investors, foreign investors overwhelm domestic institutions.

With regard to order cancelations across investor groups, the patterns are similar to those of order submissions. First, individual investors still play a dominant role. For example, the canceled buy orders for large-cap stocks by individual investors make up 74. 6% of total canceled buy orders, while those by foreign investors (domestic institutions) make up 22.6% (2.8%). For small-cap stocks, the ratio for individual investors is even higher and reaches up to 89.6%. Despite the dominant roles of individual investors shown above, foreign investors proportionally cancel their own orders more than others do. For example, for large-cap stocks, the proportion of buy order cancelations by foreign investors (0.226) is larger than that of their buy order submissions (0.161). This inequality does not hold for other investor groups.

After realizing a preliminary picture of the relative tendency of order cancelations among the three investor groups over the entire sample period, Figure 2 separately draws their order cancelation ratios. The ratio for a given investor group over a trading day is

[6] In fact, our results in Table 2 support this traditional wisdom. For example, the buy order volumes in 1000 shares for large- and small-cap stocks by foreign investors (domestics institutions) are respectively 13.524 and 7.504 (27.465 and 19.143), while those by individual investors are respectively 6.441 and 6.940.

defined as the number of canceled orders divided by the number of submitted orders by the same group. Again, it is apparent that, regardless of market capitalization, the cancelation ratios by foreign investors and domestic institutions are higher than those by individual investors. Moreover, institutional investors canceled their limit orders more frequently in 2008 than in 2007, but the inequality for individual investors is not as evident.

Additional notable evidence drawn in Figure 3 is the intraday U-shaped patterns of order cancelations are, regardless of investor groups, consistent with Liu (2009) and Fong and Liu (2010). Since overnight information uncertainty is plausibly high at the open (Madhavan and Panchapagesan, 2000; Madhavan, 1992),[7] both FTO and NE risks immediately after the open are expected to be high. Traders are prone to closely monitor the market and cancel their orders, if necessary, to prevent their orders from being unfilled or picked off by informed traders. Afterwards, information uncertainty is gradually resolved and order cancelations fall.

When the market is about to close, some traders who have unfilled limit orders may be under pressure to trade immediately. For example, day traders usually do not hold open positions overnight. If worried that previously submitted orders cannot close positions before the close, they tend to revise their orders to raise the price priorities and the likelihood of execution even at originally unfavorable prices.

4. Hypotheses

The preliminary evidence above shows that the overall tendencies to cancel limit orders among the three investor groups over the sample period of 2007 and 2008. From now on, we shall examine the effects of the monitoring costs and the limit-order risks on their order cancelations, and, more importantly, the behavior differences. Furthermore, we pay attention to the impacts of the global financial tsunami on order cancelations across them. Next, we propose several hypotheses to stepwise highlight the purposes of this paper.

4.1 Monitoring costs

Confronting potential changes in the FTO and the NE risks, limit-order traders typically have two choices. They can either (1) price-protect themselves by submitting limit orders at

[7] According to Brockman and Chung (1999), trading activities are more intense right after the open and before the close, leading to a U-shaped intraday pattern in price volatility.

prices far from the best quotes at the cost of a higher NE risk, or (2) closely monitor the market and swiftly cancel/revise their limit orders, if necessary. The first choice is often adopted by patient limit order traders who concern more about the FTO risk than about the NE risk, while the second one is adopted when traders have a low monitoring cost; otherwise, the first choice is relatively feasible (Hollifield *et al.* 2004; Fong and Liu, 2010). The traders with a high monitoring cost usually place unaggressive limit orders to represent their interests when they are unable or unwilling to continuously monitor the market (Harris, 1998). How far the non-marketable limit price is from the prevailing midquote at submission, measured as order aggressiveness, expectedly depends on the magnitude of the monitoring cost for the traders, implying that order aggressiveness closely relates to the traders' monitoring costs.

Fong and Liu (2010) observe a negative relation between order revisions/cancelations and order aggressiveness at submission. If traders' monitoring cost is low, they reasonably cancel their unfilled limit orders more often than aggressive orders after submission. It is because the less aggressive the limit order, the longer it takes to execute, the higher uncertainty it encounters.

Different from Fong and Liu (2010), in this paper we additionally consider a scenario in which traders' monitoring cost is quite high and closely monitoring the market is not possible. They then are likely to submit unaggressive limit orders rather far from the best quotes, and part of them are not even able to cancel their orders. This scenario, if valid, implies that cancelations of limit orders with rather low order aggressiveness do not happen often. Thus, if sufficiently distinguishing limit orders with different order aggressiveness, the relation between order cancelations and order aggressiveness may not be monotonically decreasing, but inverted U-shaped.[8] The following hypothesis explicitly tests this scenario's implication.

Hypothesis 1: Order cancelations demonstrate an inverted U-shaped relation with respect to order aggressiveness at submission.

After showing the importance of the monitoring cost, it is next of interest to compare the costs among the three investor groups that possibly differ a lot. For instance, most individual investors are neither full-time workers in securities-related industries nor available to

[8] Fong and Liu (2010) separate non-marketable limit orders into "price improve", "at quote", and "outside quote", based on order aggressiveness, which may not be detailed enough to observe an inverted U-shaped pattern.

constantly monitor the market. They plausibly have a higher monitoring cost. Putting together the argument above, a testable hypothesis goes as follows:

Hypothesis 2a: Individual investors submit more non-marketable limit orders at prices farther from the best quotes than institutional investors.

Other than order aggressiveness, another two kinds of behavior could reflect a high monitoring cost for individual investors having daytime jobs. First, they tend to submit orders before the open when not yet at work, because trading stocks is costly during working hours. By contrast, institutional investors are unlikely to submit orders before the open as often as individual traders do. This is because, as mentioned earlier, information about the limit order book helping resolve high overnight information uncertainty is not dissimilated before the open. Submitting pre-open orders is unnecessarily risky for traders who can closely monitor the market afterwards. Second, a good time for individual investors to manage their unfilled limit orders is after 12 pm, lunchtime, when they are temporarily free from work. Usually, they go back to work by 1:30 pm, which is the time the market closes.

Hypothesis 2b: Individual investors submit more limit orders before the open than institutional investors. After 12 pm, order cancelations by individual investors rise.

To explore more intraday behavior differences possibly related to the monitoring costs across investor groups, let us consider their behavior of order submission or liquidity provision during a trading day. Bloomfield *et al.* (2005) suggest that it depends on the value of their private information. Informed traders take (provide) liquidity when the value of their information is high (low). When trading begins, informed traders, with a low monitoring cost, are more likely to demand liquidity than other traders, picking off stale orders to profit from their private information. As prices move toward true values, the informed traders shift to submitting limit orders and providing liquidity. Anand *et al.* (2005), Duong *et al*. (2009), and Menkhoff *et al.* (2010) posit that, given high information uncertainty around the open, informed (institutional) traders tend to demand liquidity earlier in a trading day while acting as liquidity suppliers later in the day, while individual investors behave oppositely.

When demanding liquidity, traders submit marketable limit orders and expect immediate executions of these orders; later on, they may not be able to change their mind and

cancel/revise the orders. Conversely, traders supplying liquidity submit non-marketable limit orders at the cost of a smaller likelihood of execution and longer expected waiting time. The less aggressive the limit orders, the longer they take to execute, the more likely the traders are to monitor the market and cancel/revise their orders, if doing so is not too costly. A testable hypothesis capturing the differences above is given as follow.

Hypothesis 3: Institutional investors cancel limit orders less frequently right after the open and more frequently before the close.

4.2 Limit-order risks

As argued in the previous section, traders having different monitoring costs submit limit orders with different levels of order aggressiveness to control their exposure to the FTO risk in the first place. However, subsequent price dynamics could also alter the FTO risk, inducing the traders to take further actions to manage the time-varying risk. Fong and Liu (2010) state that, when closely monitoring the market, once adverse news hits, traders possibly cancel their limit orders or revise them to reduce the likelihood of execution. The limit prices of these orders are often closer to the prevailing best quotes or have higher price priorities, implying that these orders bear a higher FTO risk before cancelation.

Regarding the strategies dealing with the NE risk, some traders may tend to cancel or revise their limit orders with low price priorities and a high NE risk. For instance, Harris (1998) suggests that traders under pressure could become impatient, particularly toward the close of trading. When the prevailing best quotes trend away from the limit prices, they revise their orders to raise the likelihood of execution. Taken together, the relation between order cancelations and price priority at cancelation is expected to be U-shaped.

Hypothesis 4a: Order cancelations demonstrate a U-shaped relation with respect to order price priority at cancelation.

Earlier evidence has shown that traders in different groups are likely to have different monitoring costs, resulting in different order submission behavior and, thus, different distributions of the FTO and NE risks. For instance, institutional (individual) investors, having a lower (higher) monitoring cost, may submit more non-marketable limit orders

around (far from) the midquotes. Thus, they confront a higher FTO (NE) risk and cancel more limit orders in the highest (lowest) price priority group.

Furthermore, the market capitalization of a stock, also changing the distributions of the FTO and the NE risks that traders face, indirectly affect their order cancelation behavior for the stock. For example, Aitken *et al.*(2007) and Duong *et al.* (2009) state that aggressive institutional investors (e.g., hedge funds) actively monitor the trading activities of large-cap stocks, which raises the possibility for limit orders to be picked off around the best quotes. Conversely, the NE risk for small-cap stocks is more pronounced, because those stocks are generally less liquid, indicating that their demand curves are steeper (Campbell, Grossman and Wang, 1993). Once demand shocks hit and prices change substantially, the rising NE risk encourages traders to revise their limit orders with low price priorities for those stocks. Finally, the traditional wisdom (e.g., Kang and Stulz (1994), Gompers and Metrick (2001), and Frieder and Subrahmanyam (2005)) suggests that institutional investors, particularly foreign investors, prefer large-cap stocks. Taking into account the arguments above, we expect that different investor groups with different investment preferences and monitoring costs face different time-varying limit-order risks and, hence, exhibit different order-cancelation behavior with respect to price priority at cancelation.

Hypothesis 4b: Foreign investors cancel more limit orders in the highest price priority group, while individual investors do so in the lowest price priority group.

4.3 The sensitivities of order cancelations to the limit-order risks

Up to now, we have developed hypotheses that describe the behavior of order cancelations across investor groups and emphasize their differences. In the following, we sharpen the picture by applying multivariate regressions (to be introduced in the next section) to jointly test the sensitivities of order cancelations across investor groups to the limit-order risks in a more rigid manner. If the preceding hypotheses hold, we should expect that the order cancelations by institutional investors are more sensitive to the limit-order risks than those by individual investors. We propose a hypothesis as follows.

