Intraday Liquidity Provision by Trader Types in a Limit Order Market: Evidence from Taiwan Index Futures

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This study examines the dynamic liquidity provision process by institutional and individual traders in the Taiwan index futures market, which is a pure limit order market. The empirical analysis obtains several interesting empirical results. We find that trader type affects liquidity provision in a number of interesting ways. First, although institutional traders use more limit orders than market orders, foreign institution (individual) traders use a relatively higher percentage of market (limit) orders in the early trading session and then switch to more limit (market) orders for the remainder of the day until close to the end of the trading day. Second, 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. Third, net limit order submissions by institutional traders are positively related to one-period lagged spread. Finally, both the state of limit order book and order size significantly influence all types of traders' strategy on submission of limit order versus market order during the intraday trading session. © 2012 Wiley Periodicals, Inc. Jrl Fut Mark 34:145–172, 2014

1. INTRODUCTION

Electronic limit order market is one of major trading venues in equity, futures, and option exchanges around the world. Because no designated market makers exist in these markets, limit orders supply liquidity and market orders consume liquidity. Thus, liquidity arises endogenously from the orders submitted by market participants in the exchanges. Because liquidity is a major performance measurement for exchanges, understanding the factors affecting the limit order submission rate by different types of traders under different market conditions is of interest to researchers, exchange officials, and investors.

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Previous literature has approached limit order trading strategy through both theoretical models and empirical analysis. Earlier theoretical models assume that informed traders who trade on short-lived, private information are impatient and thus place market orders, whereas uninformed traders who use limit orders must await execution (Glosten, 1994; Seppi, 1997). Later theoretical models (e.g., Chakravarty & Holden, 1995; Harris, 1998; Kaniel & Liu, 2006) relax this restrictive assumption. They suggest that informed traders use both limited orders and market orders. In general, they show that the time horizon of private information is positively related to the probability of using limit orders by informed traders.

Using an experimental asset market, Bloomfield, O'Hara, and Saar (2005) investigate empirically the evolution of the liquidity provision by trader type in a pure limit order market under an experimental market setting. They find that informed and liquidity traders use reverse strategies: Although informed traders consume liquidity earlier in the trading day, gradually becoming liquidity providers as they increasingly place more limit orders as the trading day progresses, liquidity traders provide liquidity early in the trading day, gradually shifting to consume liquidity as the day progresses. They also report that informed traders use relatively more limit orders. These experimental results challenge the assumptions of the theoretical models on the order choice of informed traders in a limit order market.

Goettler, Parlour, and Rajan (2005) study the dynamics of order choices in a limit order market under asymmetric information. They suggest that the volatility of changes in the fundamental value of an asset affects agents acquiring information about the asset, which in turn affects the choice of order type of informed traders and market outcomes.[1] Keim and Madhavan (1995) present empirical evidence on the order choices of institutional traders. They find that informed traders with short-lived information tend to use market orders whereas informed traders with long horizon information (e.g., value traders) are more likely to use limit orders.

On the empirical literature, Biais, Hillion, and Spatt (1995) examine the relation between the limit order book and the order flow in the Paris Bourse. They find that the conditional probability of submitting limit (market) orders by investors is higher when the spread is wide (tight). Chung, Van Ness, and Van Ness (1999) also show that traders place more limit orders when the intraday spread is wide in New York Stock Exchange (NYSE). Ahn, Bae, and Chan (2001) examine the role of limit orders in providing liquidity in the Stock Exchange of Hong Kong (SEHK), a pure limit order market. They find that one lagged period transitory volatility is the major determinant of market depth (due to the submission of limit orders) and that a rise in market depth is followed by a decrease in volatility.[2] Volatility also determines the changing mix of market and limit orders.

Bae, Jang, and Park (2003) examine the trader's choice between limit and market orders using a sample from the NYSE SuperDot. They find that the order size, spread, and expected transitory volatility are positively related with trader's limit order choice. Using data from the Moscow Interbank Currency Exchange, Menkhoff, Osler, and Schmeling (2010) investigate the use of aggressive price limit orders by informed and uninformed traders in an ordered logit regression framework. They show that informed traders are more sensitive to changes in the spread, volatility, and market depth than uninformed traders in a pure limit market. We extend this line of research by investigating the difference in market impact on order submission

[1]Goettler et al. (2009, p. 68) obtain their results numerically from a theoretical model because they cannot obtain a closed form solution when the relevant frictions of a limit order market are incorporated in the model. The relevant frictions of a limit order market are discrete price staggered trader arrivals and asymmetric information. For other theoretical models on the dynamics of order choice in limit order markets, see Rosu (2009) and Parlour and Seppi (2008).

