

Order Aggressiveness, Trading Patience, and Trader Types in a Limit Order Market

Junmao Chiu,* Huimin Chung, and George H. K. Wang

This study examines the order aggressiveness and trading patience of foreign institutional traders, futures proprietary firm traders, individual day and non-day traders in the Taiwan index futures market. We consider order choice given a completely transparent limit order book. Our empirical results show that individual (foreign institutional) traders use a more aggressive (patient) order submission strategy than the other trader types. We find significant differences among trader types in the timing of order aggressiveness and trading patience over the intraday time period. Both top and rest-of-the-order-book activities affect traders' order submission decisions. © 2016 Wiley Periodicals, Inc. *Jrl Fut Mark* 37:1094–1123, 2017

1. INTRODUCTION

The electronic limit order market is a major mechanism for trading on equity, futures, and option exchanges around the world. In this type of market, traders post bids and offers that are transparent to other market participants. At the time of order submission, traders must decide whether to submit either a market order, which is a bid or offer to transact at the prevailing market price, or a limit order, which is a bid or offer to transact at a price at or better than the specified limit price. With a market order, traders achieve execution certainty, but may pay an unfavorable price for such immediacy. With a limit order, traders have the probability of improving their execution price by setting a favorable limit price, but run the risk of non-execution. Unlike a quote-driven market, there are no designated market makers. In general, limit orders supply liquidity, whereas market orders consume liquidity. Market liquidity is endogenous, determined by different order flow composition of limit versus market orders in this market. Therefore, understanding the major factors that affect how traders make an order choice given a completely transparent (i.e., full) limit order book at the order submitting time interval is critically important for the analysis of the liquidity performance of a limit order book market.

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The main purpose of this paper is to perform statistical tests on the hypotheses that different types of traders (i.e., individual day traders, individual non-day traders, foreign institutional traders, and futures proprietary traders in Taiwan index futures) who access different sources of information and have different motives for trading in the index futures market would lead them to have different order aggression submission behavior. To the best of our knowledge, there is very limited literature focusing on the differences among foreign institutional investors and other types of traders in their order aggressiveness strategies at the order submission level based on complete limit order book information.

Prior theoretical papers (Glosten, 1994; Kumar & Seppi, 1993; Seppi, 1997) assume limit orders and market orders are exogenously determined in their static models. These models do not allow traders to choose between a market order and a limit order. Thus, these models cannot derive implications concerning the proportion of limit and market orders in the composition of order flow. More recent theoretical papers have analyzed traders' optimal order placement strategies and market liquidity in the dynamic setting of a limit order book market (Foucault, 1999; Foucault, Kadan, & Kandel, 2005; Parlour, 1998; Rosu, 2009).

Previous empirical papers provide evidence for the effect of spread, volatility, and market depth on traders' order placement strategies (order aggression) in different markets and over different sample periods (e.g., Chiu, Chung, & Wang, 2014; Chou and Wang, 2009; Griffiths et al., 2000; Menkhoff, Osler, & Schmeling, 2010; Rinaldo, 2004). These papers examine order submission decisions only between market orders, marketable limit orders (orders between the best bid ask quotes) and limit orders at the top of the limit order book.¹ However, traders often submit their orders behind the best quote, leading to more depth away from the best quote (Aitken et al., 2007; Hollifield et al., 2004). Another set of empirical papers examine order submission strategies and characteristics of order books based on market order and complete depth of order book (e.g., Biais, Hillion, & Spatt, 1995; Cao, Hansch, & Wang, 2008; Xu, 2014), but these papers do not examine differences in order placement strategies between institutional versus individual traders.

Recent literature shows that different trader types differ in their possession of information, pricing kernel, investors' beliefs, and investor sophistication (Barber & Odean, 2008; Chakravarty, 2001; Goettler, Parlour, & Ranjan, 2005; Locke & Mann, 2005; Polkovnichenko & Zhao, 2013). These differences can lead them to respond differently to information shocks across trader types in their liquidity needs and trading and order submission behaviors. For example, Aitken et al., (2007) find a major difference in the supply of liquidity by several types of institutional investors. Kuo and Lin (2013) posit that individual investors who trade more actively are not only overconfident of their information but also biased in their interpretation of their information.

Based on previous empirical evidence mentioned above and a unique dataset available to us, we perform empirical tests to explore whether these four types of traders have different order aggression submission strategies in Taiwan's index futures market due to the reason that they have different sources of information, trading motives and trading strategies. We include the market order and different limit order price quotes to examine how both top and rest-of-the-order-book activities affect the investor order choice decision at order submission level under various market conditions.² We divide traders into four groups (individual day

¹Duong et al. (2009) did include a category (labeled number 6 in their study) that includes buy (sell) orders at a price less (greater) than the best bid (ask) quote. These orders are submitted behind the best quote, but Duong et al. (2009) did not further classify the order aggressiveness categories in the rest of the order book.

²Our order submission choices exclude cancellation activity since investors face order submission decisions according to the market order and limit order in different limit order price quotes. If the limit order is not initially executed, then investors could choose to cancel or revise their submission limit order (Cao et al., 2008; Fong & Liu, 2010).

traders, individual non-day traders, foreign institutional firms, and proprietary futures firm traders) to examine the differences among these types of traders in their order submission choices and trading patience. We investigate how different type of traders use order book information behind the top of the limit order book in their order aggressiveness decision. We also examine which traders are able to provide liquidity at individual price steps that are below the best prevailing quotes, as modeled by Goettler et al. (2005).

Our research differs from the previous literature in several important ways. First, we investigate the impact of information from different price levels quoted at the top and the rest of the complete order book on traders' order submission decisions, while controlling for other market condition variables. In this way, we can examine which trader types access more information from the pre-trade transparency of the market and how that information affects traders' order submission choices.

Second, we compare the order aggressiveness strategies of individual day traders, individual non-day traders, foreign institutional traders, and futures proprietary traders. In emerging markets, foreign institutions have increased their level of participation in recent years. In Taiwan, individual traders play an important role in trading activity (Barber et al., 2009; Chiu et al., 2014). In contrast, Duong, Kalev, and Krishnamurti (2009) focus on differences between institutional and individual traders in their order submission strategies at the best quotes. However, foreign and local institutional traders may have different information sources and advantages, especially in an emerging market. Several prior studies have examined the magnitude of the impact of foreign investor trading on host-country returns. The debate about whether foreign or domestic investors have an information advantage over the other is mixed in the literature.³ Thus, we explore whether there are differences in order submission choices among foreign institutional traders, local institutional traders (futures proprietary firm traders), individual day, and individual non-day traders. We provide new empirical results on how differences in degree of access to information and in trading preference among four types of traders affect their order placement strategies. Third, most prior empirical studies examine order submission choices by investors in equity and foreign exchange markets. We contribute to the literature by investigating order submission choices by different trader types in the index futures market.⁴ When traders possess an information advantage, they may choose to trade in the derivative markets instead of equity markets because futures markets are much more liquid and allow traders with higher leverage ratios. Several prior studies also note that information-based trading is prevalent within the futures markets (e.g., Frino, Walter, & West, 2000; Pizzi, Economopoulos, & O'Neill, 1998).

Finally, our paper differs from two closely related papers by Chou and Wang (2009) and Chiu et al. (2014). Although their analysis explores order submission choices between limit and market orders by the different trader types in Taiwan stock index futures, their analysis neither considers order choice at each order submission level nor examines how order book information behind the top of the limit order book affects investors' order aggressiveness decisions. Currently, investors can often access limit order market information from their

³Foreign and domestic institutional traders have different information advantages; in measuring performance results, the findings in previous literature have not been consistent. One set of studies finds superior performance for domestic investors (Chan, Menkveld, & Yang, 2007; Choe, Kho, & Stulz, 2005), while another set finds that foreign investors do better (Froot, O'Connell, & Seasholes, 2001; Griffin, Nardari, & Stulz, 2004; Richards, 2005). However, Huang and Shiu (2009) document that foreign institutional investors have information superior to domestic institutional investors in Taiwan.

⁴Xu (2014) examines the shape of the limit order book, trading patience, co-movements in bid-ask spreads, and liquidity in the OMXS 30 index futures market. She did not, however, consider order aggressiveness by trader types in the OMXS 30 index futures markets.

screens, and various price quotes and quantities beyond the top of the limit order book (that is, the rest of the order book). The contents of the limit order book often provide valuable information and affect investor order submission strategy (Aitken et al., 2007; Cao et al., 2008; Goldstein & Kavajecz, 2000).⁵ Therefore, understanding the factors affecting traders' trading strategies at the order submission levels based on complete order book information is an important research area.

We obtain several interesting results. First, individual traders place more aggressive orders and are associated with a higher fill rate and the lowest cancel and unexecuted rates. Institutional traders place less aggressive orders and are associated with a lower fill rate and higher cancel and unexecuted rates. Second, we find significant differences among trader types in the timing of order aggressiveness strategies and trading patience over the intraday time period. Third, order submission levels by individual day traders exhibit an L shape and there is a skewed U shape of order submission by foreign institutional traders in the limit order book. This indicates that foreign institutional traders are value traders who are very concerned with trading costs, consistent with the experimental results of Bloomfield et al. (2005). Fourth, both the top and rest of the book activities affect traders' order submission decisions. These results suggest that investors use the order book information not only from the top of the limit order book but also the rest of the limit order book to formulate their order placement strategies. Fifth, for the price gap imbalance, institutional traders provide liquidity and individual traders consume liquidity when own-side liquidity is reduced.⁶ Finally, there are significant differences in submission strategies by trader types depending on the spread, transitory volatility, and momentum shocks.

The remainder of this study is organized as follows. Section 2 reviews the literature related to order aggressiveness. Section 3 describes the market structure, data source, and sample selection. Section 4 presents the exploratory data analysis of trading patience and order submission by trader types. Section 5 reports the empirical results for determinants of order aggressiveness of different trader types, and Section 6 summarizes our conclusions.

2. PREVIOUS LITERATURE

The literature on the limit order book market includes both theoretical and empirical papers.⁷ These papers provide the basis to specify our empirical model of factors affecting order aggression and to test the consistency of our empirical results with implications from recent theoretical models and empirical papers.

2.1. Theoretical Models for Dynamic Analysis of Limit Order Market

Parlour (1998) provides a one-tick dynamic model of a limit order book market, where traders choose to submit a limit order or a market order depending on the state of the limit order book. Her model suggests that traders are less likely to use limit orders if the limit order book on the same side of the trade is thicker. This is the so-called "crowding effect." However, traders are more likely to use limit orders if the book on the opposite side of the trade is thicker. Foucault (1999) provides a game-based theoretical dynamic model where traders can

⁵Cao et al. (2008) argue that investors can capture information from the order flow since it is the next most valuable piece of information that investors can pursue.

⁶Price gap imbalance is defined on pages 21–22 as the imbalance in the price gap between the best 1 and best 5 limit orders.

⁷See earlier literature of Parlour and Seppi (2008) on limit order book markets.

choose either a limit order or a market order, showing that the optimal choice between a market order and a limit order depends on the order submission choices of future trading. In equilibrium, his primary findings are the following: (1) the proportion of limit orders in order flow is positively related to asset volatility and (2) the proportion of limit order in order flow also increases when the size of the posted spread increases. Foucault theorizes that when the asset volatility increases due to informed traders, the risk of “pick-off” increases. Thus, limit order traders must increase their bid-ask spreads to insure against losses. The cost of trading using market orders is less attractive, and traders find it more cost effective to trade using limit orders.

Goettler et al. (2005) extend the analysis of Foucault (1999) to a dynamic model with asymmetric information. Since this model can not be obtained in closed form, they characterize its solution numerically. They suggest that the volatility of changes in the fundamental value of an asset affects how traders acquire information about the asset, which in turn affects the choice of order type made by informed traders and the market outcomes. Their model also shows that order flow persistence can arise because of persistence in the state of the book to which subsequent traders react. Biais et al. (1995) also observed the order persistence pattern in their empirical analysis of the Paris Bourse limit order book market. Foucault et al. (2005) develop a dynamic model of the limit order book market in which traders differ in their level of impatience. They suggest that each trader chooses to place a market or limit order according to his degree of patience and conditional on the state of the book so as to minimize his total execution cost. They find that the proportion of patient traders and the order arrival rate are two key determinants of the limit order book dynamics in equilibrium.