Hypothesis 5a: The sensitivities of order cancelations by institutional investors to the FTO and the NE risks are higher than those by individual investors.

4.4 Impacts of the global financial tsunami on order cancelations

The year 2008, when the global financial tsunami peaked and turned the global economy upside down (Shefrin and Statman, 2011),[9] is plausibly an information-rich period. Recall that Figure 2 shows that the cancelation ratio is higher during 2008. Rising uncertainty reasonably made investors extra conservative during this crisis, as collapsing financial institutions quickly spread out and economies worldwide suffered. Traders having unfilled limit orders were faced with possibly increasing FTO and NE costs, relative to their monitoring costs, encouraging them to monitor the market and cancel their orders, if necessary.

Foreign investors, more familiar with changes in the global business environment, can effectively incorporate such marketwide information into prices of related large and leading listed firms with adequate liquidity (Chiao *et al.*, 2010). We expect that order cancelations by institutional investors will be even more sensitive to the limit-order risks than those by individual investors during market turmoil. The development of the global financial tsunami years, 2007 and 2008, provides an ideal opportunity to examine whether traders became extra sensitive to the limit-order risks and accordingly changed their behavior on order cancelations. The following hypothesis is proposed to test the difference.

Hypothesis 5b: The increments in the sensitivities of order cancelations by institutional investors to the FTO and the NE risks from 2007 to 2008 are higher than those by individual investors.

5 Measurement of variables and model specifications

5.1 Order aggressiveness at submission

Traders could submit orders at very different prices, trading off the probabilities of execution with transaction costs. Measuring the distance between the limit price and a benchmark price at submission (e.g., the best quotes), order aggressiveness captures traders' eagerness for executions (Biais *et al.*, 1995; Ranaldo, 2004; Griffiths *et al.*, 2000). A

[9] The S&P 500's returns for the years 2006-2009 are respectively 15.8%, 5.5%, -37.0%, and 26.9%.

marketable limit order in a pure limit order book is equivalent to a market order in floor or dealer markets (Hasbrouck and Saar, 2001).

5.1.1 Limit orders submitted after the open

The order aggressiveness of a limit buy and a limit sell after the open is defined as:

$$\begin{aligned} &\text{the order aggressiveness of buy order } j \text{ for stock } i = (P_{i,j} - P_{i,j,ask,s})/P_{i,j,ask,s}, \\ &\text{the order aggressiveness of sell order } j \text{ for stock } i = -(P_{i,j} - P_{i,j,bid,s})/P_{i,j,bid,s}, \end{aligned} \quad (1)$$

where $P_{i,j}$ is the limit price of order j for stock i and $P_{i,j,ask,s}$ ($P_{i,j,bid,s}$), the benchmark price, is the best ask (bid) price in the limit order book at submission. All orders are sorted into the following five order aggressiveness groups: $0 \leq$ order aggressiveness (group 5, the most aggressive group), $-0.5\% \leq$ order aggressiveness $< 0\%$, $-1\% \leq$ order aggressiveness $< -0.5\%$, $-2\% \leq$ order aggressiveness $< -1\%$, order aggressiveness $< -2\%$ (group 1, the least aggressive group). Group 5 consists of marketable limit orders expectedly demanding liquidity, while groups 1 to 4 include all non-marketable limit orders providing liquidity. The higher the order aggressiveness is for a limit order, the more eager the trader is to trade.

5.1.2 Limit orders submitted before the open

As mentioned earlier, since no real-time order information regarding the limit order book is disseminated before the open, it may be inappropriate to follow most of prior papers to apply the definition of order aggressiveness of limit orders submitted after the open to that before the open. Instead, we follow Chiao *et al.* (2009) to define it before the open as:

$$\begin{aligned} &\text{the order aggressiveness of buy order } j \text{ for stock } i = (P_{i,j} - P_{i,C})/P_{i,C}, \\ &\text{the order aggressiveness of sell order } j \text{ for stock } i = -(P_{i,j} - P_{i,C})/P_{i,C}, \end{aligned} \quad (2)$$

where $P_{i,C}$, the benchmark price, is the closing price of stock i in the preceding trading day. Namely, the applied order aggressiveness measures the deviation of the limit price from the preceding day's closing price. All pre-opening orders are sorted into the following five groups: $0 \leq$ order aggressiveness (group 5, the most aggressive), $-0.5\% \leq$ order aggressiveness $< 0\%$, $-1\% \leq$ order aggressiveness $< -0.5\%$, $-2\% \leq$ order aggressiveness $< -1\%$, and order aggressiveness $< -2\%$ (group 1, the least aggressive).

5.2 Order price priority at cancelation

The price priority measures the distance from the limit price of a buy (sell) order to the best bid (ask) in the limit order book at cancelation. The specific definition is as follows:

$$\begin{aligned}&\text{the price priority of canceled buy order } j \text{ for stock } i = (P_{i,j} - P_{i,j,ask,c})/P_{i,j,ask,c},\\&\text{the price priority of canceled sell order } j \text{ for stock } i = -(P_{i,j} - P_{i,j,bid,c})/P_{i,j,bid,c},\end{aligned} \tag{3}$$

where $P_{i,j,ask,c}$ ($P_{i,j,bid,c}$) is the best (ask) bid in the limit order book for stock i at cancelation, and $P_{i,j}$ is the original limit price. All canceled buy and sell orders are separately grouped into the following six groups, based on price priority: group k, if (-0.2% × (6 – k) ≥ price priority > -0.2% × (7 – k)), k = 6 to 2, and group 1, if price priority ≤ -1%.

5.3 Regression models

Mainly following Hasbrouck and Saar (2009) and Fong and Liu (2010) to test the determinants of cancelation ratios, we propose a Tobit regression for each stock across investor groups on the selected firm characteristics and market conditions as follows:

$$\begin{aligned}CANCEL_{i,t} = {} & \alpha_{i,0} + \sum_{n=1}^{17} \alpha_{i,n} \cdot INTER_n + \beta_{i,1} \cdot PUT_{i,t} + \beta_{i,2} \cdot CALL_{i,t} + \beta_{i,3} \cdot RETURN_{i,t-1} \\ & + \beta_{i,4} \cdot RSPREAD_{i,t-1} + \beta_{i,5} \cdot VOL_{i,t-1} + \beta_{i,6} \cdot MARKETRET_{t-1} \\ & + \beta_{i,7} \cdot MARKETVOL_{t-1} + \beta_{i,8} \cdot BIDDEPTH_{i,\Delta t-1} + \beta_{i,9} \cdot ASKDEPTH_{i,\Delta t-1} \\ & + \beta_{i,10} \cdot AVOLU_{i,t,d,m} + \beta_{i,11} \cdot ORDERSIZE_{i,t-1} + \varepsilon_{i,t},\end{aligned} \tag{4}$$

where:

- $CANCEL_{i,t}$ is the cancelation ratio defined as the number of canceled orders for stock i by a given investor group over 15-minute interval t relative to the number of submitted orders by the same investor group over the same trading day. It ranges between 0 and 1.
- $PUT_{i,t}$ and $CALL_{i,t}$, the intrinsic FTO values of limit buy and sell orders or the NE costs of limit sell and buy orders, are respectively defined as:

$$PUT_{i,t} = \max(a_{i,t} - \min(p_{i,t+1}), 0),\ CALL_{i,t} = \max(\max(p_{i,t+1}) - b_{i,t}, 0), \tag{5}$$

where $a_{i,t}$ ($b_{i,t}$) is the best ask (bid) for stock i at the end of interval t. $CALL_{i,t}$ and $PUT_{i,t}$ capture the post-cancelation price movement. max($p_{i,t+1}$) and min($p_{i,t+1}$) are respectively

the maximum and the minimum of $p_{i,t+1}$ over 15-minute interval t+1. Due to the dual nature of the FTO and the NE risks, the NE costs for a limit buy and limit sell are given by $CALL_{i,t}$ and $PUT_{i,t}$, respectively (Fong and Liu, 2010). Namely, an effective FTO risk ($PUT_{i,t}$) facing a limit buy trader implies an ineffective NE risk ($CALL_{i,t}$), and vice versa.

Quite differently, Liu and Sawyer (2003) respectively define $PUT_{i,t}$ and $CALL_{i,t}$ as:

$$PUT_{i,t} = \max(a_{i,t} - p'_{i,t+1}, 0),\ CALL_{i,t} = \max(p'_{i,t+1} - b_{i,t}, 0), \quad (6)$$

where $p'_{i,t+1}$ is the end-of-period bid-ask midpoint. It follows that the FTO values of the buy (sell) orders become effective only when the bid-ask midpoint falls (rises) by more than half of the spread from the end of the previous interval. However, we regard that the end-of-period midquote ($p'_{i,t+1}$) is not as sufficient as the maximum and the minimum over the interval in capturing the true development of the put and the call values. As a special case, the put values in Equations (5) and (6) are equivalent, only if the end-of-period midquote is the lowest over interval t+1.

To show a potential deficiency in the measures proposed by Liu and Sawyer (2003), let us consider a possible scenario. Suppose that the midquote during interval t+1 falls below the end-of-period best ask in interval t, and the option associated with a limit buy becomes in-the-money and opposite-side traders have a chance to exercise the option. However, the midquote at the end of interval t+1 rebounds above the end-of-period ask, which resets $PUT_{i,t}$ to zero, according to Equation (6). It implies that the FTO would not be exercised during the interval, although having been in-the-money.

The implication above is clearly counter-intuitive, and the FTO derived under Equation (6) is apparently undervalued, because the end-of-period midquote employed in Equation (6) fails to capture the true value of the put option value over the interval. On the contrary, under Equation (5), the revised put value remains positive and well captures the turning point of the FTO risk more precisely than that under Equation (6) does. The measures under Equation (5) are expected to better reflect the trade-off limit-order traders truly face over the 15-minute interval.

- $BIDDEPTH_{i,\Delta t\text{-}1}$ and $ASKDEPTH_{i,\Delta t\text{-}1}$, the rates of changes in quoted depths on the bid and ask sides, respectively, are given by:

$$BIDDEPTH_{i,\Delta t-1} = \frac{\sum_{b_{i,t-1} \geq B_{i,t-2}} Q^{b}_{i,t-1}}{Q^{b}_{i,t-2}} - 1,\ ASKDEPTH_{i,\Delta t-1} = \frac{\sum_{a_{i,t-1} \leq A_{i,t-2}} Q^{a}_{i,t-1}}{Q^{a}_{i,t-2}} - 1,$$

where $B_{i,t\text{-}2}$ ($A_{i,t\text{-}2}$) denotes the best bid (ask) price at the end of interval t-2, and $Q^{b}_{i,t-1}$ ($Q^{a}_{i,t-1}$) is the depth in 1000 shares at a bid (ask) price of b (a) at the end of interval t-1.