[2]Ahn et al. (2001) do not accurately estimate transitory volatility; they use realized volatility to approximate transitory volatility.

strategy by different trader types in the real world market settings. We then divide traders by type into individual traders and institutional traders with individual (institutional) traders further categorized as day traders and nonday traders (foreign institutional firms and proprietary futures firm traders). To the best of our knowledge, this analysis is the first study to examine and compare the dynamic liquidity provision process by institutional and individual traders.

To investigate liquidity provision of these four trader types, we first document the intraday liquidity provision in a pure limit order market using the actual intraday data from the Taiwan index futures market for the period from January 2007 to December 2008.[3] Second, we examine the impact of various market conditions (i.e., one-period lagged transitory and informational volatility, one-period lagged spread, one-period lagged same and opposite side market depth, and limit order size) on the liquidity provision by trader types in a joint regression framework.[4] Finally, we compare our empirical results on the changing liquidity provision by trader type in a natural market setting with the experimental market results of Bloomfield et al. (2005).

Our study contributes to the literature in several ways. First, our empirical results from a natural market setting support the experimental market setting results of Bloomfield et al.'s (2005) study on the intraday trading strategies of informed traders and uninformed traders. Second, in the influence of market characteristics on the limit and market order choices decision, we show 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. We conduct a direct test on the prediction of Handa and Schwartz (1996) (vs. Foucault, 1999) on the influence of transitory volatility and informational volatility on institutional versus individual trader's decision on selection of limit versus market orders. To the best of our knowledge, this portion of our analysis adds new findings to the limit order literature. Third, we find that the net limit order submissions by foreign institutional traders and futures proprietary firm traders are positively related to one period lagged spread; conversely, no significant relation exists between lagged one period spreads and the limit order submissions by individual day or noonday traders. Finally, the results also suggest that both the state of limit order book and order size significantly influence the strategy of all trader types on submission of limit order versus market order during the intraday trading session.

Our study is organized as follows. In Section 2, we present a literature review related to the impact of market conditions on the supply of liquidity by institutional and individual traders in a limit order market. In Section 3, we describe the Taiwan index futures market structure and the data. In Section 4, we present the empirical methodology. In Section 5, we present the empirical results, and Section 6 concludes.

2. LITERATURE REVIEW AND HYPOTHESES

2.1. Trading Strategies: Informed Versus Uninformed Traders

In a pure limit order market, traders face decisions between limit orders and market orders. Market orders consume liquidity and are executed with certainty at the posted prices in the

[3]The financial literature generally agrees that institutional traders are informed traders because they collect and analyze market information more quickly than uninformed traders in index futures markets. However, individual investors often follow their observed market prices pattern as their major inputs for their trading decision.

[4]Prior studies include only a subset of our market condition variables in their regression models. For example, Bae et al. (2003) do not include the state of limit order book variable in their regression, and Bloomfield et al. (2005) examine the impact of each market condition variables separately on the submission of limit versus market orders by trader types in their experimental setting.

market. Limit orders supply liquidity and have the advantage of execution at more favorable prices than market orders. However, limit orders face execution uncertainty and an adverse selection risk because limit order prices are fixed. Limit order traders provide free options to the arrival of informed traders (Copeland & Galai, 1983).

Earlier theoretical models (e.g., Glosten, 1994; Seppi, 1997) assume that informed traders place market orders because they are impatient and that private information is short-lived whereas uninformed traders supply liquidity by submitting limit orders and waiting for execution. Later theoretical models relax this restrictive assumption. For example, Chakravarty and Holden (1995) analyze the behavior of the informed trader in a single-period call-type market. They show that in this type of market the informed trader may simultaneously submit a market buy order and a limit sell order, and limit order acts as a safety net for the market order. In this way, an optimal mix of limit orders and market orders leads to a higher payoff than submitting only market orders when uncertainty exists regarding the price that a market order will fetch.