Rosu (2009) presents a dynamic model in which traders dynamically choose limit or market orders, trading off waiting costs, and execution prices. In equilibrium, the bid and ask prices depend only on the numbers of buy and sell orders in the book. His model has several interesting empirical implications for bid-ask prices, the temporary price impacts of market orders versus limit orders, characteristics of the dynamics of the limit order book (a hump-shape order book), and a comovement effect in direction in bid-ask prices. Xu (2014) provides empirical evidence that the limit order book of OMXS 30 index futures markets exhibits a hump shape, which is consistent with the prediction from the theoretical model by Rosu (2009).

2.2. Empirical Analysis of Determinants of Order Aggression

Griffiths et al. (2000) use an ordered probit model to examine determinants of the order aggressiveness of investors in the Toronto stock exchange for 1 month's data in June 1997. They examine order aggressiveness for both the buy and sell sides and adopt the six order aggressiveness classifications suggested by Biais et al. (1995).⁸ Griffiths et al. (2000) find that aggressive buy (sell) orders tend to follow other aggressive buy (sell) orders when the limit order book immediately prior to the order has a narrow bid-ask spread and the depth is large on the same side and small on the opposite side. However, that study does not examine the impact of limit orders at different price quotes and orders sizes behind the best bid and ask quotes on order aggressiveness.

Using transaction data from the Swiss Stock Exchange, Rinaldo (2004) examines the order aggressiveness of investors in a purely order-driven electronic stock market without

⁸For example, for buy orders, the order aggressiveness is ranked as follows: (1) order price > ask and order size > depth at ask; (2) order price = ask and order size > depth at ask; (3) order price = ask, order size ≤ depth at ask; (4) Ask > order price < bid; (5) order price = bid; and (6) order price < bid. The most aggressive orders are in number (1) and the least aggressive classification is in number (6).

market makers. He uses an ordered probit regression model and ranks the discrete dependent variables by five classes of order aggressiveness: large market order, small market order, limit order within quotes, limit order at the quote, and cancellation. He provides empirical evidence that traders become more aggressive when their own (opposite) side book is thicker (thinner). These results imply that traders use more aggressive orders when they believe the non-execution probability is relatively high and use less aggressive orders when they believe the non-execution probability is relatively low. Rinaldo's ordered probit regression results also confirm that traders use less aggressive orders when the spread is wider and temporary volatility is high. However, he does not examine the influence of limit orders behind the best bid and ask quotes in the limit order book on traders' order submission decisions.

Using a unique data set from the largest institutional brokers in Australia, Aitken et al. (2007) find that institutional traders simultaneously supply liquidity at multiple prices in the limit order book. They compare the aggressiveness in liquidity supply of proprietary trading desks, hedge funds, mutual funds, index funds, and insurance companies. They examine the order aggressiveness of limit orders after they have already been submitted to the order book. The limitation of their data is that they can only examine the state of the limit order book at given points of time every 20 minutes apart. Therefore, they can not examine dynamic limit order strategies according to trader types. They find that priority trading desks and hedge funds are more aggressive liquidity suppliers than mutual funds, index funds and insurance companies. Retail traders are the least aggressive liquidity suppliers among these three types of traders.

Cao et al. (2008) investigate order aggressiveness of investors based on complete limit order book information from the Australian Stock Exchange, finding that the top of the book activities affect order submission. Furthermore, the rest of the order book (e.g., the book information beyond Step 1) does not significantly affect an investor's order submission decision. Their results also show that a large spread discourages market order submission, whereas greater depth at the top price step encourages more market orders.

The issue of comparing the order aggressiveness of different trader types has received increasing attention in recent years. For example, Duong et al. (2009) investigate the factors affecting the order aggressiveness of institutional and individual traders on the Australian Stock Exchange. They report that both institutional and individual traders become more aggressive when same-side market depth increases or the spread tightens. They also find that individual traders use less aggressive orders early in the trading day and increase their order aggressiveness throughout the trading day, and that institutional traders are more aggressive during the opening hour of the trading day. However, the author's order choices do not include multiple order choices according to the different limit order price quotes and do not consider how the full limit order book information affects investors' order submission decisions. In addition, they cannot distinguish foreign and domestic institutional traders within their data set. In contrast, our paper examines the order aggressiveness at the order submission level based on complete order book information. Furthermore, we further classify institutional traders into foreign and domestic traders because they may access different levels or types of information.

Chou and Wang (2009) calculate the limit order aggressiveness index by different trader types in the Taiwan stock index futures market from 2001 to 2006. Their empirical results show that foreign institutional traders and futures proprietary firms prefer to place more limit orders and fewer marketable limit orders in order to avoid causing any large impact on price. However, the order submission choices in Chou and Wang (2009) do not include market order and order choice behind the best quote. In addition, their analysis does not examine how market conditions and order book activity variables affect investor order choice decisions. Our paper differs from that paper in that we examine how factors based on the

overall order book information and market condition variables affect traders' order choice for different levels of aggressiveness at the time of order submission.

Using electronic interdealer market data from the Moscow Interbank Currency Exchange (MICEX), Menkhoff et al. (2010) find that informed traders are more sensitive to changes in the spreads, volatility, and depths than uninformed traders. Menkhoff et al. (2010) also find the order aggressiveness strategy of both informed and uninformed traders has a negative relationship with spread and volatility and a positive relationship with the same side depth. However, their data only include a seven intraday period, which may be too short for reliable empirical analysis. In addition, their order submission choice does not include realized market order, and they are only concerned with how the top of the order book activity affects the investor's choice of order.

Using a unique data set for the Taiwan stock index futures market, Chiu et al. (2014) examine liquidity provision measured by net limit order submission (i.e., the sum of limit orders minus the sum of market orders) over 15-minute intervals by the different trader types. They find that institutional traders place more limit orders than market orders, especially foreign institutional traders during regular trading hours. In addition, they find that net limit order submissions by both institutional and individual traders are positively related to one-period lagged transitory volatility and negatively related to informational volatility. However, their analysis neither considers order choice at each order submission level nor examines how order book information behind the top of the limit order book affects investor's decision on order aggressiveness.

In summary, based on the above literature review, we find that information from the complete state of the order book provides key information for traders to formulate their order placement strategies in theoretical models; however, there is very little use of information from the complete state of the book in empirical analysis papers. The major contribution of our paper is to examine the major determinant of order aggressiveness by trader types at order submission level based on information from market orders, information from the complete order book, and market condition variables.

3. MARKET STRUCTURE AND DATA SET

3.1. Taiwan Index Futures Market Structure

The Taiwan Futures Exchange (TAIFEX) is a pure order-driven market. Because there are no designated market makers, liquidity is generated endogenously by orders placed by market participants. There are no hidden orders. Limit orders are automatically cancelled at the end of the trading day, so traders work with a 1-day limit order book. Investors submit limit and market orders through brokers to an automated trading system (ATS). The ATS orders matches, and executes orders continuously following a price-time priority rule, setting a single transaction price. Limit orders are consolidated into the electronic limit order book, and market buy (sell) orders hit the best ask (bid) prices. Buy (sell) orders with a higher (lower) limit price than the set transaction price are executed at the transaction price. Market participants can also submit cancel orders at any time prior to matching. TAIFEX disseminates order and transaction prices to the public in real time.

Investors can observe the following information from their screens: (1) the anonymous best five bids and best five asks at specific prices and (2) the number of contract sizes associated with each respective anonymous best five bids and five asks. The pre-opening session is from 8:30 to 8:45 a.m. During this period, investors can submit limit and market orders to the ATS through brokers, and the exchange uses the single period auction system to

establish the opening prices for regular trading hours. Regular trading hours are weekdays, excluding public holidays, from 8:45 a.m. to 1:45 p.m. The contract size of the Taiwan stock index futures (FITX) is equal to the index value of FITX multiplied by \$200 New Taiwan dollars. The maximum of each order size of TIFX is 100 contracts. We use nearby futures contracts in our analysis, and we use trading volume in the delivery month as the indicator to decide when to switch from first-deferred contracts to nearby futures contracts. The Appendix provides details of the contract specifications.

3.2. Data Source and Sample Selection

We use two different data sets to investigate order submission by different trader types in the FITX market: (1) the FITX order book data set obtained from the TAIEX and (2) the market depth data set obtained from the *Taiwan Economic Journal* (TEJ) database. Our sample covers the period from January 1, 2008 to December 31, 2008.

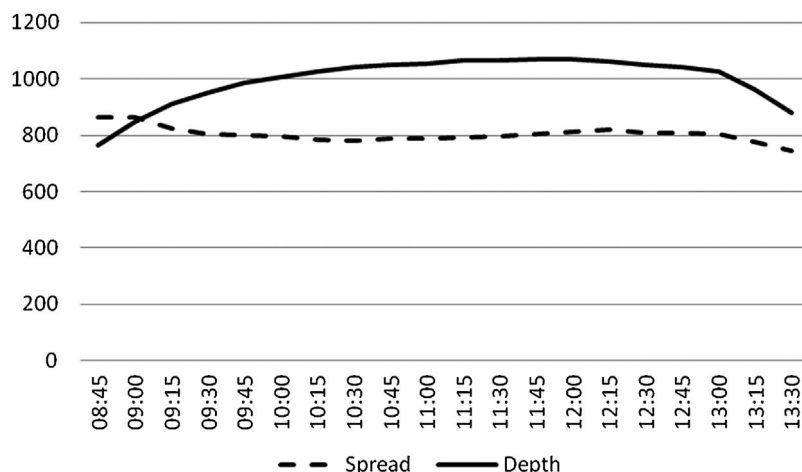
The FITX order book data set contains the detailed history of order flows, order book, tick-by-tick transaction data, and the identity of the traders. For example, this data set contains all information for the date and time of arrival of each order, its direction (buy or sell initiation), the quantity demanded or supplied, and the trader identification for each order. The trader identification enables us to categorize three types of traders: individual traders, futures proprietary firms, and foreign institutional traders.⁹ Barber et al. (2009) and Chiu et al. (2014) both find that day trading by individual traders is over 20%, and individual day traders play an important role in the Taiwan stock and stock index futures market. We divide individual traders into two groups: (1) individual day traders and (2) individual non-day traders in our later analysis.¹⁰ We eliminate trading that occurs during price limit days, outliers in limit order prices, time periods without limit order information, and days with missing trading data.¹¹ We also delete an observation when there is a missing value in the order book data set. The market depth data set includes the best five bids and best five asks limit prices along with the number of contracts submitted with each order. We eliminate the data from the sample if the bid price is higher than the ask price at any of the limit price levels and if the bid (ask) price is not in strict descending (ascending) order from the first to the fifth best prices. Finally, we merge the order book and market depth data sets according to order submission time. Thus, we can identify each order submission time, quote price, volume, direction, trader identification, and the best five bids and best five asks limit prices with the number of contracts submitted.

Figure 1 shows the intraday variation patterns for the bid-ask spread and market depth, using 15-minute intervals. The results, which are similar to previous literature, show a U-shaped intraday pattern for the bid-ask spread (Ahn & Cheung, 1999; Biais et al., 1995; Lee, Mucklow, & Ready, 1993) and an inverse U-shaped pattern for market depth (Ahn & Cheung, 1999; Brockman & Chung, 1999; Lee et al., 1993).

⁹In the rest of our analysis, we concentrate only on activities of individual traders, foreign institutional traders, and futures proprietary firm traders because the trading activity of domestic institutional traders accounts for only 3.02% of the average daily trade volume and 1.92% of the average daily submission orders. In addition, domestic institutional firms do not trade very frequently. As a result, we often face inadequate observations of domestic institutional firms in our 15-minute time interval.

¹⁰Day trader is defined as a trader who satisfies the following rule: the amount of contracts purchased is equal to the amount of contracts sold in the same trading day. We do not sub-classify day and non-day traders into foreign institutional traders and futures proprietary firm traders because day trading in these two types of traders represent very small percentages of the totals.

¹¹There is missing data for 8 days in June 2008 and for three days in December 2008.

**FIGURE 1**

Intraday Pattern for Bid-Ask Spread and Market Depth in Taiwan Stock Index Futures from January 1, 2008 to December 31, 2008

The depth is defined as the numbers of shares of limit orders at the best bid and ask price at the end of each 15-minute interval. The spread is defined as the mean of dollar quote spread during the 15-minute interval.