Depths in the limit order book impact not only traders' order submission, but also order cancelation behavior. Cao *et al.* (2008) suggest that incremental information is embedded in limit orders behind the best bid and offer quotes. Changes in depth are likely to induce variations in the FTO and the NE risks (Duong *et al.*, 2009). For example, when the buy- (sell-) side depths become thin (thick), the stock price faces downward pressure and pending buy orders are more likely to be filled (Parlour, 1998). At this moment, unfilled buy (sell) orders then face a rising FTO (NE) risk. Responding to these changes, order cancelation behavior could change accordingly.

To assess the effect associated with changes in quoted depths, following Fong and Liu (2010), we calculate $BIDDEPTH_{i,\Delta t\text{-}1}$ and $ASKDEPTH_{i,\Delta t\text{-}1}$ by using the best quotes at the end of the previous interval, $B_{i,t\text{-}2}$ and $A_{i,t\text{-}2}$, as the benchmarks, respectively. When the best bid (ask) rises (falls), all the orders with limit prices equal to or greater than the benchmark are counted, and $BIDDEPTH_{i,\Delta t\text{-}1}$ ($ASKDEPTH_{i,\Delta t\text{-}1}$) increases. A fall (rise) in the best bid (ask) implies that trades exhaust the depth at the benchmark, and $BIDDEPTH_{i,\Delta t\text{-}1}$ ($ASKDEPTH_{i,\Delta t\text{-}1}$) is set to -1.

- $ORDERSIZE_{i,t\text{-}1}$ is the average order size in 1000 shares for stock i over interval t-1. As suggested by the literature (e.g., Fong and Liu, 2010; Yeo, 2005), order cancelations increase with order size. The larger the limit order, the longer the order takes to execute, the higher risk the order is exposed to, and the more likely the order is to be canceled.
- $RSPREAD_{i,t\text{-}1}$ is the average 15 minute-by-minute snapshots of the relative spread for stock i over interval t-1. Bid-ask spreads could impact the limit-order risks. A widening spread reflects an increase in the possibility to be picked off or, equivalently, the FTO risk. On the other hand, a larger spread may not necessarily imply higher information asymmetry, but could be driven by liquidity shortage, encouraging some limit order traders to provide liquidity and revise their limit orders inside the spread so as to raise the likelihood of execution (Fong and Liu, 2010).
- $VOL_{i,t\text{-}1}$ is the standard deviation of the minute-by-minute snapshots of the midquote for stock i over interval t-1. High price volatility increases the likelihood of order-execution, thus leading to a higher FTO risk (Copeland and Galai, 1983; Foucault, 1999; Fong and Liu, 2010). However, the impact of high volatility on the NE risk is uncertain and

depends on whether the high volatility is associated with high adverse selection costs (Wald and Horrigan, 2005).

- $RETURN_{i,t\text{-}1}$ is the log change in quote midpoint for stock i over interval t-1, i.e. $\ln p_{i,t\text{-}1} - \ln p_{i,t\text{-}2}$. Stoll (2003) argues that, when bad (good) news for a stock hits, the stock price is likely to trend downwards (upwards). When the FTO (NE) risk of the associated sell (buy) orders rises, the dynamics are likely to impact order cancelation behavior.
- $MARKETVOL_{t\text{-}1}$ is the standard deviation of 15 minute-by-minute snapshots of the market index over interval t-1. $MARKETRET_{t\text{-}1}$ is the log index change of the market, i.e., $\ln(INDEX_{t\text{-}1}) - \ln(INDEX_{t\text{-}2})$. $MARKETRET_{t\text{-}1}$ and $MARKETVOL_{t\text{-}1}$, measuring the impacts of market-wide information (Hollifield *et al.*, 2004), are expected to change traders' order cancelation behavior, similar to the influences of $RETURN_{i,t\text{-}1}$ and $VOL_{i,t\text{-}1}$.
- $AVOLU_{i,t,d,m}$, the abnormal trading volume, is defined as:

$$AVOLU_{i,t,d,m} = \frac{VOLUME_{i,t,d,m}}{MARKETVOLUME_{t,d,m}} - \frac{\overline{VOLUME_{i,t,m}}}{\overline{MARKETVOLUME_{t,m}}},$$

where $VOLUME_{i,t,d,m}$ and $MARKETVOLUME_{t,d,m}$ are respectively the trading volumes of stock i and the market over interval t on day d of month m. $\frac{\overline{VOLUME_{i,t,m}}}{\overline{MARKETVOLUME_{t,m}}}$ is the average relative trading volume over the tth intervals in all trading days of month m. $AVOLU_{i,t,d,m}$ measures the ratio of the trading volume of stock i to the market volume. A positive $AVOLU_{i,t,d,m}$, implying abnormally thick volume and rich information on the stock, encourages traders to closely monitor the market, and vice versa.[10]

- $INTER_n$, n = 1, …, 17, is a dummy variable and takes a value of one, if the cancelations take place in the nth 15-minute interval within any trading day.

The year 2008, when the global financial tsunami peaked and turned the world economy upside down (Shefrin and Statman, 2011), is plausibly an information-rich period. We present Figures 1 and 2 as preliminary evidence showing that the average cancelation ratios separately by all investors and each investor group in 2008 are all higher than those in 2007. Without loss of generality, we further conjecture that order cancelations may have different

[10] Fong and Liu (2010) and Liu and Sawyer (2003) posit that monitoring the market usually relies on the level of trading activities. For example, the thicker the trading volume, then not only the richer the information, but also the lower the monitoring cost. Moreover, high trading volume is likely to attract not only noise traders but also informed traders, raising the FTO values of limit orders and encouraging traders to monitor the market.

sensitivities to the included variables in Equation (4) between 2007 and 2008. To verify our conjecture, we add an interaction term for each independent variable in Equation (4) to highlight the increment from 2007 to 2008. The revised specification is as follows:

$$
\begin{aligned}
CANCEL_{i,t} = {} & \alpha_{i,0} + \sum_{n=1}^{17} \alpha_{i,n} \cdot INTER_n + \sum_{n=1}^{17} \rho_{i,n} \cdot (D \times INTER_n) \\
& + \beta_{i,1} \cdot PUT_{i,t} + \beta_{i,2} \cdot CALL_{i,t} + \beta_{i,3} \cdot RETURN_{i,t-1} + \beta_{i,4} \cdot RSPREAD_{i,t-1} + \beta_{i,5} \cdot VOL_{i,t-1} \\
& + \beta_{i,6} \cdot MARKETRET_{t-1} + \beta_{i,7} \cdot MARKETVOL_{t-1} \\
& + \beta_{i,8} \cdot BIDDEPTH_{i,\Delta t-1} + \beta_{i,9} \cdot ASKDEPTH_{i,\Delta t-1} \\
& + \beta_{i,10} \cdot AVOLU_{i,t,d,m} + \beta_{i,11} \cdot ORDERSIZE_{i,t-1} \\
& + \rho_{i,0} \cdot D + \delta_{i,1}(D \times PUT_{i,t}) + \delta_{i,2}(D \times CALL_{i,t}) + \delta_{i,3}(D \times RETURN_{i,t-1}) \\
& + \delta_{i,4}(D \times RSPREAD_{i,t-1}) + \delta_{i,5}(D \times VOL_{i,t-1}) + \delta_{i,6}(D \times MARKETRET_{t-1}) \\
& + \delta_{i,7}(D \times MARKETVOL_{t-1}) + \delta_{i,8}(D \times BIDDEPTH_{i,\Delta t-1}) + \delta_{i,9}(D \times ASKDEPTH_{i,\Delta t-1}) \\
& + \delta_{i,10}(D \times AVOLU_t) + \delta_{i,11}(D \times ORDERSIZE_{i,t-1}) + \nu_{i,t} \,,
\end{aligned}
\tag{7}
$$

where D is a dummy variable set to one for order cancelations in 2008, and zero otherwise. Similarly, a significantly positive (negative) $\delta_{i,n}$ implies that the sensitivity of order cancelations to the nth independent variable for stock i rises (falls) from 2007 to 2008.

6. Empirical results

In this section, we shall conduct empirical analyses to test the hypotheses developed in Section 4, by employing variables and models introduced in Section 5. Specifically, in Sections 6.1, 6.2, and 6.3, we apply conditional analyses to, first, uncover the differences in the monitoring costs across investor groups. Then, taking these differences as given, we explore how investors cancel their limit orders, reacting to the trade-offs between the limit-order risks. Section 6.4 employs Tobit regressions to further study the sensitivities of order cancelations across investor groups. We, then, examine the changes in the sensitivities to the limit-order risks from 2007 to 2008, the worst year of the global financial tsunami.

6.1 Monitoring costs

Table 3 reports the distributions of buy and sell order cancelations based on order aggressiveness during regular trading hours, as defined in Equation (1). Basically, all submitted limit orders are grouped into five groups. Group 5, the most aggressive one, contains all marketable limit orders expected to be filled immediately, if the order size is not

too large; otherwise, after walking up the limit order book, the part of limit orders unfilled will enter the limit order book and possibly be canceled. Groups 4 to 1 include all non-marketable limit orders, with group 1 as the least aggressive group.[11] The order cancelation ratio is defined as the number of canceled limit orders to the number of submitted limit orders in a given aggressiveness group.

Evidence from Table 3 shows that canceled orders by any investor group demonstrate an inverted U-shaped pattern, regardless of buy or sell orders for large- or small-cap stocks. Most of the cancelation ratios reach their peaks in group 3, lending support to Hypothesis 1. The first (upward-sloping) half of the pattern is plausible and consistent with the literature that order aggressiveness is negatively related to order cancelations. Intuitively, the more aggressive the order, the less time it takes to be filled, the less frequently traders cancel it. The second (downward-sloping) half of the pattern may reflect the behavior of traders who have rather high monitoring costs and are possibly unable to cancel their limit orders.

As argued in Section 4, traders with a high monitoring cost tend to submit limit orders either before the open or at prices far from the best quotes to protect themselves from the FTO risk. To explore the monitoring costs across investor groups, as a first step, we compare their order submission behavior after and before the open, as respectively reported in Tables 3 and 4. Four useful ratios, WEIGHT, RG5, RG4, and RG1, are additionally calculated. WEIGHT, defined as the weight of limit orders submitted by a given investor group to all submitted limit orders, captures the share of limit orders submitted by the investor group. RG5, RG4, and RG1 are respectively the ratios of the numbers of group-5, group-4, and group-1 limit orders to the number of all non-marketable limit orders from groups 4 to 1. Intuitively, RG5 captures traders' preferences toward marketable limit orders, while RG4 and RG1 describe the nearness of the limit prices for traders' non-marketable orders to the best quotes. The higher the RG1 and the lower the RG4, the farther the limit prices are to the best quotes. The higher the RG5, the higher tendency is for the traders to consume liquidity.