Harris (1998) develops optimal order submission strategies for trading problems faced by an informed trader, a uniformed trader, and a value-motivated trader. He suggests that informed traders are more likely to use market orders when private information will soon become public, reflecting the desire of informed traders to realize their valuable private information. He also predicts that liquidity traders will start by using limit orders and then switch to market orders as the end of trading approaches to meet their trading target. When informed traders face early deadlines, they also employ market orders. Finally, Harris finds that both informed and uninformed traders submit limited orders when the deadline is distant and the bid–ask spread is large to minimize transaction costs. In general, Harris (1998) suggests that informed traders use relatively more market orders than limit orders.

Kaniel and Liu (2006) analyze informed traders' equilibrium choice of limit and market orders. They show that the time horizon of private information is positively related to the probability of using limit orders by informed traders. Their empirical results show that informed traders prefer to use limit orders, which are indeed more informative.

Bloomfield et al. (2005) employ experimental asset markets to investigate the evolution of liquidity provisions by informed and liquidity traders in a pure limit order market. Their study focuses on how trading strategies are affected by trader type, market conditions, and characteristics of the asset at different time points during a trading day. They find that informed traders use more market orders than limit orders at the earlier stage of the trading session because informed traders are likely to capitalize on their private information. As the trading progresses, informed traders switch to liquidity provisions. The change in the behavior of informed traders seems to be in response to the dynamic adjustment of price to information. Informed traders perform better in terms of profit as liquidity suppliers because they face less adverse selection risk when placing limit orders in comparison to uninformed traders.

Their result suggests that informed traders take (provide) liquidity when the value of information is high (low). Uninformed traders supply relatively more liquidity in the earlier stage of the trading session and use relatively more market orders as trading comes to a close because of their need to meet the target value of their trading purposes. Bloomfield et al. (2005) also document the difference in the impacts of market conditions (i.e., the volatility, the spread, the state of limit orders) on order choice between informed and uninformed traders. Their experimental results suggest the need to further relax the assumptions of theoretical models and point to an urgent need for a dynamic model on the order choice by trader types in a limit order market.

Anand, Charkravarty, and Martell (2005) empirically investigate the evolution of liquidity and changing of trading strategies of institutional traders (i.e., informed traders) and find that institutional traders use market orders more often in the first half than in the second

half of the trading day. They also document that limit orders placed by institutional traders perform better than those placed by individual traders (i.e., uninformed traders). However, their tests are based on the intraday data for the period from November 1990 to January 1991 obtained from NYSE, which is not a pure limit order market.

2.2. Influence of Market Characteristics: Limit Versus Market Orders

The important market characteristic variables that affect the trader's choice on limit or market orders are volatility, spread, the state of limit order book, and order size. Handa and Schwartz (1996) develop a model to explain the rationale of trader choice between markets and limit order and the profitability of limit order trading. In their model, the trader's choice depends on the probability of whether their limit order is executed against an informed trader or an uninformed (liquidity) trader. A limit order suffers a loss when executed against an informed trader and experiences a profit when executed against a liquidity trader. Thus, traders will submit more limit orders than market orders when the increase in price volatility is caused by change in market liquidity reasons. That is, the profitability of limit orders increases as traders increase in the supply of liquidity. Thus, Handa and Schwartz (1996) predict a positive relation between submission of limit orders and transitory price volatility.

Foucault (1999) develops a model that explicitly incorporates a trader's decision to submit market versus limit orders. He theorizes that when the asset volatility increases due to informed traders, the risk of adverse selection increases. Thus, limit order traders must increase their bid–ask spreads to insure against losses. The cost of trading on market orders is less attractive, and traders find it more cost-effective to trade using limit orders.

Ahn et al. (2001) use 33 component stocks in the Hang Seng Index (HIS) between July 1996 and June 1997 and show that an increase in market depth follows a rise in transitory volatility due to an increase in submission of limit orders. A decrease in volatility subsequently follows an increase in market depth. These results are consistent with the predication of the theoretical model of Handa and Schwartz (1996). Bae et al. (2003) use a sample of 144 NYSE list stocks over the period from November 1, 1990 to January 31, 1991 to investigate trader's choice between limit and market orders. They find that traders use more limit orders when they expect an increase in transitory volatility. They find the impact of the asset (informational) volatility on trader's choice between limit and market orders is inclusive. Bloomfield et al. (2005) also find that volatility is one of the major factors affecting both informed and uninformed traders' choice between limit and market orders.