4. ORDER SUBMISSION AND TRADING PATIENCE BY TRADER TYPES

This section provides data analysis of order submission statistics, intraday variation of trading patience, and order submission level by trader types from the FITX entire order book data. We focus on how investors choose among order types. Because the levels of order aggressiveness are ordered, we follow the spirit of Ranaldo (2004) and Cao et al. (2008) and use ordered logit regression models to examine the determinants of order aggressiveness by different trader types. Based on the best five bid and ask prices recorded in the limit order book displayed on the screen, we use the following rules to classify five levels (categories) of increasing order aggressiveness: Category 1 (Behind Best 5)—limit orders that are submitted behind the best five quotes (i.e., least aggressive); Category 2 (Best 2–5)—limit orders that are submitted behind the best single quote but at or before the best five quotes; Category 3 (Best 1)—limit orders that are submitted to the best single quote, that is, submission of limit buy (sell) orders equal to the best bid (ask) quote; Category 4 (Better Best 1)—marketable limit orders and prices of limit orders are submitted at better than best one quote, prices of buy (sell) orders are greater (less) than the best bid (ask) quote; and Category 5 (Market Orders)—market orders that demand liquidity and are executed immediately at the best prices currently standing in the market (i.e., most aggressive).

4.1. Order Submission Statistics

Table I provides summary statistics for the order book by different trader types for the overall sample period, and we look at the entire limit order book. In the pre-opening period, institutional traders (i.e., foreign institutional and futures proprietary firm traders) place a higher percentage of market orders than in the regular trading period, while individual traders (i.e., individual day and non-day traders) show the opposite behavioral pattern. For example, foreign institutional traders (individual day traders) submit 3.44% (4.33%) of their total average daily orders as market orders in the pre-opening period and submit 0.37% (18.58%) of their average daily orders as market orders in the regular trading period.

TABLE I
Order Book Statistics by Trader-Type Categories

	Individual Traders (%)				
	Day Traders (%)	Non-Day Traders (%)	Foreign Institutional Traders (%)	Futures Proprietary Firm Traders (%)	Total Order Submission Number
Panel A: Percentage of Order Submission Volume by Trader Types in the Pre-Open Period					
Market order	(29.67) [4.33]	(57.53) [5.93]	(5.57) [3.44]	(7.23) [2.50]	43,134 (100) [4.75]
Limit order	(32.67) [95.67]	(45.48) [94.07]	(7.79) [96.56]	(14.06) [97.50]	865,499 (100) [95.25]
Total order submission number	295,571 (32.53) [100]	418,472 (46.05) [100]	69,784 (7.68) [100]	124,806 (13.74) [100]	908,633 (100) [100]
Panel B: Percentage of Order Submission Volume by Trader Types in the Regular Trading Period					
Market order	(54.33) [18.58]	(42.95) [18.29]	(1.25) [0.37]	(1.47) [0.49]	5,829,430 (100) [8.62]
Better best 1 quote	(34.86) [25.04]	(23.50) [21.01]	(12.16) [7.65]	(29.48) [20.70]	12,240,998 (100) [18.01]
Best 1 quote	(35.94) [18.34]	(24.92) [15.83]	(11.08) [4.95]	(28.06) [14.00]	8,696,859 (100) [12.86]
Best 2–5 quote	(31.65) [22.68]	(26.54) [23.67]	(18.07) [11.35]	(23.74) [16.64]	12,214,949 (100) [18.06]
Behind best 5 quote	(9.14) [15.36]	(10.14) [21.20]	(51.40) [75.68]	(29.32) [48.17]	28,644,398 (100) [42.36]
Total order submission number	17,045,648 (25.21) [100]	13,692,615 (20.25) [100]	19,454,246 (28.77) [100]	17,434,125 (25.77) [100]	67,626,634 (100) [100]
Total order submission frequency	8,772,394 (32.19) [100]	6,305,141 (23.14) [100]	3,961,062 (14.53) [100]	8,214,131 (30.14) [100]	27,252,728 (100) [100]

Notes. The table presents order book statistics by trader type for the futures contract FITX from January 1, 2008 to December 31, 2008. Panel A shows the percentage of order submission volume in the pre-open period and Panel B shows the percentage of order submission volume in the regular trading period for individual day traders, individual non-day traders, foreign institutional traders, and futures proprietary firm traders. We divide all order books into the following categories based on quotes: Market Order; Better Best 1, which refers to limit orders that are submitted to the better best 1 quote; Best 1, which refers to limit orders that are submitted to best 1 quote; Best 2–5, which refers to limit orders that are submitted to behind the best 1 quote but at or before the best 5 quotes; and Behind Best 5, which refers to limit orders that are submitted to behind the best 5 quote. The numbers in parentheses for each row represent the percentages of order types by individual day traders, individual non-day traders, foreign institutional traders, and proprietary firm traders. The numbers in brackets for each column represent the percentages of order types by each trader types. The pre-open period is from 8:30 to 8:45 a.m.

In addition, individual traders prefer to submit orders in the Category 5 (Market Order) to Category 3 (Best 1) during the regular trading period. However, foreign institutional and futures proprietary firm traders more often place their orders in Category 2 (Best 2–5) and 1 (Behind Best 5). For example, of their total average daily orders, foreign institutional traders submit 75.68% in Category 1 and 0.37% in Category 5, whereas individual day traders place 15.36% in Category 1 and 18.58% in Category 5.

The general results of Table I suggest that individual traders often use a more aggressive order submission strategy than the order submission strategy implemented by foreign institutional traders and futures proprietary firm traders.

We observed the submission limit order final status in our dataset and divided each submission order into fill, cancel, or unexecuted orders. Table II, which shows summary statistics of the limit order submission fill rates, cancel rates, and unexecuted rates by trader types, provides several interesting results. First, fill rates are positively related to the order aggressiveness for all type of traders. Second, both cancel rates and unexecuted rates are negatively related to traders' order aggressiveness. Finally, the fill rate of individual traders is larger than the fill rate of institutional traders. Consequently, the cancel and unexecuted rates of individual traders are smaller than those of foreign institutional traders and futures proprietary firm traders. These results contradict the assumptions often made by some earlier theoretical models on limit order book markets that informed traders place only market orders and uninformed traders only place limit orders (e.g., Glosten, 1994; Seppi, 1997). However, our results are consistent with the theory suggested by Kaniel and Liu (2006) that informed traders use more limit orders.¹²

4.2. Intraday Variation of Trading Patience and Order Submission Level by Trader Types

Foucault et al. (2005) and Rosu (2009) suggest that trading patience is one of the most important factors affecting traders' order submission strategies and market liquidity in limit order book markets. However, it is very challenging to measure the degree of trading patience empirically. It is generally agreed that the most impatient traders use market orders and patient traders use various levels of limit orders. Thus, there is an inverse relationship between order aggressiveness and traders' degree of trading patience. We follow a proxy measure of trading patience suggested by Xu (2014). Trading patience by all types of traders in 15-minute intervals is measured as follows:¹³

$$\text{Patience}_t = \frac{1}{2}(\text{Sell Patience}_t + \text{Buy Patience}_t), \quad (1a)$$

$$\text{Sell Patience}_t = \frac{\text{SLO}_t}{\text{SLO}_t + \text{MBO}_t}, \quad (1b)$$

$$\text{Buy Patience}_t = \frac{\text{BLO}_t}{\text{BLO}_t + \text{MSO}_t}, \quad (1c)$$

where the SLO_t and BLO_t are the sums of the sell and buy side limit orders, excluding marketable limit orders,¹⁴ by all types of traders in each 15-minute interval t . MBO_t and MSO_t

¹²The financial literature generally agrees that institutional traders are informed traders because they collect and analyze market information more quickly than uninformed traders in stock index futures markets. However, individual investors often make their trading decisions based on observed market price patterns. Goettler, Parlour, and Rajan (2009, p. 68) suggest institutional traders are informed traders who view the current expected value of cash flow of the instrument.

¹³There is no one best proxy to measure trading patience. Hagströmer and Nordén (2014) suggest another measure of trading patience using the average of volume of patient orders to volume of impatient orders at a given time interval (p. 314, [7]).

¹⁴Marketable limit orders are limit orders that come with better quotes than best bid and lower than best ask quotes. It lies within the range of best bid-ask quote.

TABLE II
Limit Order Submission Fill, Cancel, and Unexecuted Rates by Trader-Type Categories

	<i>Individual Traders (%)</i>		<i>Foreign</i>	<i>Futures Proprietary</i>	<i>Total</i>
	<i>Day</i>	<i>Non-Day</i>	<i>Institutional</i>	<i>Firm Traders (%)</i>	<i>Average (%)</i>
	<i>Traders (%)</i>	<i>Traders (%)</i>	<i>Traders (%)</i>		
<i>Panel A: Pre-Open Period</i>					
Limit order					
Fill rate	11.18	26.94	15.13	11.17	18.63
Cancel rate	72.29	65.71	78.56	73.13	69.93
Unexecuted rate	16.53	7.35	6.30	15.70	11.44
<i>Panel B: Regular Trading Period</i>					
Better best 1					
Fill rate	93.57	95.45	91.14	88.12	92.08
Cancel rate	6.42	4.51	8.68	11.84	8.55
Unexecuted rate	0.01	0.04	0.18	0.04	0.05
Best 1					
Fill rate	65.27	70.36	69.66	63.06	66.43
Cancel rate	34.69	29.34	29.89	36.84	33.40
Unexecuted rate	0.04	0.30	0.45	0.10	0.17
Best 2–5					
Fill rate	37.66	43.79	16.37	23.69	32.16
Cancel rate	62.02	55.06	83.15	76.02	67.27
Unexecuted rate	0.32	1.15	0.48	0.29	0.56
Behind best 5					
Fill rate	24.26	31.95	0.81	1.47	6.38
Cancel rate	69.73	59.64	99.01	98.06	91.97
Unexecuted rate	6.01	8.41	0.18	0.48	1.66
Total order average					
Fill rate	44.98	48.64	13.66	34.91	37.23
Cancel rate	54.22	50.10	86.11	64.59	61.87
Unexecuted rate	0.80	1.26	0.23	0.49	0.90

Notes. This table presents limit order fill rate, cancel rate, and unexecuted rate in different order aggressiveness levels by trader type on the futures contract FITX from January 1, 2008 to December 31, 2008. The fill rate is the number of different order aggressiveness level categories that are subsequently executed divided by the total number of limit orders submitted. The cancel rate is the number of different order aggressiveness level categories that are subsequently canceled divided by the total number of limit orders submitted. The unexecuted rate is the number of different order aggressiveness level categories that are unexecuted divided by the total number of limit orders submitted. Panel A shows the fill rates, cancel rate, and unexecuted rate of limit orders in pre-open period and Panel B shows the fill rates, cancel rate, and unexecuted rate for five categories of limit order in the regular trading period for individual day traders, individual non-day traders, foreign institutional traders, and futures proprietary firm traders. In Panel A, limit order refers to limit order submissions to limit order book in the pre-open period. In Panel B, we divide all order books into the six categories: Market Order; Better Best 1, which refers to limit orders that are submitted to the better best 1 quote; Best 1, which refers to limit orders that are submitted to best 1 quote; Best 2–5, which refers to limit orders that are submitted to behind the best 1 quote but at or before the best 5 quotes; and Behind Best 5, which refers to limit orders that are submitted to behind the best 5 quote. The pre-open period is from 8:30 to 8:45 a.m.

are the sums of the sell and buy side market orders, including marketable limit orders, respectively, by all types of traders in each 15-minute interval t . Using the above trading patience measurement, we can posit a higher ratio indicating higher trading patience during 15-minute intervals.

We present empirical measures of intraday buy patience, sell patience, and trading patience measures in 15-minute intervals by trader types in Table IV.¹⁵ Figure 2(1–4) describes the time variation pattern of trading patience ratios by trader types. We have obtained several interesting results. First, in the pre-opening period, institutional traders are less patient (0.597) than other types of traders. On the other hand, individual day traders are more patient (0.783) than other types of traders in this pre-opening period. This is expected because foreign institutional traders have relatively easy access to valuable related trading information from overseas markets during Taiwan's pre-opening period.