As reported in the left half of Table 3, it is clear that the limit orders after the open submitted by individual investors have the lowest RG4 and the highest RG1 (e.g., 0.383 and 0.283 in Panel A, respectively). Moreover, individual investors have the lowest RG5s (e.g., 0.819 in Panel A), implying that they not only prefer non-marketable to marketable limit orders, but also submit non-marketable limit orders at less aggressive prices than other

[11] For robustness, we use different price ranges to define the levels of order aggressiveness. The results are qualitatively equivalent to what we report in the context.

investor groups do. On the contrary, institutional investors having higher RG5 overall consume liquidity. Moreover, when placing non-marketable limit orders, their limit prices are likely to be closer to the best quotes, supporting Hypothesis 2a.

To test Hypothesis 2b, let us shift our focus to the comparisons between Tables 3 and 4 across investor groups. WEIGHT reveals that individual investors playing an overwhelming role submit more than 96% of total limit orders, even higher than that in Table 3. Taking buy orders for large-cap stocks as an example, the WEIGHT reported in Panel A of Table 4 (Table 3) for foreign investors and domestic institutions is respectively 0.014 and 0.019 (0.145 and 0.035), whereas that for individual investors is 0.967 (0.820). The evidence confirms that individual investors submit more limit orders before the open than institutional investors.

Most individual investors cannot closely monitor the market, because of their daytime jobs. However, lunchtime may be an exceptional period during which they can be temporarily free from work and engaged in trading activities. To verify this statement, let us take a look at Figure 3 that plots the 15-minute intraday pattern of canceled orders for each investor group. Most noteworthy is the rising pattern of order cancelations, starting around 12 pm, by individual investors. Explicitly, their lowest buy and sell order cancelations take place all in the interval between 12:00 pm and 12:15 pm, regardless of market capitalization, which is likely to relate to the working schedule of most daytime workers. Namely, they have a time-varying monitoring cost that is particularly high during the morning hours and decreases afterwards until the market closes at 1:30 pm. All the evidence confirms Hypothesis 2b.

Regarding the behavior of institutional investors, Figure 3 shows that they cancel limit orders less frequently rightly after the open and more frequently before the close, whereas individual investors conversely behave. It is possible that, because of the unavailability of real-time information before the open regarding the limit order book that helps resolve overnight information uncertainty, institutional investors with low monitoring costs hesitate to submit orders before the open to avoid unnecessary risk exposures.

After the open, overnight information is incorporated into stock prices, albeit possibly imprecisely. According to Anand *et al.* (2005) and Menkhoff *et al.* (2010), informed traders tend to demand liquidity earlier in a trading day. Hence, it is highly possible that, after the open, institutional investors enthusiastically act as liquidity takers and quickly pick off stale limit orders. In fact, our unreported results demonstrate that institutional investors submit proportionally more marketable limit orders in the 15-minute interval right after the open

than in subsequent 15-minute intervals. Since submitting less non-marketable limit orders, they cancel less limit orders. Before the close, institutional investors supplying liquidity tend to submit non-marketable limit orders. Then, they actively monitor the market and react fast to news by canceling/revising their orders. The evidence supports Hypothesis 3

In this subsection, we have learned how order aggressiveness affects limit order cancelations. However, it is determined at submission, so its relation with order cancelations cannot link to the dynamics of the limit-order risks. Next, applying another measure (the price priority defined in Equation (3)) to assess the distance from the limit price to the prevailing best quotes at cancelation, we shall pay attention to the relation, in a more dynamic sense, between order cancelations and the limit-order risks.

6.2 Limit-order risks

Table 5 reports the distributions of buy and sell canceled orders conditional on price priority. The order cancelation ratio in each priority group is defined as the number of canceled limit orders to the number of submitted limit orders by a given investor group. Firstly, as expected, the canceled orders by all or any investor group exhibit a U-shaped pattern, confirming Hypothesis 4a. There is a monotonically decreasing pattern from group 6 (with the highest price priority) to group 2; however, a sudden jump occurs for group-1 stocks (with the lowest price priority), reflecting the dynamics of the FTO and the NE risks and the trade-off between them facing investors. Plausibly, the higher the price priority, the higher the FTO value, and the more likely investors are to cancel their limit orders, other things being equal. For example, from groups 6 to 2, the buy order cancelation ratios for small-cap stocks by all investors are decreasing and respectively 0.276, 0.132, 0.101, 0.071, and 0.061. Differently, the cancelation ratio in group 1 is 0.360 and even higher than that in group 6. For limit orders in group 6, the FTO risk is reasonably not as effective as for that in other groups. By contrast, the increasingly effective NE risk may exert pressure on traders who have unfilled limit orders so as to revise (part of) them at more aggressive prices to raise the likelihood of execution. The inducement is even stronger, when traders expect stock prices to trend away from their orders' prices.

Secondly, across investor groups, foreign investors proportionally cancel the most limit orders in the highest price priority group, while individual investors do so in the lowest price priority group, supporting Hypothesis 4b. For example, for small-cap stocks, the cancelation

ratios of buy orders in the highest and the lowest price priority groups are respectively 0.486 and 0.122, while the ratios by domestic institutions (individual investors) are 0.266 and 0.358 (0.259 and 0.382), respectively. The sharp differences reflect the groups' monitoring costs and order submission behavior, consistent with earlier observations. Namely, foreign investors, having the lowest monitoring cost and submitting more non-marketable limit orders near the best quotes, closely monitor the market to reduce their exposure to the FTO risk, which explains why they cancel proportionally more limit orders near the best quotes.[12]

Thirdly, market capitalization matters for order cancelations as well. In Table 5, taking the sell orders as an example, the difference in the order cancelation ratios by all investors between large- and small-cap stocks in group 6 is 0.052 (=0.290 – 0.238), while that in group 6 is -0.070 (=0.360 – 0.430). Obviously, order cancelations for large-cap stocks are likely to take place at prices closer to the best quotes than those for small-cap stocks, which is consistent with Duong *et al.* (2009) and Aitken *et al.*(2007).

As reported in Table 3, the RG4 for small-cap stocks is smaller than those for large-cap stocks, implying not only that limit orders for small-cap stocks are less aggressive, but also that the associated FTO risk for small-cap stocks is not as serious as that for large-cap stocks. On the contrary, the NE risk for small-cap stocks is more visible than that for large-cap stocks. As suggested by the traditional wisdom (e.g., Gompers and Metrick (2001) and Frieder and Subrahmanyam (2005)) and Table 2 in this paper, foreign investors prefer large-cap stocks, which partly explains the observations consistent with Hypothesis 4b.

6.3 The sensitivities of order cancelations to the limit-order risks

In this sub-section we apply Tobit regressions, as described in Equations (4) and (7), to test the relation between order cancelations and the monitoring cost as well as the limit-order risks across investor groups. Recall that we revise the definition of $PUT_{i,t}$ ($CALL_{i,t}$) proposed by Liu and Sawyer (2003) by replacing the end-of-the-period bid-ask midpoint with the minimum (maximum) midpoint over interval t+1, as explained in Equations (5) and (6). For conciseness, we do not report the full regression results applying the original $PUT_{i,t}$ and

[12] As a robustness test, we divide the sample into price-priority groups based on different ranges from those in the context, and the qualitative changes do not essentially alter our conclusions.

$CALL_{i,t}$, but do mention the differences between the two sets of coefficients in the context. Table 6 reports the regression results applying the revised $PUT_{i,t}$ and $CALL_{i,t}$.[13]

The coefficients on $PUT_{i,t}$ and $CALL_{i,t}$ are, as expected, mostly significantly positive and consistent with Fong and Liu (2010). It follows that the FTO and the NE risks unambiguously play a positive role in order cancelations. When stock prices move closer to (away from) the best quotes, the rising FTO (NE) risk raises the possibility of order cancelations. Among investor groups, regardless of buy or sell orders, the impacts of the FTO and the NE risks on order cancelations are highest for foreign investors, whereas those for individual investors are the least. In Panel B, three out of four coefficients of the order cancelation ratio for individual investors are even negative. Since individual investors have a higher monitoring cost, it is reasonable that they can neither closely monitor the market nor be as keen as institutional investors to respond to changes in the FTO and the NE risks, as unexpected information arrives. The evidence supports Hypothesis 5a that the sensitivities of individual investors' order cancelations to $PUT_{i,t}$ and $CALL_{i,t}$ are the lowest among the investor groups.[14]

However, if applying Equation (6) to measure $PUT_{i,t}$ and $CALL_{i,t}$, as originally proposed by Liu and Sawyer (2003), the (unreported) coefficients are very different from those reported in Table 6. For instance, in Panel A of Table 6 the coefficients on $PUT_{i,t}/100$ for buy (sell) orders by foreign investors, domestic institutions, and individual investors are respectively 0.289, 0.148, and 0.036 (0.254, 0.214, and 0.168), while the unreported coefficients on the Liu and Sawyer's $PUT_{i,t}/100$ are 0.335, 0.116, and 0.029 (0.118, 0.246, and 0.173). Only half of them are significant at the 10% level, while those reported in Panel A are all significant at the 1% level. Furthermore, the unreported coefficient on the Liu and Sawyer's $PUT_{i,t}/100$ for sell orders by individual investors (0.173) is counter-intuitively greater than that by foreign investors (0.118). Instead, those reported in Table 6 are more credible, suggesting an improvement by the measures proposed by this paper.

As for the coefficients on other (control) variables, those on $VOL_{i,t-1}$ are all significantly positive, regardless of investor groups, implying that owing to the option-like feature, the higher the price volatility, the more costly the limit orders. This is because rising volatility makes the FTO associated with the orders more valuable and likely to become in-the-money (Foucault, 1999). To deal with it, limit-order traders require larger compensation for the

[13] For brevity, the coefficients on the interval dummies are unreported, but available upon request.

[14] The unreported results for the pairwise comparisons of the coefficients on $PUT_{i,t}$ and $CALL_{i,t}$ between investor groups confirm that their order-cancelation sensitivities to the limit-order risks are different.

rising FTO risk, by revising currently unfilled limit orders and resubmitting new orders with lower price priorities. Proxying for the arrival of public information, the market index volatility ($MARKETVOL_{t\text{-}1}$) similarly impacts order cancelations, indicating that high market index volatility implies high uncertainty. As for the impacts of $RETURN_{i,t\text{-}1}$ and $MARKETRET_{t\text{-}1}$ on order cancelations, they are not as strong as those of $VOL_{i,t\text{-}1}$ and $MARKETVOL_{t\text{-}1}$, although most of them are significantly positive. This is actually not surprising, because part of the impacts of price movement on order cancelations have been absorbed by the FTO and the NE costs, denoted by $PUT_{i,t}$ and $CALL_{i,t}$ in (5).