Menkhoff et al. (2010) investigate the use of aggressive price limit orders by informed traders and uninformed traders in an ordered logit regression framework with data from the Moscow Interbank Currency Exchange. They show that the volatility variable is negative and highly significant for informed traders and significant at the 10% level for uninformed traders. Their results suggest that both types of traders increase their use of limit orders following an increase in volatility.

Menkhoff et al. (2010) also find that informed traders are more sensitive to change in the spreads, volatility, and depths than uninformed traders in a pure limit market. There are two major concerns in their quality of data used in empirical tests: (a) the data lack trader identification codes on trader type, and thus the authors identify traders as either informed or uninformed based on their inference from the trade size and location information and (b) the data cover only a seven-intraday data period, which may be too short for reliable empirical tests.

Biais et al. (1995) provide empirical evidence that when the spread is large, the conditional probability increases that investors will place more limit orders than market

orders. In contrast, traders will use more market orders (i.e., hitting the quote) than limit orders when the spread is tight. Similarly, Chung et al. (1999) examine limit order book and the bid–ask of 144 stocks traded in NYSE. They provide evidence that more traders submit limit orders when the spread is wide and use market orders when the spread is tight. These results, which suggest that when the spread is wide, traders place more limit orders, may be due to the high cost of submitting market orders or because traders receive higher compensation by executing limit orders.

Previous literature has shown that the state of the limit order book influences a trader's order choice. Parlour (1998) provides a theoretical model that suggests that traders are less likely to use limit orders if the limit book on the same side of the trade is thicker. This so-called "crowding out" effect arises because the time priority of orders already in the book lowers the probability of executing of a new order on the same side. However, traders are more likely to use limit orders if the book on the other side of the trade is thicker. Bloomfield et al. (2005) examine this hypothesis in an experimental market setting. Their results lend support to Parlour's model prediction that traders will use more limit orders as the depth of the other side increases. However, Bloomfield et al. (2005) find that informed and liquidity traders have higher limit order submission ratio when the same side of order book is thicker. This result is inconsistent with Parlour's model prediction.

Based on order and transaction intraday data from the Swiss stock exchange, Ranaldo (2004) also demonstrates that patient traders become more order aggressive when their own (opposite) side book is thicker (thinner). Using limit order book information from the Australian Stock Exchange (ASX), Cao, Hansch, and Wang (2008) also provide additional empirical evidence that traders use more market orders when the same side of limit order book is thicker.

In general, traders have strong motives to minimize their trading cost when the order size is relatively larger. Bae et al. (2003) divide their sample into two order groups based on size and find that, on average, traders in large order size group use more limit orders, ranging from 66% to 79% of the total orders in a trading day. In small order size group, 28–36% of the orders are limit orders. These results provide evidence that traders tend to use limit orders when the order size is relatively large.

Building on the results from previous literature, we use unique real world data to examine the differences among institutional, individual day and nonday traders in providing liquidity in response to changes in market conditions during a trading day in a joint regression model.

3. TAIWAN INDEX FUTURES MARKET STRUCTURE AND THE DATA

The Taiwan Futures Exchange (TAIFEX) is a pure order-driven market. Investors submit limit and market orders through brokers to the automated trading systems (ATSs). Limit orders are consolidated into the electronic limit-order book. The ATS order matches and executes orders continuously following a price–time priority rule and setting a single transaction price. Markets buy (sell) orders hit the best ask (bid) prices. The buy (sell) order with higher (lower) limit price than the set transaction price is executed at the transaction price. Market participants can also submit cancel orders at any time prior to matching. The preopen session is from 8:30 a.m. to 8:45 a.m. During this period, investors can submit limit and market orders to the ATS system through brokers, and the exchange uses the single-price auction system to establish the opening prices of regular trading hours. The regular trading hours conducted on weekdays excluding public holidays are 8:45 a.m. to 1:45 p.m. Limit orders are automatically canceled at the end of trading day; thus, we work with a one-day limit order book. No hidden orders exist.