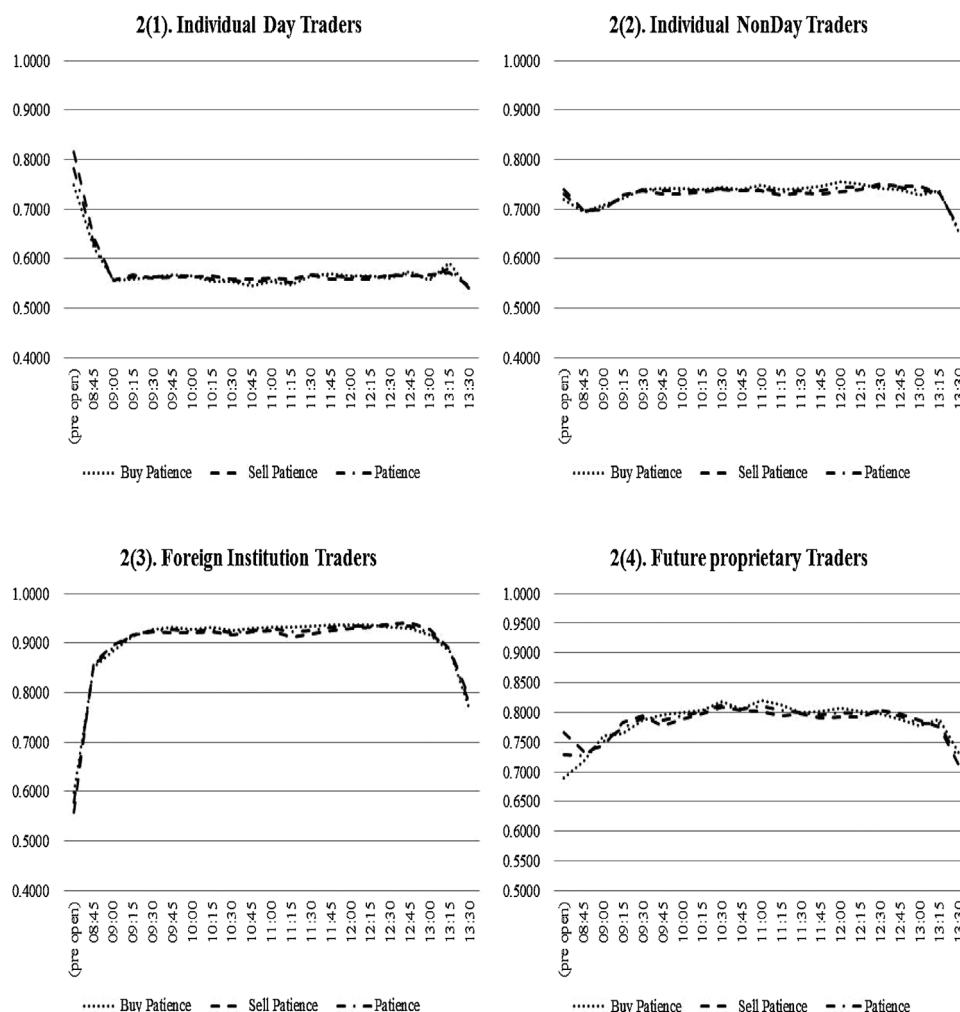
Second, during regular trading periods, the median patience measures of individual day and non-day traders are 0.56 and 0.63, respectively. The median patience measure of futures proprietary firm traders and foreign institutional traders are 0.81 and 0.92, respectively. These results confirm that individual traders are less patient than institutional traders because individual day traders use more aggressive orders to implement their quick turnaround trading strategies. Third, we find that the lowest measures of patience for all trader types occur in the final trading time interval between 1:30 and 1:45 p.m. These results indicate that both individual traders and especially institutional traders do not like to take the overnight risk and use more market orders at the end of the day to close their holding positions (Table III).

Table IV presents the intraday variation of order submission level by trader types. In the pre-opening period, we again classify the five levels of order aggressiveness according to the last best five bids and asks prices for the prior trading day. Table IV, which presents the distribution of order aggressiveness levels in 15-minute intervals by trader types, offers several interesting findings. First, in the pre-opening period, institutional traders place the highest percentage of their orders as marketable orders (Market Order and Better Best 1) than limit orders over the trading day, and individual traders place the least percentage of their orders as marketable orders over the trading day. Specifically, foreign institutional traders place 42.21% of their orders between Categories 5 (Market Orders) and 4 (Better Best 1) during the pre-opening period—the highest percentage over the trading day—whereas individual day traders only place 21.45% of their orders in Categories 5 and 4—the lowest percentage over the trading day.

Second, during the regular trading period, both individual day traders and individual non-day traders place more than 50% of their orders among Categories 5 (Market Orders), 4 (Better Best), and 3 (Best 1). They place roughly only 15% of orders in Category 1 (Behind Best 5). Conversely, foreign institutional traders place more than 70% of their orders in Category 1 and fewer than 17% among Categories 5, 4, and 3, except in the early first time interval between 8:45 and 9:00 a.m.

Third, in the final time interval between 1:30 and 1:45 p.m., foreign institutional traders become more aggressive and increase their order submissions in Categories 5 to 2 and decrease their order submissions in Category 1 (Behind Best 5). Futures proprietary firm traders also increase their order submissions of marketable orders and decrease their limit order submissions. Individual traders also increase marketable order submission but are less aggressive than institutional traders. These results indicate that both individual traders and especially institutional traders do not like to take the overnight risk and use more aggressive orders at the end of the day to close their holding positions.

¹⁵We follow two principles in selecting the length of the time interval. Since we are interested in short time variations of limit versus market order submissions, the time interval should not be too long. On the other hand, if the time interval is too short, there may not be enough observations for obtaining reliable estimates of intraday patterns. Balancing between these two guidelines, we decide to select a 15-minute interval as the time interval of our intraday empirical analysis (Ahn, Bae, & Chan, 2001).

**FIGURE 2****Patience Ratios by Trader Types**

The means of patience ratios during the 15-minute intervals of each trading day for the futures contract FITX from January 1, 2008 to December 31, 2008. The preopen session is from 8:30 to 8:45 a.m. Buy patience ratio is defined as the ratio of the number of buy limit order to the sum of buy limit and sell market orders during each 15-minute interval. Sell patience ratio is defined as the ratio of the number of sell limit order to the sum of sell limit and buy market orders during each 15-minute interval. Patience ratio is the ratio of half of buy patience ratio plus sell patience ratio. The four types of traders are individual day traders, individual non-day traders, foreign institutional traders, and futures proprietary firm traders.

In sum, we find that there are significant differences among these four types of traders in the timing of submitting aggressive orders over the intraday time period. During the pre-opening period, institutional traders submit a higher percentage of aggressive orders and large size orders, while individual traders show the reverse behavior. In the regular trading period, individual traders place more aggressive orders at more aggressive price levels than foreign institutional traders. In Section 5, we use an ordered logit model to statistically identify the important factors that affect order aggressiveness by trader types at order submission time intervals.

TABLE III
Limit Order Patience Ratio by Trader-Type Categories

Time Interval	Marketwise			Individual Day Traders			Individual Non-Day Traders			Foreign Institutional Traders			Futures Proprietary Firm Traders		
	Patience	Buy	Sell	Patience	Buy	Sell	Patience	Buy	Sell	Patience	Buy	Sell	Patience	Buy	Sell
0. 08:30–08:45	0.7303	0.7492	0.8167	0.7829	0.7290	0.7060	0.7175	0.5988	0.5593	0.5790	0.6906	0.7669	0.7287	0.7180	0.7347
1. 08:45–09:00	0.6956	0.6226	0.6429	0.6327	0.6037	0.5753	0.5895	0.8514	0.8615	0.8564	0.7180	0.7347	0.7263	0.7601	0.7433
2. 09:00–09:15	0.7038	0.5556	0.5563	0.5559	0.5852	0.5586	0.5719	0.8854	0.8961	0.8908	0.7601	0.7433	0.7517	0.7642	0.7822
3. 09:15–09:30	0.7250	0.5588	0.5667	0.5628	0.5930	0.5972	0.5951	0.9144	0.9171	0.9158	0.7642	0.7822	0.7732	0.7877	0.7950
4. 09:30–09:45	0.7388	0.5635	0.5613	0.5624	0.6144	0.6107	0.6126	0.9285	0.9236	0.9261	0.7877	0.7950	0.7913	0.7965	0.7783
5. 09:45–10:00	0.7364	0.5681	0.5640	0.5661	0.6121	0.6148	0.6134	0.9325	0.9216	0.9270	0.7965	0.7783	0.7874	0.7994	0.7891
6. 10:00–10:15	0.7369	0.5645	0.5637	0.5641	0.6193	0.6208	0.6200	0.9279	0.9207	0.9243	0.7994	0.7891	0.7943	0.8034	0.7986
7. 10:15–10:30	0.7374	0.5534	0.5654	0.5594	0.6192	0.6254	0.6223	0.9314	0.9233	0.9273	0.8034	0.7986	0.8010	0.8178	0.8089
8. 10:30–10:45	0.7415	0.5533	0.5587	0.5560	0.6154	0.6247	0.6200	0.9245	0.9164	0.9204	0.8178	0.8089	0.8134	0.8053	0.8042
9. 10:45–11:00	0.7382	0.5455	0.5574	0.5515	0.6103	0.6243	0.6173	0.9294	0.9236	0.9265	0.8053	0.8042	0.8047	0.8212	0.8017
10. 11:00–11:15	0.7428	0.5535	0.5615	0.5575	0.6207	0.6235	0.6221	0.9332	0.9247	0.9289	0.8212	0.8017	0.8115	0.8121	0.7937
11. 11:15–11:30	0.7350	0.5478	0.5573	0.5526	0.6164	0.6222	0.6193	0.9322	0.9128	0.9225	0.8121	0.7937	0.8029	0.7994	0.7987
12. 11:30–11:45	0.7379	0.5655	0.5673	0.5664	0.6107	0.6199	0.6153	0.9344	0.9186	0.9265	0.7994	0.7987	0.7991	0.8012	0.7900
13. 11:45–12:00	0.7386	0.5695	0.5588	0.5642	0.6127	0.6101	0.6114	0.9371	0.9258	0.9315	0.8012	0.7900	0.7956	0.8078	0.7917
14. 12:00–12:15	0.7452	0.5650	0.5587	0.5618	0.6188	0.6011	0.6099	0.9377	0.9309	0.9343	0.8078	0.7917	0.7998	0.8023	0.7929
15. 12:15–12:30	0.7451	0.5661	0.5594	0.5627	0.6110	0.6207	0.6158	0.9373	0.9316	0.9344	0.8023	0.7929	0.7976	0.7987	0.8031
16. 12:30–12:45	0.7463	0.5612	0.5675	0.5643	0.6144	0.6306	0.6225	0.9321	0.9389	0.9355	0.7987	0.8031	0.8009	0.7890	0.7983
17. 12:45–13:00	0.7434	0.5749	0.5662	0.5705	0.6175	0.6188	0.6181	0.9301	0.9402	0.9351	0.7890	0.7983	0.7936	0.7766	0.7866
18. 13:00–13:15	0.7371	0.5553	0.5670	0.5612	0.6052	0.6205	0.6128	0.9162	0.9275	0.9218	0.7766	0.7866	0.7816	0.7886	0.7753
19. 13:15–13:30	0.7361	0.5915	0.5713	0.5814	0.6108	0.6199	0.6154	0.8819	0.8881	0.8850	0.7886	0.7753	0.7819	0.7310	0.7100
20. 13:30–13:45	0.6571	0.5374	0.5458	0.5416	0.5670	0.5902	0.5786	0.7642	0.7873	0.7758	0.7310	0.7100	0.7205		

Notes. This table presents the patience ratio of FITX futures during 15-minute intervals for individual day traders, individual non-day traders, foreign institutional traders, and futures proprietary firm traders, respectively. The patience ratio estimates by the equal average of buy patience and sell patience ratio. Buy column indicates buy patience ratio and is estimated by the number of buy limit orders divided into the sum of the buy limit orders and sell market orders. Sell column indicates sell patience ratio and is estimated by the number of sell limit orders divided into the sum of the sell limit orders and buy market orders. The pre-open period is from 8:30 to 8:45 a.m.