Variations in the FTO and the NE risks could be induced by changes in depths as well (Ranaldo, 2004; Duong *et al.*, 2009). Recall that $BIDDEPTH_{i,\Delta t\text{-}1}$ ($ASKDEPTH_{i,\Delta t\text{-}1}$) employed in Equation (4) measures the cumulated depth in period *t*-1 above the best bid (ask) at the end of period *t*-2, relative to the depth at the best bid (ask) at the end of period *t*-2. If period *t*-1's bid (ask) falls below (rises above) period *t*-2's best bid (ask), the measure is equal to -1. If certain news hits the stock, then its price could be impacted by positive (negative) demand shocks, driving its $BIDDEPTH_{i,\Delta t\text{-}1}$ ($ASKDEPTH_{i,\Delta t\text{-}1}$) upwards.

The coefficients of buys (sells) on $BIDDEPTH_{i,\Delta t\text{-}1}$ are mostly positive (negative), while those on $ASKDEPTH_{i,\Delta t\text{-}1}$ are mostly negative (positive), particularly for institutional investors. Fong and Liu (2010) argue that limit-order traders would be given more opportunities to revise their orders when the market moves away from them than when the market moves against them. The above finding might imply that, when the depth increases, traders who have unfilled limit orders on the same side may feel pressure from the rising NE risk. Since the waiting orders are expected to take longer to execute, the traders can easily revise the original orders to raise their price priorities. However, the stale limit orders on the opposite side may be quickly picked off.

Compared to the coefficients for institutional investors, interestingly, those for individual investors are not as clear, and some of them even demonstrate an opposite sign. Suppose that individual investors have a higher monitoring cost and tend to submit limit orders at less aggressive prices. It is not surprising that they are less sensitive to changes in depth, especially when the concurrent best quotes are still far from the limit prices.

The coefficients on the relative spread ($RSPREAD_{i,t\text{-}1}$) are mostly significantly positive, consistent with the literature. A larger relative spread is possibly associated with greater uncertainty. Traders can either require larger compensation by resubmitting orders at prices farther from the best quotes or closely monitor the market and cancel orders, if necessary (Liu,

2009). Regarding trading volume, the coefficients are all significantly positive for each investor group. Recall that $AVOLU_{i,t,d,m}$ measures the abnormal trading volume of stock *i* and proxies for the level of trading activities. When the relative stock volume is abnormally high, traders pay attention to the stock as the opportunity cost of not monitoring it is high.

Overall, individual stock returns and price volatility, market returns and volatility, the relative bid-ask spread, and the abnormal trading volume have positive impacts on order cancelations. The buy- (sell-) side depth has a positive effect on buy (sell) order cancelations and a negative effect on sell (buy) order cancelations. Regarding the behavior differences in order cancelations across investor groups, it is unsurprising and consistent with prior observations that individual investors, who have a higher monitoring cost than institutional investors do, do not respond as sensitively as institutional investors, according to the magnitudes of the coefficients.

6.4 Impacts of the global financial tsunami on order cancelations

As mentioned earlier, different monitoring costs and order submission behavior among investor groups lead to different limit-order risks they face after submission and, hence, different order cancelation behavior. The global financial tsunami even widens the differences, as drawn in Figure 2. Equation (7) estimates the increments in the sensitivities ($\delta_{i,n}$, n = 1, …, 11) from 2007 to 2008 for a given investor group. Table 7 records the results.

First, the reported coefficients on the interaction terms are mostly significantly positive, except those on the bid and the ask depths ($D{\times}BIDDEPTH_{i,\Delta t\text{-}1}$ and $D{\times}ASKDEPTH_{i,\Delta t\text{-}1}$). In addition, the coefficients for foreign investors are mostly the highest, while those for individual investors are the lowest. It follows that investors are increasingly sensitive to most of the selected variables. Second, comparing the coefficients on $PUT_{i,t}$ and $CALL_{i,t}$ in Tables 7 and 8, the sensitivities of foreign investors and domestic institutions to the FTO and the NE risks in 2008 are strikingly more than double those in 2007. As for individual investors, their sensitivities do increase, but are not as robust. The results shed light on Hypothesis 5b.

Before concluding this paper, note that, for conciseness, all results are derived primarily using the number of canceled orders. To ensure the robustness of our results, we also apply the volume of canceled orders to study the issues of this paper. The results are not reported and essentially resemble the results reported above.

7. Concluding remarks

Employing intraday data, this paper studies the order cancelation behavior of investors and particularly places emphasis on behavior differences across investor groups. To clearly differentiate this paper from prior studies, the derived conclusions are separated into two major categories: those consistent with the literature and the others regarding the behavior across investor groups previously unexplored.

In the former category, firstly, the FTO and the NE risks are crucial determinants of order cancelations. Secondly, order cancelations exhibit a U-shaped intraday pattern– that is, investors cancel their orders more frequently after the market open and before the close. Thirdly, the relation between order cancelations and concurrent price priority is U-shaped. Namely, when the concurrent quotes move closer to (farther from) the limit prices, traders confront a rising FTO (NE) risk and are more likely to cancel these orders. Finally, firm size matters for order cancelations. Traders who submit limit orders for large-cap (small-cap) stocks face a higher FTO (NE) risk, so they are more likely to cancel the limit orders when the prevailing quotes move closer to (farther from) the limit prices.

The latter category includes the following. Firstly, institutional investors, especially foreign investors, closely monitor the market and actively cancel their orders. Individual investors with a higher monitoring cost do not frequently cancel their orders until noon, reflecting the fact that they are unable to do so during regular working hours. Secondly, foreign investors, having a lower monitoring cost and submitting limit orders around the best quotes, are more aware of the FTO risk and tend to cancel limit orders with higher price priorities. Thirdly, applying a regression analysis, we show that the sensitivities of order cancelations by foreign investors to the FTO and the NE risks are the highest, while those by individual investors are the lowest. Fourthly, order cancelations proportionally increased from 2007 to 2008, as the result of rising uncertainty. Moreover, the sensitivities of order cancelations by foreign investors and domestic institutions to the FTO and the NE risks more than doubled from 2007 to 2008.

Finally, it is worthwhile to mention that, to precisely capture the limit-order risks, this paper proposes a revision of the FTO and the NE risks initially developed by Liu and Sawyer (2003). The improvement has been empirically confirmed in this paper as a contribution to the literature.

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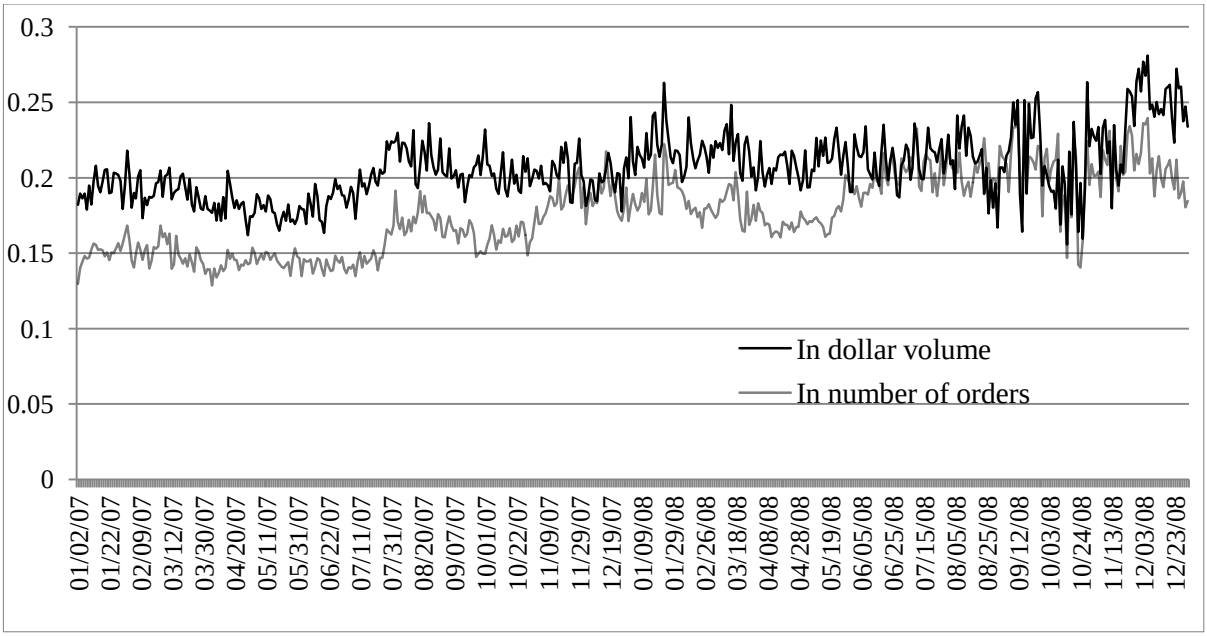
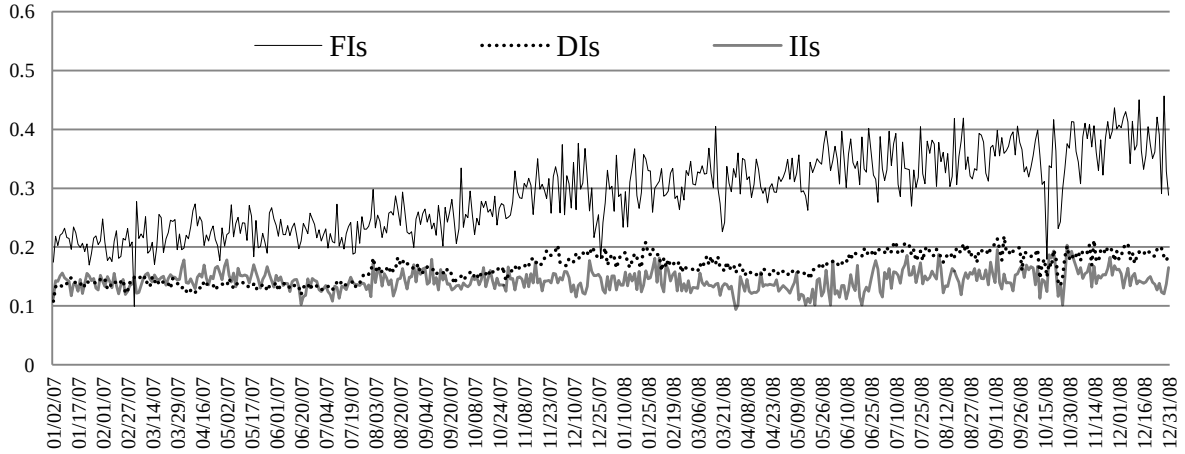


Figure 1. The daily proportions of canceled orders to all submitted orders

This figure plots the average daily proportions of canceled orders separately in dollar volume and in number of canceled orders to total submitted limit orders over 2007 and 2008. In terms of dollar volume, the averages are respectively 15.84% and 19.43% for 2007 and 2008, whereas in terms of number of canceled orders they are 19.52% and 21.75%.