5. DETERMINANTS OF ORDER AGGRESSIVENESS OF DIFFERENT TRADER TYPES

5.1. Empirical Model

In this classification, we include the order status of full limit order book information. Thus, in our analyses we can examine whether the market conditions, as well as top and rest of limit order book activities affect investors' choices for order submission by trader types. The ordered logit model for y^* is

$$y^* = x\beta + \varepsilon, \quad (2)$$

where y^* is a continuous latent variable, and so we find

$$\begin{aligned} y &= 1, & \text{if } -\infty < y^* \leq r_1 \\ y &= m, & \text{if } r_{m-1} < y^* \leq r_m, \text{ for } m = 2, 3, 4 \\ y &= 5, & \text{if } r_4 < y^* < \infty, \end{aligned} \quad (3)$$

where r_m $m = 1, 2, 3$, and 4 are the threshold parameters (cut points) of the whole space of y^* , which are estimated from data. The error terms are assumed to be logit distribution. The vector of x is $1 \times k$ observable explanatory variables and is defined in the discussion of variables in Section 5.2.

The probability for each action is calculated as

$$\begin{aligned} \text{prob}(y = 1/x) &= F[r_1 - x\beta], \\ \text{prob}(y = j/x) &= F[r_j - x\beta] - F[r_{j-1} - x\beta], \quad j = 2, 3, 4, \\ \text{prob}(y = 5/x) &= 1 - F[r_4 - x\beta], \quad k = 5, \end{aligned} \quad (4)$$

where F denotes the distribution function of the logit distribution, and the probability of each action is evaluated as the means of (x) of the explanatory variables. For the five probabilities, the marginal effects of change in explanatory variables x_j are

$$\begin{aligned} \partial \text{prob}(y = 1/x) / \partial x_j &= -f[r_1 - x\beta] \beta_j, \\ \partial \text{prob}(y = j/x) / \partial x_j &= -f[r_j - x\beta] \beta_j - f[r_{j-1} - x\beta] \beta_j, \quad j = 2, 3, 4, \\ \partial \text{prob}(y = k/x) / \partial x_j &= f[r_4 - x\beta] \beta_j, \quad k = 5, \end{aligned} \quad (5)$$

where f is the probability density function of the logit distribution. The direction of the effect of x_j on probability $(y = 1/x)$ and probability $(y = 5/x)$ is unambiguously determined by the sign of β_j , and the sign of β_j does not always determine intermediate outcomes as in $j = 2, 3$, and 4 in our case. We use a maximum likelihood procedure to estimate the parameters of equation (2) and report the marginal effect of change in the explanatory variables on the effect of change in the probabilities of order aggressiveness by trader types in Table VI.

5.2. Measurement of Variables

We include two classes of explanatory variables in the ordered logit model to identify the determinants of order aggressiveness by different trader types. First, following Ranaldo (2004) and Duong et al. (2009), we include a series of market condition variables. *Spread* is

TABLE IV
The Distribution of Order Submission Levels Over the Trading Day
by Trader-Type Categories

<i>Time Interval</i>	<i>Market Order (%)</i>	<i>Better Best 1 Quote (%)</i>	<i>Best 1 Quote (%)</i>	<i>Best 2–5 Quote (%)</i>	<i>Behind Best 5 Quote (%)</i>	<i>Total Order Submission Number</i>
<i>Panel A: Individual Day Traders</i>						
0. 08:30–08:45	4.33	17.12	0.53	1.10	76.92	295,571
1. 08:45–09:00	14.88	21.77	17.35	23.31	22.69	810,151
2. 09:00–09:15	16.98	27.43	18.53	22.70	14.36	1,143,315
3. 09:15–09:30	17.56	26.16	18.23	22.63	15.42	1,088,322
4. 09:30–09:45	18.10	25.67	18.21	22.63	15.39	973,122
5. 09:45–10:00	18.17	25.23	17.94	23.35	15.31	987,284
6. 10:00–10:15	18.53	25.06	18.60	22.56	15.25	926,385
7. 10:15–10:30	19.14	24.90	18.41	22.29	15.26	893,396
8. 10:30–10:45	19.56	24.83	18.65	21.58	15.38	825,842
9. 10:45–11:00	20.14	24.69	18.10	21.32	15.75	865,638
11. 11:15–11:30	19.90	24.34	18.67	21.80	15.29	802,380
12. 11:30–11:45	19.93	24.80	18.37	21.51	15.39	841,478
13. 11:45–12:00	18.91	24.45	18.25	23.44	14.95	896,892
14. 12:00–12:15	19.20	24.40	18.13	23.10	15.17	901,794
15. 12:15–12:30	19.00	24.83	18.25	22.66	15.26	861,149
16. 12:30–12:45	18.92	24.81	18.24	23.36	14.67	877,886
17. 12:45–13:00	18.62	24.95	18.41	23.09	14.93	868,805
18. 13:00–13:15	18.13	24.81	18.85	23.59	14.62	891,389
19. 13:15–13:30	18.30	25.58	18.83	23.06	14.23	889,287
20. 13:30–13:45	20.15	25.73	18.34	22.67	13.11	701,133
<i>Panel B: Individual Non-Day Traders</i>						
0. 08:30–08:45	5.93	22.32	0.48	1.22	70.05	418,472
1. 08:45–09:00	19.72	24.30	15.44	21.00	19.54	1,016,894
2. 09:00–09:15	19.17	23.70	15.22	21.85	20.06	930,321
3. 09:15–09:30	18.56	21.93	15.23	22.88	21.40	868,661
4. 09:30–09:45	17.18	21.57	16.22	23.25	21.78	766,620
5. 09:45–10:00	17.64	21.01	16.28	23.57	21.50	768,803
6. 10:00–10:15	17.23	20.77	15.90	24.71	21.39	716,007
7. 10:15–10:30	17.52	20.24	16.18	24.66	21.40	671,726
8. 10:30–10:45	17.85	20.13	16.43	24.28	21.31	626,934
9. 10:45–11:00	18.07	20.18	16.10	23.87	21.78	668,187
11. 11:15–11:30	17.71	20.07	16.80	23.83	21.59	618,264
12. 11:30–11:45	18.11	19.95	15.84	25.23	20.87	660,748
13. 11:45–12:00	17.98	20.48	15.65	23.94	21.95	658,815
14. 12:00–12:15	18.89	19.98	15.68	24.00	21.45	669,748
15. 12:15–12:30	18.67	20.37	15.26	23.41	22.29	622,265
16. 12:30–12:45	18.64	19.77	15.26	24.41	21.92	671,334
17. 12:45–13:00	17.85	19.89	15.92	24.76	21.58	657,050
18. 13:00–13:15	18.14	20.05	15.67	24.54	21.60	699,043
19. 13:15–13:30	18.38	20.32	15.74	24.33	21.23	741,943
20. 13:30–13:45	19.24	21.21	16.49	23.57	19.49	659,252
<i>Panel C: Foreign Institutional Traders</i>						
0. 08:30–08:45	3.44	38.77	0.36	1.52	55.91	69,784
1. 08:45–09:00	0.71	13.62	9.30	12.25	64.12	821,579
2. 09:00–09:15	0.41	10.51	6.22	12.19	70.67	1,261,478
3. 09:15–09:30	0.42	8.00	5.13	11.15	75.30	1,243,778
4. 09:30–09:45	0.41	6.99	4.59	10.61	77.40	1,158,624
5. 09:45–10:00	0.29	7.01	4.70	11.08	76.92	1,117,200

continued

TABLE IV
(Continued)

<i>Panel C: Foreign Institutional Traders</i>						
6. 10:00–10:15	0.33	7.24	4.82	11.25	76.36	1,018,665
7. 10:15–10:30	0.32	6.96	4.69	11.52	76.51	941,279
8. 10:30–10:45	0.36	7.60	5.14	11.63	75.27	928,377
9. 10:45–11:00	0.38	6.96	4.73	11.40	76.53	957,144
11. 11:15–11:30	0.30	6.81	4.54	11.36	76.99	885,626
12. 11:30–11:45	0.41	7.34	4.83	11.54	75.88	905,724
13. 11:45–12:00	0.34	6.98	4.68	11.28	76.72	949,052
14. 12:00–12:15	0.36	6.48	4.16	10.91	78.09	987,746
15. 12:15–12:30	0.34	6.22	4.02	11.12	78.30	1,029,365
16. 12:30–12:45	0.36	6.18	4.07	11.00	78.39	1,048,524
17. 12:45–13:00	0.33	6.11	4.01	10.78	78.77	1,013,035
18. 13:00–13:15	0.33	6.14	4.30	11.25	77.98	1,029,398
19. 13:15–13:30	0.27	7.52	4.28	10.97	76.96	1,131,264
20. 13:30–13:45	0.49	11.00	6.44	12.52	69.55	1,026,388
<i>Panel D: Futures Proprietary Firm Traders</i>						
0. 08:30–08:45	2.50	24.43	0.58	1.89	70.60	124,806
1. 08:45–09:00	0.75	26.54	16.83	17.90	37.98	867,767
2. 09:00–09:15	0.60	24.24	15.69	16.60	42.87	1,169,555
3. 09:15–09:30	0.49	22.18	14.50	15.99	46.84	1,075,933
4. 09:30–09:45	0.40	20.47	13.67	15.61	49.85	980,233
5. 09:45–10:00	0.45	20.82	13.69	16.03	49.01	970,429
6. 10:00–10:15	0.52	20.06	13.27	16.19	49.96	917,191
7. 10:15–10:30	0.49	19.41	13.08	15.51	51.51	900,072
8. 10:30–10:45	0.43	18.24	12.80	15.90	52.63	876,204
9. 10:45–11:00	0.50	19.03	13.18	16.60	50.69	928,124
11. 11:15–11:30	0.42	18.44	12.93	16.27	51.94	845,769
12. 11:30–11:45	0.45	19.27	13.52	16.47	50.29	879,367
13. 11:45–12:00	0.42	19.67	13.66	16.41	49.84	905,730
14. 12:00–12:15	0.45	19.99	13.84	16.49	49.23	904,525
15. 12:15–12:30	0.42	19.61	13.49	16.92	49.56	872,430
16. 12:30–12:45	0.51	19.73	13.61	17.56	48.59	916,829
17. 12:45–13:00	0.42	19.49	13.48	17.01	49.60	877,965
18. 13:00–13:15	0.45	20.19	13.86	17.43	48.07	883,308
19. 13:15–13:30	0.49	21.34	14.89	17.52	45.76	900,154
20. 13:30–13:45	0.68	23.63	15.72	18.21	41.76	762,540

Notes. The table presents the distribution of the order submission level of FITX futures during 15-minute intervals for individual day traders, individual non-day traders, foreign institutional traders, and futures proprietary firm traders respectively. The market order column is defined as those orders executed immediately at the best price currently standing in the market. The better best 1 quote column is defined as limit orders that are submitted to better best 1 quote. The submission limit orders are buy (sell) orders with prices greater (less) than the best bid (ask) quote. The best 1 quote refers to limit orders that are submitted to best 1 quote. The best 2–5 quote is defined as limit orders that are submitted to behind best 1 quote but at or before best 5 quotes. The behind best 5 quote is defined as the limit orders that are submitted to behind best 5 quote. The total column refers to the total number of orders submitted in a particular interval. 0 denotes the pre-open period for each trading day. The pre-open period is from 8:30 to 8:45 a.m.

measured as the absolute difference between the best bid price and best ask price just prior to the submission of the order. Following Ranaldo (2004), we measure transitory volatility, *Transitory Volatility*, as the standard deviation of the midquote change over the 15 seconds prior to the submission of the order. *Momentum* is measured as the cumulate signed transaction indicators over the 15 seconds prior to the submission of the order. We calculate the signed transactions by multiplying submission order flow by 1 (–1) if the order is a market buy (sell) order. *Size* is number of shares submitted in an order. *First* is a dummy variable that equals 1 if the order submission occurs during the first 15 minutes of the trading day. *Close* is

a dummy variable that equals 1 if the order submission occurs during the last 15 minutes of the trading day.

Second, we include three explanatory variables related to the state of the limit order book.¹⁶ We estimate these variables of the state of the limit order book from the best five bids and best five asks limit prices and the associated number of contracts because investors can only access limit order book information including the best five bids and best five asks limit prices along with the number of contracts submitted from the screen.