Panel A. For large-cap stocks



Panel B. For small-cap stocks

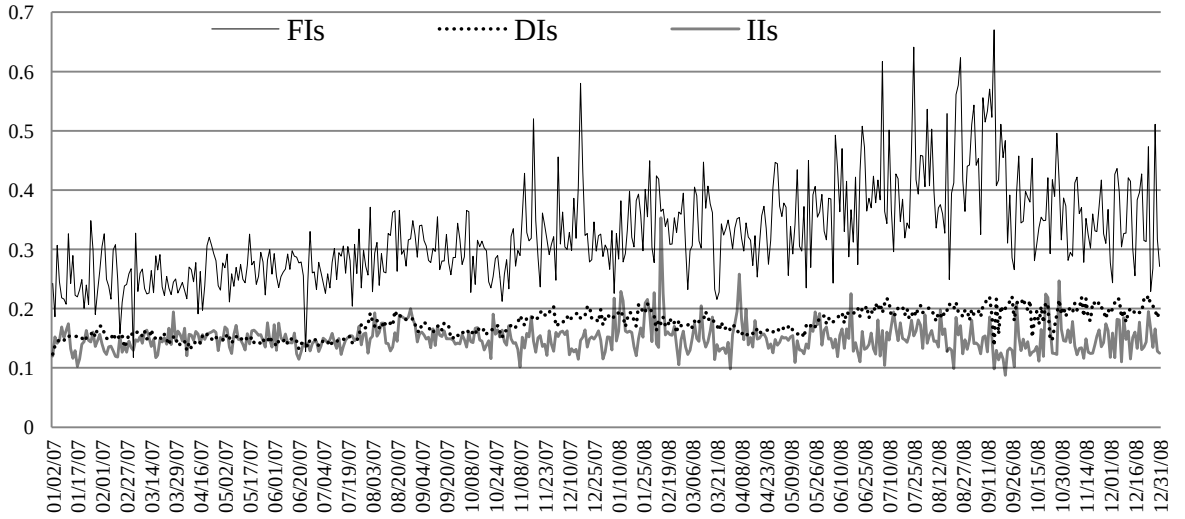


Figure 2. The proportions of canceled orders by investor groups

This figure chronologically plots the average order cancelation ratios among investor groups for large-cap (small-cap) stocks in Panel A (B). The order cancelation ratio for a given investor group over a trading day is defined as the number of canceled orders relative to the number of all submitted orders by the same investor group. The three investor groups are FIs, DIs, and IIs, standing for foreign investors, domestic institutions, and individual investors, respectively. Their averages for large-cap (small-cap) stocks are 0.290, 0.165, and 0.143 (0.326, 0.174, and 0.150), respectively.

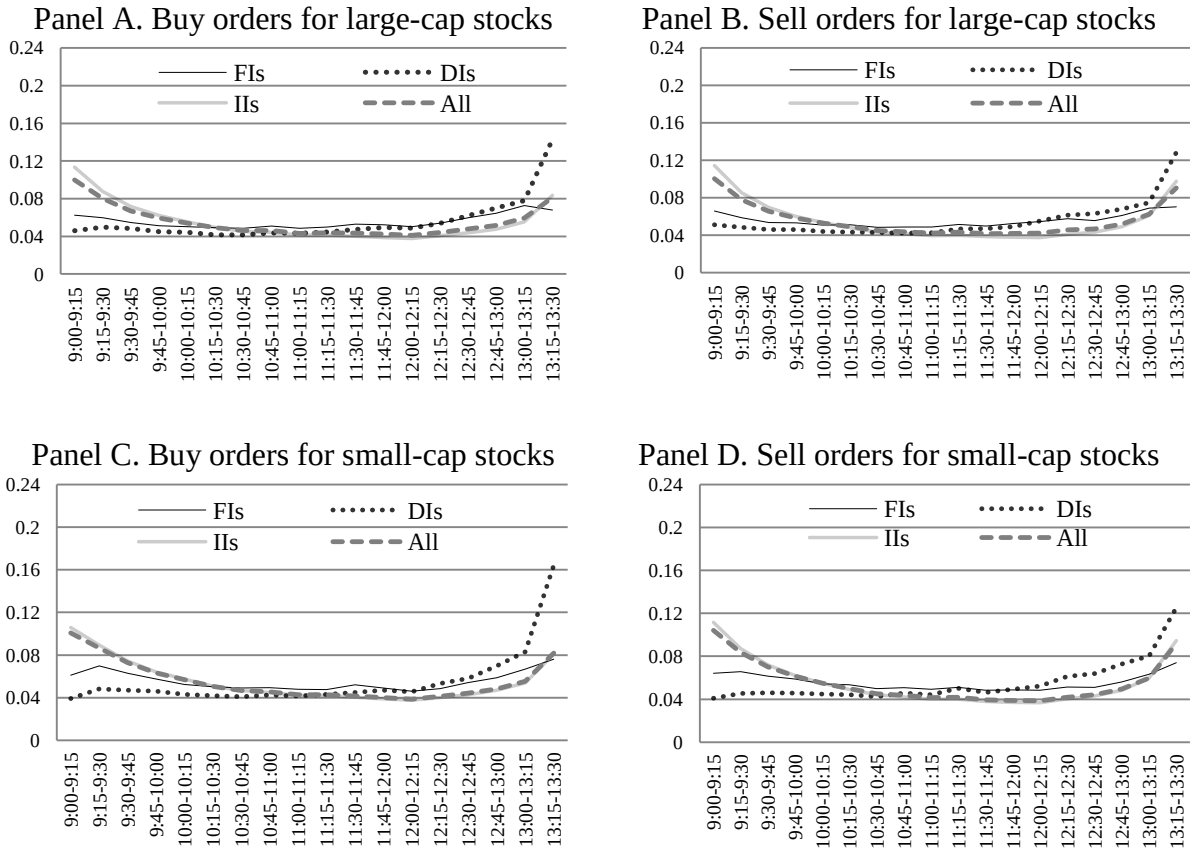


Figure 3. The proportions of canceled orders by each investor group over 15-minute intervals

This figure plots the 15-minute order cancelation ratios by each investors group over a trading day. The ratio is defined as the number of canceled buy or sell orders over a given 15-minute interval to that by the investor group over the entire trading day, separately for large- and small-cap stocks. The three investor groups are FIs, DIs, and IIs, standing for foreign investors, domestic institutions, and individual investors, respectively.

Table 1. Summary statistics of selected stocks

This table reports the cross-sectional daily trading information of our sample firms from 1/2007 to 12/2008, totaling 496 trading days and 375 common stocks. The sample stocks are the largest 50% of firms, based on market capitalization. The market capitalization of a firm is calculated as the product of the closing prices and the number of outstanding shares at the beginning of the sample period. The absolute spread is the difference between the ask and the bid prices at the close. The relative spread is defined as the ratio of the quoted spread to the midpoint of the best quotes. All reported statistics are computed by using the time-series average of each selected firm. The reported statistics are cross-sectional means over the time-series averages of individual stocks.

	Market Cap. (in billion NT$)	Trading Volume (in millions of shares)	Stock price (in NT$)	Absolute spread (in NT$)	Relative spread (%)
Mean	50.766	7.958	47.690	0.170	0.092
Median	15.199	4.502	30.521	0.094	0.085
Max	1586.321	72.966	562.825	2.839	0.297
Min	3.740	0.112	5.338	0.016	0.042

Table 2. Submitted orders and canceled orders by the three investor groups

This table reports the average daily numbers of submitted (canceled) orders by each investor group relative to the numbers of all submitted (canceled) orders and their order sizes. The three investor groups are FIs, DIs, and IIs, standing for foreign investors, domestic institutions, and individual investors, respectively.

Order characteristics		Buys			Sells		
		FIs	DIs	IIs	FIs	DIs	IIs
Panel A. For large-cap stocks							
Proportion of submitted orders		0.161	0.039	0.800	0.177	0.038	0.785
Order size in	1000 shares	13.524	27.465	6.441	14.326	27.314	6.343
	million NT$	0.613	1.251	0.252	0.636	1.244	0.249
Proportion of canceled orders		0.226	0.028	0.746	0.240	0.028	0.733
Order size in	1000 shares	11.971	28.645	9.692	13.068	28.289	7.522
	million NT$	0.562	1.372	0.381	0.609	1.374	0.317
Panel B. For small-cap stocks							
Proportion of submitted orders		0.053	0.030	0.917	0.068	0.031	0.901
Order size in	1000 shares	7.504	19.143	6.940	7.144	18.206	6.500
	million NT$	0.232	0.633	0.180	0.212	0.599	0.167
Proportion of canceled orders		0.082	0.023	0.896	0.108	0.024	0.869
Order size in	1000 shares	6.269	19.855	10.983	5.777	17.590	7.635
	million NT$	0.204	0.691	0.286	0.178	0.620	0.207

Table 3. Order cancelations and the aggressiveness of limit orders submitted after the open

This table reports the average daily numbers of submitted orders and the order cancelation ratios based on order aggressiveness. The order cancelation ratio is defined as the number of canceled limit orders to the number of submitted limit orders by a given investor group in a given aggressiveness group. Order aggressiveness measures the relative distance from the limit prices to the best quotes when the orders are submitted during regular trading hours and is defined as follows:

$$\text{the order aggressiveness of buy order } j \text{ for stock } i = (P_{i,j} - P_{i,j,ask})/P_{i,j,ask},$$
$$\text{the order aggressiveness of sell order } j \text{ for stock } i = -(P_{i,j} - P_{i,j,bid})/P_{i,j,bid},$$

where $P_{i,j,ask}$ ($P_{i,j,bid}$) is the best (ask) ask price of buy (sell) order j for stock i, and $P_{i,j}$ is the limit price of order j for stock i. All orders are sorted into the following five groups:

$0 \leq$ order aggressiveness (the most aggressive),
$-0.5\% \leq$ order aggressiveness $< 0\%$,
$-1\% \leq$ order aggressiveness $< -0.5\%$,
$-2\% \leq$ order aggressiveness $< -1\%$,
order aggressiveness $< -2\%$ (the least aggressive).

The most aggressive or the first-group orders are marketable limit orders, while those in the other groups are all non-marketable limit orders. FIs, DIs, and IIs stand for foreign investors, domestic institutions, and individual investors, respectively. WEIGHT is defined as the weight of limit orders by a given investor group to all limit orders. RG5 [RG4] (RG1) is the ratio of the number of (group-5) [group-4] (group-1) limit orders to that of all non-marketable limit orders from groups 4 to 1.

Order aggressiveness	Number of submitted orders				Order cancelation ratio			
	ALL	FIs	DIs	IIs	ALL	FIs	DIs	IIs
				Panel A. Buy orders for large-cap stocks				
Marketable								
5 (Most agg.)	207667	32791	9089	165787	0.060	0.080	0.044	0.057
Non-marketable								
4	107191	25531	4092	77568	0.282	0.448	0.253	0.227
3	39902	3974	1227	34701	0.341	0.663	0.309	0.301
2	35197	1601	736	32860	0.308	0.588	0.287	0.291
1 (Least agg.)	59212	1012	786	57414	0.216	0.402	0.235	0.211
WEIGHT		0.145	0.035	0.820				
RG5		1.021	1.329	0.819				
RG4		0.795	0.598	0.383				
RG1		0.032	0.115	0.283				
				Panel B. Sell orders for large-cap stocks				
Marketable								
5 (Most agg.)	199023	33661	8690	156672	0.051	0.082	0.046	0.044
Non-marketable								
4	88822	24959	3438	60425	0.318	0.465	0.280	0.255
3	33373	4005	1051	28317	0.370	0.679	0.331	0.321
2	35087	1710	721	32656	0.325	0.610	0.288	0.304
1 (Least agg.)	83160	1132	1106	80922	0.215	0.423	0.194	0.211
WEIGHT		0.149	0.034	0.817				
RG5		1.058	1.376	0.774				
RG4		0.785	0.544	0.299				
RG1		0.036	0.175	0.400				
				Panel C. Buy orders for small-cap stocks				
Marketable								
5 (Most agg.)	73367	3489	2239	67639	0.066	0.099	0.069	0.065
Non-marketable								
4	33583	2661	1015	29907	0.238	0.435	0.235	0.219
3	17190	719	472	15999	0.307	0.596	0.258	0.293
2	15056	337	309	14410	0.322	0.613	0.244	0.314
1 (Least agg.)	22066	152	224	21690	0.236	0.508	0.260	0.233
WEIGHT		0.046	0.026	0.928				
RG5		0.902	1.108	0.825				
RG4		0.073	0.091	0.121				
RG1		0.039	0.111	0.264				
				Panel D. Sell orders for small-cap stocks				
Marketable								
5 (Most agg.)	72511	3951	2444	66116	0.051	0.103	0.058	0.048
Non-marketable								
4	27576	2801	937	23838	0.283	0.476	0.277	0.254
3	13783	833	401	12549	0.340	0.627	0.295	0.314
2	14673	517	299	13857	0.334	0.621	0.254	0.315
1 (Least agg.)	35488	238	342	34908	0.236	0.475	0.206	0.232
WEIGHT		0.051	0.027	0.922				
RG5		0.900	1.235	0.776				
RG4		0.075	0.085	0.095				
RG1		0.054	0.173	0.410				

Table 4. Aggressiveness of limit orders submitted before the open

This table reports the average daily numbers of canceled orders based on order aggressiveness, measured as the relative distance from the limit prices to the previous closing prices. The order aggressiveness of limit orders submitted before the open in this paper as follows:

$$\text{the order aggressiveness of buy order } j \text{ for stock } i = (P_{i,j}-P_{i,C})/P_{i,C},$$
$$\text{the order aggressiveness of sell order } j \text{ for stock } i = -(P_{i,j}-P_{i,C})/P_{i,C},$$

where $P_{i,C}$ is the closing price for stock i for the preceding trading day and $P_{i,j}$ is the limit price of order j for stock i. For a given stock, the applied order aggressiveness measures the deviation of the limit price from the preceding day's closing price. All pre-opening orders are sorted into the following five groups: 0 ≤ order aggressiveness (group 5, the most aggressive group), -0.5% ≤ order aggressiveness < 0%, -1% ≤ order aggressiveness < -0.5%, -2% ≤ order aggressiveness < -1%, and order aggressiveness < -2% (group 1, the least aggressive group). WEIGHT is defined as the number of limit orders submitted by a given investor group to all limit orders. RG4 (RG1) is the ratio of the number of group-4 (group-1) limit orders to that of all non-marketable limit orders from groups 4 to 1. FIs, DIs, and IIs stand for foreign investors, domestic institutions, and individual investors, respectively.

Order	Number of submitted buy orders				Number of submitted sell orders			
aggressiveness	ALL	FIs	DIs	IIs	ALL	FIs	DIs	IIs
				Panel A. For large-cap stocks				
5 (Most agg.)	13871	159	720	12992	8147	296	712	7140
4	1305	49	43	1212	907	42	49	815
3	2591	64	47	2480	2162	69	56	2038
2	6601	126	65	6411	7216	159	76	6981
1 (Least agg.)	30814	382	188	30244	50534	673	248	49613
WEIGHT		0.014	0.019	0.967		0.018	0.017	0.966
RG4		0.079	0.125	0.030		0.045	0.114	0.014
RG1		0.615	0.548	0.750		0.714	0.578	0.835
				Panel B. For small-cap stocks				
5 (Most agg.)	5652	43	73	5535	3219	102	63	3055
4	515	12	8	495	304	13	6	285
3	961	17	6	939	754	21	7	727
2	2366	33	7	2327	2592	49	11	2531
1 (Least agg.)	10835	98	19	10718	20723	206	40	20477
WEIGHT		0.010	0.006	0.985		0.014	0.005	0.981
RG4		0.075	0.200	0.034		0.045	0.094	0.012
RG1		0.613	0.475	0.740		0.713	0.625	0.852

Table 5. Canceled orders with different price priorities at cancelation

This table reports the ratios of canceled orders with different price priorities by the three groups of investors. The order cancelation ratio is defined as the number of canceled limit orders by a given investor group in each priority group to the number of submitted limit orders by the same investor group. The price priority measures the relative distance from the concurrent stock price associated with a given buy (sell) order to the concurrent best bid (ask). The specific definitions are as follows:

$$\text{the price priority of canceled buy order } j \text{ for stock } i = (P_{i,j} - P_{i,j,bid,c})/P_{i,j,bid,c},$$
$$\text{the price priority of canceled sell order } j \text{ for stock } i = (P_{i,j,ask,c} - P_{i,j})/P_{i,j,ask,c},$$

where $P_{i,j,ask,c}$ ($P_{i,j,bid,c}$) is the concurrent best (ask) ask price of canceled buy (sell) order j for stock i, and $P_{i,j}$ is the limit price of canceled order j for stock i. All canceled buy and sell orders are separately grouped into six groups, from high to low, based on price priority:

$0 \geq$ price priority $>$ -0.2% (group 6),
-0.2% $\geq$ price priority $>$ -0.4%,
-0.4% $\geq$ price priority $>$ -0.6%,
-0.6% $\geq$ price priority $>$ -0.8%,
-0.8% $\geq$ price priority $>$ -1%,
-1% $\geq$ price priority (group 1).

The average cancelation ratios are calculated separately for buy and sell orders for all limit orders in each priority group by each group of investors over all stocks. FIs, DIs, and IIs stand for foreign investors, domestic institutions, and individual investors, respectively.

Price priority	Buy order cancelation ratio				Sell order cancelation ratio			
	ALL	FIs	DIs	IIs	ALL	FIs	DIs	IIs
				Panel A. Large-cap stocks				
High	0.318	0.513	0.298	0.263	0.290	0.508	0.277	0.225
5	0.150	0.194	0.148	0.137	0.137	0.188	0.140	0.120
4	0.102	0.110	0.105	0.098	0.095	0.108	0.102	0.089
3	0.068	0.054	0.078	0.070	0.065	0.056	0.077	0.066
2	0.054	0.035	0.063	0.059	0.053	0.037	0.064	0.057
Low	0.308	0.094	0.309	0.372	0.360	0.103	0.340	0.443
				Panel B. Small-cap stocks				
High	0.276	0.486	0.266	0.259	0.238	0.476	0.243	0.214
5	0.132	0.179	0.132	0.128	0.116	0.174	0.126	0.110
4	0.101	0.112	0.101	0.099	0.091	0.109	0.099	0.087
3	0.071	0.061	0.077	0.071	0.067	0.062	0.076	0.065
2	0.061	0.040	0.066	0.062	0.059	0.045	0.069	0.059
Low	0.360	0.122	0.358	0.382	0.430	0.136	0.387	0.465

Table 6. Tobit regressions

This table presents the cross-sectional regression results of the Tobit model for each of the three investor groups as follows:

$$CANCEL_{i,t} = \alpha_{i,0} + \beta_{i,1} \cdot PUT_{i,t} + \beta_{i,2} \cdot CALL_{i,t} + \beta_{i,3} \cdot RETURN_{i,t-1} + \beta_{i,4} \cdot RSPREAD_{i,t-1} + \beta_{i,5} \cdot VOL_{i,t-1} + \beta_{i,6} \cdot MARKETRET_{t-1} + \beta_{i,7} \cdot MARKETVOL_{t-1} + \beta_{i,8} \cdot BIDDEPTH_{i,\Delta t-1} + \beta_{i,9} \cdot ASKDEPTH_{i,\Delta t-1} + \beta_{i,10} \cdot AVOLU_{i,t,d,m} + \beta_{i,11} \cdot ORDERSIZE_{i,t-1} + \sum_{n=1}^{17} \alpha_{i,n} \cdot INTER_n + \varepsilon_{i,t},$$

where $CANCEL_{i,t}$ is the cancelation ratio defined as the number of canceled orders for stock *i* by the given investor group over 15-minute interval *t* to the number of submitted limit orders by the same investor group over that trading day. $PUT_{i,t}$ ($CALL_{i,t}$), the free option value of the buy (sell) limit orders or the cost of non-execution of the sell (buy) limit orders, is defined as:

$$PUT_{i,t} = \max(a_{i,t} - \min(p_{i,t+1}), 0),\ CALL_{i,t} = \max(\max(p_{i,t+1}) - b_{i,t}, 0),$$