P_{2-3}^{imb} is measured as the imbalance in the price gap between the best 1 (aggressiveness category 3) and best 5 (aggressiveness category 2) limit orders as

$$P_{2-3}^{\text{imb}} = \left(P_{2-3}^{\text{same}} - P_{2-3}^{\text{opposite}} \right) / \left[\left(P_{2-3}^{\text{same}} + P_{2-3}^{\text{opposite}} \right) / 2 \right], \quad (6)$$

where the $P_{2-3}^{\text{same}} (P_{2-3}^{\text{opposite}})$ is the best 1 bid price minus best 5 bid price (the best 5 ask price minus best 1 ask price) just prior to a buy order submission and the best 5 ask price minus best 1 ask price (the best 1 bid price minus best 5 bid price) just prior to a sell order's submission. Thus, an increase in P_{2-3}^{imb} indicates a decrease in liquidity supply on the same side relative to the opposite side as the steps on the same side become relatively sparse. Q_3^{imb} is measured as the market depth imbalance in the best 1 bid (ask), aggressiveness category 3, of the limit order book as

$$Q_3^{\text{imb}} = \left(Q_3^{\text{same}} - Q_3^{\text{opposite}} \right) / \left[\left(Q_3^{\text{same}} + Q_3^{\text{opposite}} \right) / 2 \right], \quad (7)$$

where $Q_3^{\text{same}} (Q_3^{\text{opposite}})$ is the market depth at the best bid (ask) just prior to a buy order submission and at the best ask (bid) just prior to a sell order submission. Q_2^{imb} is measured as the market depth imbalance in the best 2–5 bid (ask), aggressiveness category 2, of limit order book as

$$Q_2^{\text{imb}} = \left(Q_2^{\text{same}} - Q_2^{\text{opposite}} \right) / \left[\left(Q_2^{\text{same}} + Q_2^{\text{opposite}} \right) / 2 \right], \quad (8)$$

where the $Q_2^{\text{same}} (Q_2^{\text{opposite}})$ is the cumulative market depth at the best 2–5 bid (ask) just prior to a buy order submission and the best 2–5 ask (bid) just prior to a sell order submission.

5.3. Empirical Results

Table V reports the results of the ordered logit regression analysis of the influence of market conditions and the state of the order book on order aggressiveness by trader types. Table VI provides the results of the marginal analysis (response) on the results of the change in probability of order aggressiveness by change in one unit of explanatory variables in the ordered logit model.¹⁷ In Table V, the explanatory coefficients are statistically significant at least at the 5% level and the differences between coefficients of explanatory variables by trader types, are also mostly statistically significant at the 5% level.¹⁸ For example, the

¹⁶We follow the ideas suggested by Cao et al. (2008) to measure the imbalance in the price gap between the best 1 and best 5 limit orders, which are reported on the screen of the limit order book.

¹⁷For further discussion on marginal analysis of ordered logit model, refer to Greene (2008, pp. 831–835).

¹⁸In Table V, we construct 95% confidence levels for each coefficient of explanatory variables under the estimated coefficient in parentheses. The differences between the coefficient of explanatory variables of two trader types is statistically significant at the 5% level if 95% confidence intervals are not overlapped, otherwise, they are not statistically significant.

TABLE V
Ordered Logit Regression Analysis on the Influences of Market Conditions on Order Aggressiveness by Trader Types

Variables	Individual Day Traders		Individual Non-Day Traders		Foreign Institutional Traders		Futures Proprietary Firm Traders	
	Coeff.	t-stat.	Coeff.	t-stat.	Coeff.	t-stat.	Coeff.	t-stat.
Spread (Lower, upper)	0.0148 (0.0137, 0.0158)	27.53***	-0.0056 (-0.0063, -0.0049)	-16.10***	-0.0160 (-0.0178, -0.0141)	-17.04***	0.0214 (0.0202, 0.0227)	33.72***
Transitory volatility (Lower, upper)	-0.0081 (-0.0126, -0.0036)	-3.55***	-0.0033 (-0.0065, -0.0001)	-2.02*	-0.1520 (-0.1532, -0.1508)	-247.93***	-0.0497 (-0.0505, -0.0489)	-120.12***
Momentum	0.0070 (0.0069, 0.0070)	237.00***	0.0048 (0.0048, 0.0049)	231.84***	0.0023 (0.0022, 0.0024)	43.20***	0.0092 (0.0091, 0.0093)	272.38***
(Lower, upper)	0.0097 (0.0093, 0.0100)	51.60***	0.0014 (0.0012, 0.0015)	14.46***	-0.1851 (-0.1858, -0.1844)	-505.70***	0.1281 (0.1266, 0.1277)	448.85***
Size	0.0076 (0.0033, 0.0120)	3.43***	0.0050 (0.0020, 0.0081)	3.25***	-0.0003 (-0.0077, 0.0071)	-3.08**	-0.0152 (-0.0202, -0.0102)	-5.98**
P_{2-3}^{imb}	-0.0257 (-0.0267, -0.0246)	-46.39***	-0.0084 (-0.0091, -0.0076)	-21.49***	0.0058 (0.0039, 0.0077)	6.06**	0.0100 (0.0088, 0.0113)	15.69***
Q_3^{imb}	-0.1542 (-0.1558, -0.1526)	-194.22***	-0.0729 (-0.0740, -0.0718)	-129.38***	0.0098 (0.0071, 0.0125)	7.17***	0.1611 (0.1596, 0.1626)	212.83***
(Lower, upper)	-0.2594 (-0.2594, -0.2594)	-27.37***	0.0566 (0.0566, 0.0566)	34.65***	0.3940 (0.3940, 0.3940)	75.59***	0.3633 (0.3633, 0.3633)	110.80***
First	0.4967 (0.4967, 0.4967)	88.80***	0.2104 (0.2104, 0.2104)	117.87***	0.8295 (0.8295, 0.8295)	163.94***	0.5183 (0.5183, 0.5183)	160.18***
Close								
Logit thresholds								
LT1	1.3373	935.79***	0.6261	699.87***	1.3119	251.40***	-0.6305	-184.48***
LT2	1.1838	1546.91***	0.6480	1344.50***	1.0492	929.36***	0.6582	1127.34***
LT3	1.8520	2100.07***	1.0246	1808.64***	1.7039	1110.14***	1.2821	1511.81***
LT4	2.8807	2701.50***	1.6130	2353.39***	4.3305	854.78***	5.4565	892.86***
LR	114.390		86.392		475.135		463.928	
Pseudo R-squared	0.0042		0.0043		0.0544		0.0250	
Observation	8,772,394		6,305,141		3,961,062		8,214,131	

Notes. This table presents the Ordered Logit regression analysis results. The dependent variable is an index that rises with order aggressiveness. The independent variables include nine variables. The Spread is measured as the absolute difference between the best bid and ask price just prior to the submission of the order. The Transitory Volatility is measured as the absolute high low mid-quote volatility over the 15 seconds prior to the submission of the order. The Momentum is measured as the cumulative signed transaction indicators over the 15 seconds prior to the submission of the order. The positive (negative) signed is triggered by market buy (sell) orders and then we calculate the signed transaction by multiplying submission order flow by 1 (-1) if the order is a marketbuy (sell) order. The Size is number of shares submitted in an order. The First is the dummy variable that is equal to one if the order submission time is during the first 15 minutes of the trading day. The Close is the dummy variable that is equal to one if the order submission time is during the last 15 minutes of the trading day. The P_{2-3}^{imb} is measured as the imbalance in the price gap between steps 1 and 5 as the following: $P_{2-3}^{imb} = (P_{2-3}^{same} - P_{2-3}^{opposite}) / ((P_{2-3}^{same} + P_{2-3}^{opposite}) / 2)$, where the P_{2-3}^{same} ($P_{2-3}^{opposite}$) is the price gap between steps 1 and 5 at the bid (ask) just prior to a buy order's submission, and as the price gap between steps 1 and 5 at the ask (bid) just prior to a sell order's submission. The Q_3^{imb} is measured as the market depth imbalance in the top of the limit order book as the following: $Q_3^{imb} = (Q_3^{same} - Q_3^{opposite}) / ((Q_3^{same} + Q_3^{opposite}) / 2)$, where the Q_3^{same} ($Q_3^{opposite}$) is the market depth at the best bid (ask) just prior to a buy order submission and as the market depth at the best ask (bid) just prior to a sell order's submission. The Q_2^{imb} is measured as the market depth imbalance in the rest of limit order book as the following: $Q_2^{imb} = (Q_2^{same} - Q_2^{opposite}) / ((Q_2^{same} + Q_2^{opposite}) / 2)$, where the Q_2^{same} ($Q_2^{opposite}$) is the cumulative market depth at the best 2-5 bid (ask) just prior to a buy order submission and as the cumulative market depth at the best 2-5 ask (bid) just prior to a sell order's submission. The lower and upper bound is based on a 95% confidence interval for a regression coefficient. Lower (upper) is measured as each regression coefficient minus (plus) 1.96 times the standard deviation of regression coefficient. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

coefficients of *Spread* are negative for individual non-day traders and foreign institutional trades. These results suggest that the probability that foreign institutional traders and individual non-day traders will submit limit orders at behind best 5 quote (Category 1) increases, and the probability that they will submit marketable orders (market order and marketable limit order; Categories 5 and 4) decreases. These results suggest that foreign institutional traders and individual non-day traders place more limit orders and fewer market orders to avoid the higher costs of submitting market orders. This reasoning is consistent with prior research results (e.g., Cao et al., 2008; Chiu et al., 2014; Foucault, 1999; Foucault et al., 2005; Rinaldo, 2004).

In addition, when the spread is wide, the probability that futures proprietary firm traders will submit limit orders at the Best 1 to Best 5 (Categories 3 and 2) increases, but the probability that they will submit marketable orders also increases. This result may be because futures proprietary firm traders often use larger market order size and engage in quick turnaround trading to capture instant trading opportunities. Under the same condition of a wide spread, the probability that individual day traders submit marketable orders (Categories 5 and 4) will increase, and the probability that they submit limit orders (Categories 3, 2, and 1) will decrease. These results could be due to the fact that individual day traders will use more aggressive submission strategies to engage in quick turnaround trading and ignore trading cost when the spread increases.¹⁹

The coefficients of *Transitory Volatility* of all four types of traders have negative signs and are significant at the 1% level. These results indicate that all four trader types decrease placements of marketable orders (Categories 5 and 4) and increase placements of limit orders (Categories 3, 2, and 1) when transitory volatility increases. Our empirical results are consistent with our theoretical prediction and prior empirical results on the impact of changes in transitory volatility on market orders versus limit orders (see, among others, Foucault, 1999; Handa & Schwartz, 1996; Menkhoff et al., 2010).

However, we find differences in the response of order aggressiveness by trader types due to changes in transitory volatility. Table VI shows that the probability of placing marketable orders from Category 5 (Market Orders) and Category 4 (Best 1) decreases more for foreign institutional and futures propriety firm traders (especially foreign institutional traders) than for individual day and non-day traders. In addition, institutional traders only have an increased probability of submitting orders in Category 1 (Behind Best 5). However, the probability of placing orders in Categories 3 to 1 increases for individual day traders. Our results indicate that individual traders place more aggressive orders than institutional traders when higher transitory volatility could lead to higher trading costs, potential losses, and the probability of being picked off by informed investors (Foucault, 1999).

We also find a positive relationship between order aggressiveness and order flow *Momentum* for both individual traders and institutional traders. This result is consistent with the theoretical prediction by Goettler et al. (2005) that there is order flow persistence as one type of order is likely to be followed by a similar order. This result is also observed by Biais et al. (1995). However, differences exist between individual and institutional traders in their response to momentum; specifically, individual traders are more likely than institutional traders to submit orders from Categories 5 to 3 (see Table VI). This result may be due to individual traders' having a higher positive market order serial correlation. This finding is also

¹⁹In Table I, we find that total order submission frequency for individual day traders and futures proprietary firm traders is higher than that of individual non-day traders and foreign institutional traders. That individual day traders and futures proprietary firm traders have higher order submission frequency than other types of traders may be due to individual day traders and futures proprietary firm traders engaging in a quick turnaround trading strategy when the spread widens.

consistent with our prior univariate analysis in Table I that individual traders place more market orders than institutional traders.

For the *Size* variable, Tables V and VI show that foreign institutional traders use less aggressive orders when their submission order is larger. We also find a positive relation between order aggressiveness and order size for individual traders and futures proprietary

TABLE VI
Response of Order Aggressiveness to Market Shock (Marginal Effects)

<i>Variables</i>	<i>Market Order</i>	<i>Better Best 1 Quote</i>	<i>Best 1 Quote</i>	<i>Best 2–5 Quote</i>	<i>Behind Best 5 Quote</i>
<i>Panel A: Individual Day Traders</i>					
Spread	0.2448	0.1132	−0.0038	−0.1405	−0.2137
Transitory volatility	−0.1345	−0.0622	0.0021	0.0772	0.1174
Momentum	0.1263	0.0584	−0.0019	−0.0725	−0.1103
Size	0.1601	0.0740	−0.0025	−0.0919	−0.1397
P_{2-3}^{imb}	0.1157	0.0535	−0.0018	−0.0664	−0.1010
Q_3^{imb}	−0.4246	−0.1964	0.0065	0.2437	0.3708
Q_2^{imb}	−2.5525	−1.1806	0.0392	1.4648	2.2291
First	−4.2944	−1.9864	0.0660	2.4644	3.7504
Close	5.2209	0.8026	−0.1263	−2.7177	−3.1795
<i>Panel B: Individual Non-Day Traders</i>					
Spread	−0.1538	−0.0602	−0.0071	0.0525	0.1686
Transitory volatility	−0.0897	−0.0351	−0.0041	0.0306	0.0983
Momentum	0.1327	0.0519	0.0061	−0.0453	−0.1454
Size	0.0373	0.0146	0.0017	−0.0127	−0.0409
P_{2-3}^{imb}	0.1380	0.0540	0.0063	−0.0471	−0.1512
Q_3^{imb}	−0.2297	−0.1109	0.0105	0.0784	0.2517
Q_2^{imb}	−1.9993	−0.7821	−0.0917	0.6827	2.1904
First	1.5526	0.6073	0.0712	−0.5302	−1.7009
Close	2.7672	2.2560	0.2645	−1.4694	−3.8183
<i>Panel C: Foreign Institutional Traders</i>					
Spread	−0.0152	−0.1389	−0.0781	−0.1055	0.3377
Transitory volatility	−0.1445	−1.3219	−0.7430	−1.0042	3.2136
Momentum	0.0022	0.0203	0.0114	0.0154	−0.0493
Size	−0.1760	−1.6094	−0.9046	−1.2226	3.9126
P_{2-3}^{imb}	−0.0107	−0.1623	−0.0960	−0.1208	0.3898
Q_3^{imb}	0.0055	0.0504	0.0283	0.0383	−0.1225
Q_2^{imb}	0.0093	0.0855	0.0480	0.0649	−0.2077
First	0.3745	4.4256	1.9253	2.6023	−9.3277
Close	0.7886	7.2126	4.0538	5.4792	−17.5342
<i>Panel D: Futures Proprietary Firm Traders</i>					
Spread	0.0073	0.2776	0.1149	0.0939	−0.4937
Transitory volatility	−0.0168	−0.6440	−0.2664	−0.2179	1.1451
Momentum	0.0031	0.1193	0.0494	0.0404	−0.2122

continued

TABLE VI
(Continued)

Panel D: Futures Proprietary Firm Traders					
Size	0.0434	1.6614	0.6894	0.5682	-2.9624
P_{2-3}^{imb}	-0.0051	-0.1967	-0.0814	-0.0666	0.3498
Q_3^{imb}	0.0034	0.1296	0.0536	0.0438	-0.2304
Q_2^{imb}	0.0545	2.0857	0.8629	0.7057	-3.7088
First	0.1229	3.7046	1.9465	1.5917	-7.3657
Close	0.1753	6.7109	2.7765	2.2706	-11.9333

Notes. This table shows the marginal effect for the ordered logit regression model. The *Spread* is measured as the absolute difference between the best bid and ask price just prior to the submission of the order. The *Transitory Volatility* is measured as the absolute high low mid-quote volatility over the 15 seconds prior to the submission of the order. The *Momentum* is measured as the cumulate signed transaction indicators over the 15 seconds prior to the submission of the order. The positive (negative) signed is triggered by market buy (sell) orders and then we calculate the signed transaction by multiplying submission order flow by 1 (-1) if the order is a market buy (sell) order. The *Size* is number of shares submitted in an order. The *First* is the dummy variable that is equal to one if the order submission time is during the first 15 minutes of the trading day. The *Close* is the dummy variable that is equal to one if the order submission time is during the last 15 minutes of the trading day. The P_{2-3}^{imb} is measured as the imbalance in the price gap between steps 1 and 5 as the following: $P_{2-3}^{imb} = (P_{2-3}^{same} - P_{2-3}^{opposite}) / [(P_{2-3}^{same} + P_{2-3}^{opposite}) / 2]$, where the P_{2-3}^{same} ($P_{2-3}^{opposite}$) is the price gap between steps 1 and 5 at the bid (ask) just prior to a buy order's submission, and as the price gap between steps 1 and 5 at the ask (bid) just prior to a sell order's submission. The Q_3^{imb} is measured as the market depth imbalance in the top of limit order book as the following: $Q_3^{imb} = (Q_3^{same} - Q_3^{opposite}) / [(Q_3^{same} + Q_3^{opposite}) / 2]$, where the Q_3^{same} ($Q_3^{opposite}$) is the market depth at the best bid (ask) just prior to a buy order submission and as the market depth at the best ask (bid) just prior to a sell order's submission. The Q_2^{imb} is measured as the market depth imbalance in the rest of limit order book as the following: $Q_2^{imb} = (Q_2^{same} - Q_2^{opposite}) / [(Q_2^{same} + Q_2^{opposite}) / 2]$, where the Q_2^{same} ($Q_2^{opposite}$) is the cumulate market depth at the best 2-5 bid (ask) just prior to a buy order submission and as the cumulate market depth at the best 2-5 ask (bid) just prior to a sell order's submission.

firm traders. Foreign institutional traders tend to place the largest order size in Category 1 (Behind Best 5). Futures proprietary firm traders often place large market orders to capture instant trading opportunities. Individual day and non-day traders often submit larger orders at a more aggressive price level.

Results for the *First* and *Close* variables show that foreign institutional, futures proprietary firms, and individual non-day traders all prefer to place more aggressive orders during the first and last 15 minutes of the trading day (see Tables V and VI). Individual day traders prefer to place relatively fewer market orders during the first 15 minutes of the trading day and relatively more aggressive market orders during the last 15 minutes of the trading day. In addition, foreign institutional and futures proprietary firm traders are more aggressive than individual day and non-day traders during the first and last 15 minutes of the trading day. Specifically, foreign institutional traders (individual day traders) are most (least) aggressive during the first and last 15 minutes of the trading day. These results are consistent with implications from the theoretical model by Foucault et al. (2005). They suggest that there are intraday liquidity patterns by time variations in the proportion of patient traders. This result is also supported by our univariate analysis of order aggressiveness patterns (degree of patient pattern) by institutional and individual traders in their percent of market versus limit order in first and close time intervals reported in Table III. Duong et al. (2009) also observed similar order aggressiveness by individual and institutional traders in first and close time intervals in Australia equity markets.

Following Cao et al. (2008), we calculate the imbalance in the price gap, p_{2-3}^{imb} , to capture the price imbalance between differences in price quotes on the two sides of the limit order book. The empirical results show a significantly negative relation between p_{2-3}^{imb} and

order aggressiveness for the institutional traders and a significantly positive relation between p_{2-3}^{imb} and order aggressiveness for the individual traders. These results suggest that institutional traders increase limit order submissions to provide liquidity when own-side liquidity becomes relatively sparse compared to the opposite condition. Individual traders increase market orders and decrease limit order submissions to demand liquidity when own-side liquidity is relatively sparse in comparison to the opposite condition.

Table V reports the impact of market depth imbalance between the two sides of the limit order book on trader's choice of aggressiveness. The coefficients of Q_3^{imb} and Q_2^{imb} are positive and significant at the 1 percent level for foreign institutional and futures proprietary firm traders, and the coefficients of Q_3^{imb} and Q_2^{imb} are negative and significant at the 1 percent level for individual traders. These results suggest that information from limit orders in the top and in the rest of the limit order book affects investors' order submission decisions. In addition, Table VI also shows that institutional traders become more aggressive to increase marketable order (Categories 5 and 4) and reduce limit order (Categories 3, 2, and 1) submissions when the same-side market depth is greater than the market depth of the opposite side.

These results support Parlour's (1998) theoretical prediction of a crowding-out effect.²⁰ Since institutional traders could capture more limit order book information, they could be less risk averse and place more aggressive orders to increase their execution probability when the market depth of the same side is greater than the market depth on the opposite side of the limit order book.

The coefficients of Q_3^{imb} and Q_2^{imb} are significantly negative for individual traders. These empirical results suggest that individual traders place less aggressive orders when the same-side market depth is greater than the market depth of the opposite side. In general, individual traders have less capital and higher fixed costs, so they may have less access to real-time information about the changing state of the limit order book. As a result, their cost of non-execution falls well below that of institutional traders. Thus, individual traders place less aggressive orders in their liquidity supply than do institutional traders (Aitken et al., 2007).

5.4. Robustness Tests

We perform two robustness tests.²¹ First, we stratify our overall sample period (January 1, 2008 to December 31, 2008) into bullish markets, defined as when the average return of the month is positive, and bearish markets, defined as when the average return of the month is negative. Bullish markets are February, March, April, August, and December, and bearish markets are January, May, June, July, September, October, and November. Table VII presents the empirical results of the ordered logit regression analysis of the influence of the complete state of order book information and set of market variables on order aggressiveness by trader types during bullish and bearish market periods. In general, the empirical results based on the bullish and bearish market data are quite similar qualitatively to our ordered logit regression results

²⁰Parlour (1998) finds that limit buy orders will decrease and incoming market buy orders will increase when the buy side of the order book is thick or potential buyers increase. In other words, a crowding-out effect occurs because the price-time priority rule may reduce the probability of execution of a new limit order submission on the same side. In addition, traders are more likely to use limit orders if the book on the other side of the trade is thicker.

²¹Following the referee's suggestion, we have also estimated ordered logit regression model in (5) based on order aggressiveness measure of Rinaldo (2004) and Duong et al. (2009), respectively; the empirical results are qualitatively very similar to equation (5). These empirical results are not reported here to save space and are available upon request.

TABLE VII
Ordered Logit Regression Analysis on the Influences of Market Conditions on Order Aggressiveness by Trader Types: Under Bullish Versus Bearish Markets

	Individual Day Traders		Individual Non-Day Traders		Foreign Institutional Traders		Futures Proprietary Firm Traders	
Variables	Coeff.	t-stat.	Coeff.	t-stat.	Coeff.	t-stat.	Coeff.	t-stat.
Panel A: Bullish Market								
Spread	0.0101	11.21***	-0.0122	-19.61***	-0.0117	-7.78***	0.0213	33.57***
Transitory Volatility	-2.5365	-31.38***	-1.3374	-26.59***	-0.1503	-162.95***	-0.0490	-118.42***
Momentum	0.0088	136.02***	0.0058	134.02***	0.0031	32.73***	0.0094	278.12***
Size	0.0124	40.26***	0.0015	10.04***	-0.1637	-289.18***	0.1271	445.50***
P_{2-3}^{imb}	0.0160	4.54***	0.0065	2.66***	-0.0177	-2.93***	-0.0228	-8.97***
Q_3^{imb}	-0.0216	-25.43***	-0.0067	-11.20***	0.0145	9.75***	0.0264	41.34***
Q_2^{imb}	-0.1552	-125.60***	-0.0747	-85.30***	0.0208	9.58***	0.1455	151.30***
First	-0.3076	-20.84***	0.0476	19.07***	0.3762	45.03***	0.3651	111.43***
Close	0.5097	61.05***	0.1930	71.76***	0.7233	92.39***	0.5115	158.23***
Pseudo R-squared	0.0040		0.0041		0.0421		0.0327	
Observation	3,709,176		2,691,486		1,558,990		3,312,550	
Panel B: Bearish Market								
Spread	0.0176	26.23***	-0.0033	-7.21***	-0.0134	-7.36***	0.0374	46.75***
Transitory volatility	-0.0072	-3.16***	-0.0023	-1.74*	-0.1394	-110.82***	-0.0487	-88.40***
Momentum	0.0065	177.06***	0.0046	179.55***	0.0038	39.14***	0.0094	278.12***
Size	0.0078	33.22***	0.0013	10.56***	-0.2116	-273.11***	0.1015	294.99***
P_{2-3}^{imb}	0.0021	0.72	0.0039	1.94*	-0.0722	-9.70***	-0.0071	-2.21**
Q_3^{imb}	-0.0285	-39.20***	-0.0096	-18.62***	0.0033	1.75*	0.0075	9.20***
Q_2^{imb}	-0.1534	-148.07***	-0.0717	-97.37***	0.0128	4.67***	0.1488	198.17***
First	-0.2440	-19.69***	0.0620	28.65***	0.3237	31.37***	0.4406	103.95***
Close	0.4709	62.31***	0.2191	91.54***	0.7837	73.18***	0.4645	110.19***
Pseudo R-squared	0.0040		0.0044		0.0672		0.0211	
Observation	5,063,218		3,613,655		2,402,072		4,901,581	