where $a_{i,t}$ ($b_{i,t}$) are the best ask (bid) for stock *i* at the end of interval *t*, and $p_{i,t+1}$ is the quote midpoint at the end of interval *t*+1. $RSPREAD_{i,t-1}$ is the average 15 minute-by-minute snapshots of the relative spread for stock *i* over interval *t*-1. $VOL_{i,t-1}$ is the standard deviation of the minute-by-minute snapshots of the midquote over interval *t*-1, and $MARKETVOL_{t-1}$ is the standard deviation of 15 minute-by-minute snapshots of the market index over interval *t*-1. $RETURN_{i,t-1}$ and $MARKETRET_{t-1}$ are the log changes in stock *i*'s midquote and market index over interval *t*-1, respectively. The rates of changes in depths on the bid and ask sides are defined as follows:

$$BIDDEPTH_{i,\Delta t-1} = \frac{\sum_{b_{i,t-1} \geq B_{i,t-2}} Q^b_{i,t-1}}{Q^b_{i,t-2}} - 1,\ ASKDEPTH_{i,\Delta t-1} = \frac{\sum_{a_{i,t-1} \leq A_{i,t-2}} Q^a_{i,t-1}}{Q^a_{i,t-2}} - 1,$$

where $B_{i,t-2}$ ($A_{i,t-2}$) denotes the best bid (ask) price at the end of interval *t*. $Q^b_{i,t-1}$ ($Q^a_{i,t-1}$) denotes the depths in thousands of shares at price *b* (*a*) in the bid (ask) side at the end of interval *t*-1. The abnormal trading volume ($AVOLU_{i,t,d,m}$) is calculated as:

$$AVOLU_{i,t,d,m} = \frac{VOLUME_{i,t,d,m}}{MARKETVOLUME_{t,d,m}} - \frac{\overline{VOLUME_{i,t,m}}}{MARKETVOLUME_{t,m}}$$

where $VOLUME_{i,t,d,m}$ and $MARKETVOLUME_{t,d,m}$ are respectively the trading volumes of stock *i* and the market over interval *t* on day *d* of month *m*. $\frac{\overline{VOLUME_{i,t,m}}}{MARKETVOLUME_{t,m}}$ is the average trading volume over intervals *t* in all trading days of month *m*. $ORDERSIZE_{i,t-1}$ is the order size in thousand shares. $INTER_n$, n = 1, ..., 17, is a dummy variable and takes a value of one, if the cancelation requests are submitted in the n*th* interval of a given trading day. For brevity, the coefficients on the interval dummies are not reported. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. FIs, DIs, and IIs stand for foreign investors, domestic institutions, and individual investors, respectively.

Independent variable	Buys			Sells		
	FIs	DIs	IIs	FIs	DIs	IIs
			Panel A. Large-cap stocks			
Constant	0.014***	0.028***	0.013***	0.014***	0.023***	0.019***
$PUT_{i,t}$/100	0.289***	0.148	0.036	0.254***	0.214***	0.168***
$CALL_{i,t}$/100	0.276***	0.121*	0.083***	0.427***	0.335***	-0.158***
$RETRUN_{i,t-1}$	0.073***	0.189***	0.067***	0.021	-0.072***	0.051***
$RSPREAD_{i,t-1}$	0.827***	0.242***	0.250***	0.845***	0.230***	0.317***
$VOL_{i,t-1}$	0.006***	0.011***	0.013***	0.008***	0.012***	0.013***
$MARKETRET_{t-1}$	0.221***	0.039***	-0.066***	-0.057***	0.139***	-0.001
$MARKETVOL_{t-1}$/100	0.163***	0.048***	0.063***	0.206***	0.068***	0.089***
$BIDDEPTH_{i,\Delta t-1}$/10000	0.188***	0.157***	0.044	-0.130***	-0.081***	0.041***
$ASKDEPTH_{i,\Delta t-1}$/10000	-0.115***	-0.099***	0.012	0.120	0.069	0.039
$AVOLU_{i,t,d,m}$	2.441***	2.217***	2.188***	2.072***	2.600***	2.335***
$ORDERSIZE_{i,t-1}$/10000	0.020 **	0.008***	0.009***	0.025***	0.011***	-0.002*
			Panel B. Small-cap stocks			
Constant	0.012***	0.015***	0.012***	0.010***	0.012***	0.018***
$PUT_{i,t}$/100	0.341***	0.269***	-0.008	0.510***	0.287***	0.175***
$CALL_{i,t}$/100	0.445***	0.300***	-0.002	0.461***	0.449***	-0.159***
$RETRUN_{i,t-1}$	0.045***	0.121***	0.066***	0.079***	-0.042***	0.032***
$RSPREAD_{i,t-1}$	0.413***	0.107*	0.279***	0.570***	0.058	0.249***
$VOL_{i,t-1}$	0.021***	0.011***	0.012***	0.022***	0.014***	0.015***
$MARKETRET_{t-1}$	0.370***	0.055***	-0.072***	-0.090***	0.122***	-0.016***
$MARKETVOL_{t-1}$/100	0.168***	0.054***	0.073***	0.188***	0.055***	0.088***
$BIDDEPTH_{i,\Delta t-1}$/10000	0.168***	0.114***	0.203***	-0.045	-0.067**	0.075***
$ASKDEPTH_{i,\Delta t-1}$/10000	-0.132**	-0.084***	-0.009	0.233***	0.242***	0.147***
$AVOLU_{i,t,d,m}$	2.749***	3.587***	2.905***	2.895***	3.664***	3.218***
$ORDERSIZE_{i,t-1}$/10000	0.149***	0.031***	0.007***	0.202***	0.032***	0.000

Table 7. Tobit regressions with an additional dummy for the year 2008

This table presents the cross-sectional regression results of the Tobit model for each of the three investor groups as follows:

$$
\begin{aligned}
CANCEL_{i,t} = {} & \alpha_{i,0} + \beta_{i,1} \cdot PUT_{i,t} + \beta_{i,2} \cdot CALL_{i,t} + \beta_{i,3} \cdot RETURN_{i,t-1} + \beta_{i,4} \cdot RSPREAD_{i,t-1} + \beta_{i,5} \cdot VOL_{i,t-1} \\
& + \beta_{i,6} \cdot MARKETRET_{t-1} + \beta_{i,7} \cdot MARKETVOL_{t-1} + \beta_{i,8} \cdot BIDDEPTH_{i,\Delta t-1} + \beta_{i,9} \cdot ASKDEPTH_{i,\Delta t-1} \\
& + \beta_{i,10} \cdot AVOLU_{i,t,d,m} + \beta_{i,11} \cdot ORDERSIZE_{i,t-1} + \sum_{n=1}^{17} \alpha_{i,n} \cdot INTER_n \\
& + \rho_i \cdot D + \delta_{i,1}(D \times PUT_{i,t}) + \delta_{i,2}(D \times CALL_{i,t}) + \delta_{i,3}(D \times RETURN_{i,t-1}) \\
& + \delta_{i,4}(D \times RSPREAD_{i,t-1}) + \delta_{i,5}(D \times VOL_{i,t-1}) + \delta_{i,6}(D \times MARKETRET_{t-1}) \\
& + \delta_{i,7}(D \times MARKETVOL_{t-1}) + \delta_{i,8}(D \times BIDDEPTH_{i,\Delta t-1}) + \delta_{i,9}(D \times ASKDEPTH_{i,\Delta t-1}) \\
& + \delta_{i,10}(D \times AVOLU_t) + \delta_{i,11}(D \times ORDERSIZE_{i,t-1}) + \sum_{n=1}^{17} \rho_{i,n} \cdot (D \times INTER_n) + \nu_{i,t},
\end{aligned}
$$

where D is a dummy variable and takes a value of one, if interval t is in 2008, and zero otherwise. Other variables' definitions are identical to those described in Table 7. For brevity, only the coefficients on the interaction terms ($\delta_{i,n}$, n = 1, …, 11) are reported. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. FIs, DIs, and IIs stand for foreign investors, domestic institutions, and individual investors, respectively.

Independent variable	Buys			Sells		
	FIs	DIs	IIs	FIs	DIs	IIs
			Panel A. Large-cap stocks			
$D \times PUT_{i,t}/100$	0.441***	0.596***	0.087***	0.361***	0.477***	0.026
$D \times CALL_{i,t}/100$	0.532***	0.479***	0.158***	0.354***	0.800***	0.021
$D \times RETRUN_{i,t-1}$	0.053***	0.066***	0.000	0.145***	0.151***	0.049***
$D \times RSPREAD_{i,t-1}$	0.705***	0.775***	0.224***	0.905***	0.839***	0.096
$D \times VOL_{i,t-1}$	0.018***	0.017***	0.007***	0.021***	0.021***	0.007***
$D \times MARKETRET_{t-1}$	0.178***	0.173***	0.077***	0.228***	0.274***	0.094***
$D \times MARKETVOL_{t-1}/100$	0.058***	0.097***	-0.007	0.021*	0.095***	-0.026***
$D \times BIDDEPTH_{i,\Delta t-1}/10000$	-0.055	0.030	-0.027	0.070	-0.023	0.011
$D \times ASKDEPTH_{i,\Delta t-1}/10000$	0.007	-0.006	-0.117	0.279	0.308*	-0.019
$D \times AVOLU_{i,t,d,m}$	0.829*	1.246***	0.478*	0.583	1.194***	0.735***
$D \times ORDERSIZE_{i,t-1}/10000$	0.066*	0.004**	-0.006***	0.035	0.005***	-0.019***
			Panel B. Small-cap stocks			
$D \times PUT_{i,t}/100$	0.771***	0.523***	0.064**	0.785***	0.478***	0.120***
$D \times CALL_{i,t}/100$	0.724***	0.617***	0.089***	0.571***	0.508***	0.081**
$D \times RETRUN_{i,t-1}$	0.245***	0.049***	0.006	0.072***	0.151***	0.050***
$D \times RSPREAD_{i,t-1}$	0.327***	0.340***	0.117***	0.824***	0.466***	0.107***
$D \times VOL_{i,t-1}$	0.018***	0.018***	0.006***	0.010***	0.018***	0.006***
$D \times MARKETRET_{t-1}$	0.148***	0.196***	0.077***	0.265***	0.162***	0.095***
$D \times MARKETVOL_{t-1}/100$	0.098***	0.059***	-0.001	0.027*	0.078***	-0.015***
$D \times BIDDEPTH_{i,\Delta t-1}/10000$	0.151*	0.138**	0.030	-0.151	-0.054	0.003
$D \times ASKDEPTH_{i,\Delta t-1}/10000$	0.042	0.044	-0.007	0.094	0.033	0.083**
$D \times AVOLU_{i,t,d,m}$	2.892***	1.929***	1.676***	4.488***	3.399***	2.631***
$D \times ORDERSIZE_{i,t-1}/10000$	0.361***	0.019***	-0.013***	0.171***	0.024***	-0.020***