Notes. This table presents the Ordered Logit regression analysis results on the influences of market conditions. We divide our whole sample into bullish and bearish markets. The bullish (bearish) market is the average return of the month is positive (negative). The dependent variable is an index that rises with order aggressiveness. The independent variables include nine variables. The *Spread* is measured as the absolute difference between the best bid and ask price just prior to the submission of the order. The *Transitory Volatility* is measured as the absolute high low mid-quote volatility over the 15 seconds prior to the submission of the order. The *Momentum* is measured as the cumulate signed transaction indicators over the 15 seconds prior to the submission of the order. The positive (negative) signed is triggered by market buy (sell) orders and then we calculate the signed transaction by multiplying submission order flow by 1 (-1) if the order is a market sell order. The *Size* is number of shares submitted in an order. The *First* is the dummy variable that is equal to one if the order submission time is during the first 15 minutes of the trading day. The *Close* is the dummy variable that is equal to one if the order submission time is during the last 15 minutes of the trading day. The P_{2-3}^{imb} is measured as the imbalance in the price gap between steps 1 and 5 as the following: $P_{2-3}^{imb} = (P_{2-3}^{same} - P_{2-3}^{opposite}) / [(P_{2-3}^{same} + P_{2-3}^{opposite}) / 2]$, where the P_{2-3}^{same} ($P_{2-3}^{opposite}$) is the price gap between steps 1 and 5 at the bid (ask) just prior to a buy order's submission, and as the price gap between steps 1 and 5 at the ask (bid) just prior to a sell order's submission. The Q_3^{imb} is measured as the market depth imbalance in the top of limit order book as the following: $Q_3^{imb} = (Q_3^{same} - Q_3^{opposite}) / [(Q_3^{same} + Q_3^{opposite}) / 2]$, where the Q_3^{same} ($Q_3^{opposite}$) is the market depth at the best bid (ask) just prior to a buy order submission and as the market depth at the best ask (bid) just prior to a sell order's submission. The Q_2^{imb} is measured as the market depth imbalance in the rest of limit order book as the following: $Q_2^{imb} = (Q_2^{same} - Q_2^{opposite}) / [(Q_2^{same} + Q_2^{opposite}) / 2]$, where the Q_2^{same} ($Q_2^{opposite}$) is the cumulate market depth at the best 2-5 bid (ask) just prior to a buy order submission and as the cumulate market depth at the best 2-5 ask (bid) just prior to a sell order's submission. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

TABLE VIII

Ordered Logit Regression Analysis on the Influences of Market Conditions on Order Aggressiveness by Trader Types During January 2007–July 2007

Variables	Individual Day Traders		Individual Non-Day Traders		Foreign Institutional Traders		Futures Proprietary Firm Traders	
	Coeff.	t-stat.	Coeff.	t-stat.	Coeff.	t-stat.	Coeff.	t-stat.
Spread	0.0302	20.29***	-0.0446	-35.45***	-0.0231	-8.18***	0.0054	2.20**
Transitory volatility	-0.0013	-23.76***	-0.0004	-9.58***	-0.0026	-30.16***	-0.0002	-6.88***
Momentum	0.0154	102.62***	0.0132	107.59***	0.0754	23.18***	0.0063	29.69***
Size	0.0260	5.10***	0.0175	3.94***	-0.0024	-0.26	-0.0251	-3.08***
P_{2-3}^{imb}	0.0217	216.89***	0.0329	297.67***	-0.0049	-12.91***	-0.0402	-106.42***
Q_3^{imb}	-0.5444	-32.29***	0.1237	10.60***	0.5141	15.69***	0.0520	2.20**
Q_2^{imb}	0.8154	72.78***	0.7895	95.68***	0.3412	6.75***	1.7250	96.84***
First	-0.0833	-34.60***	-0.0678	-31.83***	0.0049	23.68***	0.0100	56.49***
Close	-0.1085	-44.22***	-0.1228	-56.80***	0.0047	21.62***	0.1406	65.32***
Logit thresholds								
LT1	1.1320	385.29***	1.1496	436.81***	0.0317	5.53***	2.6936	414.96***
LT2	1.0802	699.93***	1.1469	826.67***	0.5150	302.87***	1.5954	389.29***
LT3	1.7686	969.57***	1.8210	1119.46***	1.2290	468.42***	2.7403	603.26***
LT4	2.9261	1278.24***	2.9780	1452.59***	5.5044	291.83***	7.1018	698.92***
LR	92,347		172,854		4903.5		41,163	
Pseudo	0.0145		0.0211		0.0030		0.0196	
R-squared								
Observation	1,985,839		2,558,450		650,847		846,310	

Notes. This table presents the Ordered Logit regression analysis results from January 2007 to July 2007. The dependent variable is an index that rises with order aggressiveness. The independent variables include nine variables. The *Spread* is measured as the absolute difference between the best bid and ask price just prior to the submission of the order. The *Transitory Volatility* is measured as the absolute high low mid-quote volatility over the 15 seconds prior to the submission of the order. The *Momentum* is measured as the cumulate signed transaction indicators over the 15 seconds prior to the submission of the order. The positive (negative) signed is triggered by market buy (sell) orders and then we calculate the signed transaction by multiplying submission order flow by 1 (−1) if the order is a market buy (sell) order. The *Size* is number of shares submitted in an order. The *First* is the dummy variable that is equal to one if the order submission time is during the first 15 minutes of the trading day. The *Close* is the dummy variable that is equal to one if the order submission time is during the last 15 minutes of the trading day. The P_{2-3}^{imb} is measured as the imbalance in the price gap between steps 1 and 5 as the following: $P_{2-3}^{imb} = (P_{2-3}^{same} - P_{2-3}^{opposite}) / [(P_{2-3}^{same} + P_{2-3}^{opposite}) / 2]$, where the P_{2-3}^{same} ($P_{2-3}^{opposite}$) is the price gap between steps 1 and 5 at the bid (ask) just prior to a buy order's submission, and as the price gap between steps 1 and 5 at the ask (bid) just prior to a sell order's submission. The Q_3^{imb} is measured as the market depth imbalance in the top of limit order book as the following: $Q_3^{imb} = (Q_3^{same} - Q_3^{opposite}) / [(Q_3^{same} + Q_3^{opposite}) / 2]$, where the Q_3^{same} ($Q_3^{opposite}$) is the market depth at the best bid (ask) just prior to a buy order submission and as the market depth at the best ask (bid) just prior to a sell order's submission. The Q_2^{imb} is measured as the market depth imbalance in the rest of limit order book as the following: $Q_2^{imb} = (Q_2^{same} - Q_2^{opposite}) / [(Q_2^{same} + Q_2^{opposite}) / 2]$, where the Q_2^{same} ($Q_2^{opposite}$) is the cumulate market depth at the best 2–5 bid (ask) just prior to a buy order submission and as the cumulate market depth at the best 2–5 ask (bid) just prior to a sell order's submission. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

estimated with whole sample data in Table V.²² Second, we test to examine whether our empirical results are sensitive to the sample periods we use (i.e., financial crisis period versus normal time period). We re-estimate our ordered logit model with data from January 2007 to June 2007, and the empirical results are reported in Table VIII. We find these empirical results

²²We also divide our sample period into the pre-financial crisis period from January 1 to June 31, 2008, and financial crisis period from July 1 to December 31, 2008. The empirical results are qualitatively similar to Table V. To save space, these tables are not reported here and are available upon request.

are qualitatively very similar to those results using our data from January 2008 to December 31, 2008. Thus, we conclude our empirical results are immune to the financial crisis effects during the 2008 sample period.

Finally, we test whether the change in margin requirements in June 2008, has any impact on traders' order placement strategies by trader types. We incorporate a dummy variable equal to one for the period after the margin requirement changes and zero otherwise in our ordered logit model. We find the coefficients of all explanatory variables to be very similar to the empirical coefficients of the ordered logit model without the dummy variable, as reported in Table V. Therefore, we cannot observe that the change in margin requirements in June has any impact on traders' order aggressiveness during this sample period.²³

6. CONCLUSIONS

We use an ordered logit regression to examine how the top and the rest of the order book activities and market variables affect the order aggressiveness strategy of four types of traders (individual day traders, individual non-day traders, foreign institutional traders, and futures proprietary firm traders) in the Taiwan stock index futures market. Our empirical results reveal that there are significant differences among these four types of traders in their responses to changes in the determinants of order aggressiveness. We summarize the major results as follows:

First, individual day and non-day traders tend to use a more aggressive order submission strategy, and they have a higher limit order fill rate and lower cancel and unexecuted rates than foreign institutional traders and futures proprietary firm traders who place more limit orders than market orders. Second, during the intraday time period, order submission levels at limit order book by individual day traders exhibited an L shape and there is a skewed U shape of order submission by foreign institutional traders to limit order book.

Third, our results show that foreign institutional traders and individual non-day traders are less aggressive in their trading strategies when the spreads widen and order size increases. This finding indicates that these trader types are interested in reducing their trading costs. However, both individual day traders and futures proprietary firm traders become more aggressive in their trading strategies when the spreads increase. This result may be due to the fact that these trader types engage in quick-turnaround trading, and thus they demand liquidity in this situation.

Fourth, when transitory volatility increases, all trader types tend to place less aggressive orders. We also observe that the response of foreign institutional traders to changes in volatility is greater than the response of individual traders to changes in transitory volatility (marginal effect, see Table VI).

Fifth, we find a positive relationship between order aggressiveness and order flow momentum for all types of traders. This result suggests that order flow is persistent. Furthermore, individual traders' response to change in momentum shocks is greater than foreign institutional traders' response to change in momentum shocks.

Sixth, we document that information from the complete limit order book affects most traders' order submission decisions. For the price gap imbalance, we find that institutional (individual) traders increase (decrease) their submission of limit orders to provide (demand) liquidity when own-side liquidity becomes relatively sparse. Furthermore, we also observe the

²³To save space we do not report these empirical results of ordered logit with the dummy variable to reflect the margin requirement change in June 2008. Interested readers may obtain the table of these empirical results from one of the authors.

crowded-out effect for institutional traders, indicating that institutional traders place more aggressive orders when same-side depth is greater than opposite-side depth.

Overall, the contribution of our paper is the identification of major determinants of order submission aggressiveness by individual day and non-day traders, domestic and foreign institutional traders at submission time interval in a limit order book market. In particular, we provide new empirical evidence that information from the complete order book is one of the important variables affecting traders' order placement decisions.

APPENDIX I

TAIFEX INDEX FUTURES CONTRACT SPECIFICATIONS

<i>Taiwan Stock Exchange Index futures (FITX)</i>	
Underlying index	Taiwan Stock Exchange Capitalization Weighted Stock Index (TAIEX).
Contract size	NT\$200 × index.
Minimum price fluctuation	NT\$200 (one index point).
Minimum tick size	One index point.
Settlement	Cash settlement.
Daily price limit	±7% of previous day's settlement price.
Delivery months	Spot month, the next calendar month, and the next 3 quarter months.
Last trading day	The third Wednesday of the delivery month of each contract.
Trading hours	The pre-open session is from 8:30 to 8:45 a.m. The regular trading hours conducted on weekdays excluding public holidays from 8:45 a.m. to 1:45 p.m.
Each order size limit	300 contracts.
Position limit	
Individual	300 contracts.
Institutional	1000 contracts.
Futures proprietary	3000 contracts.
Information disclose	Investors can observe best five bids and asks specific prices with the number of contracts in anonymous basis from screen.
Exemption	Institutional investors may apply for an exemption from the above limit on trading accounts for hedging purpose. Exemptions are allowed for futures proprietary firms and omnibus accounts.

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