TABLE I
Daily Trading Volume Statistics by Trader Type

	Individual Traders (%)					
	Day Trader (%)	*Nonday Trader (%)*	*Domestic Institutional Traders (%)*	*Foreign Institutional Traders (%)*	*Futures Proprietary Firms (%)*	*Total Daily Average*
Panel A: Percentage of Total Volume by Trader Type						
Trading volume	30.40	30.31	3.69	12.26	23.34	93,683.69
Panel B: Percentage of Total Volume of Day Trading Versus Nonday Trading by Trader Type						
Day trading	94.78	1.54	2.83	0.85	100	
	(50.06)	(13.40]	(7.41)	(1.17)	(32.07)	
					[30,044.36]	
Nonday trading	44.64	4.70	16.71	33.96	100	
	(49.94)	(86.60]	(92.59)	(98.83)	(67.93)	
					[63,639.33]	
Total	60.72	3.69	12.26	23.34	100	
	(100)	(100)	(100)	(100)	(100)	
	[56,875.37]	[3,456.93]	[11,485.62]	[21,865.77]	[93,683.69]	

Note. In this table, we provide daily trading volume statistics by trader type in the Taiwan Stock Exchange index futures from January 1, 2007 to December 31, 2008. Panel A shows the percentage of daily trading volume for individual day traders, individual nonday traders, domestic institutional traders, foreign institutional traders, and futures proprietary firms traders. Panel B separates trading volume into day trading and nonday trading. The numbers in parentheses represent the percentages of day trading and nonday trading for each trader type. For example, among foreign institutional traders, 7.41% engage in day trading and 92.59% engage in nonday trading. A trader is defined as a day trader when the amounts of contracts purchased and sold are the same in a specific day. The numbers in brackets are the total number of average trades by trader type.

TAIFEX disseminates order and transaction prices to the public in real time. Investors can observe on the screen the specific anonymous best five bid and best five ask prices with the number of contracts. Because no designed market makers exist, market participants generate liquidity endogenously by placing orders.

We use intraday tick-by-tick data of Taiwan stock index futures (FITX) obtained from TAIFEX in our analysis. Our sample period covers from January 1, 2007 to December 31, 2008. The contract size is the index value of FITX multiplied by 200 New Taiwan Dollars (NT$). The maximum of each order size of TIFX is 100 contracts. We use nearby futures contracts in our analysis, and trading volume in the delivery month is used as the indicator to switch from first deferred contract to nearby futures contract. In our data-editing process, we eliminate price limit days, time periods without limit order information and days with missing trading data.[5] The data set contains the detailed history of order flows, order book, transaction data, and the identity of the traders. For each order, the date and time of arrival of the order, its direction (buy or sell initiation), the quantity demanded or supplied, and the trader identification are recorded. The trader identification enables us to categorize four types of traders: individual traders, domestic institution traders, futures proprietary firms, and foreign institutional traders.

Panel A of Table I shows that the daily average trading volume is about 93,684 contracts. Individual traders account for 61% of the total daily average volume. Futures proprietary firms are different from futures brokers in that they trade for their own accounts to make profits and also make commissions by trading for clients. Their trading activity accounts for 23.34% of daily average total volume. Foreign Institutional traders executed about 12.26%, and domestic

[5]Data are missing for eight days in June 2008 and three days in December 2008.

institutional traders account for only 3.69% of daily average trading volume. Due to their low trading activity, which leads to frequent inadequate observations, we drop domestic institutional traders from our sample.[6] Our analysis assumes that foreign institutional investors and futures proprietary firms are members of institutional traders and that individual traders are uninformed or liquidity traders.[7] Panel A shows that day trading in total trading volume accounts for about 30.4%, whereas individual nonday trading accounts for 30.31% of total volume.[8] Our results are similar to the results reported by Barber et al. (2009), who find that day trading by individual traders is over 20% in the Taiwan stock market.

4. METHODOLOGY

Our empirical analysis consists of two steps. First, we use one-way analysis of variance model to estimate the intraday submission patterns of limit orders, market orders, and limit order submission ratios. Second, we use regression models to estimate the influences of market condition variables (i.e., $Transitory\_Volatility_{t-1}$, $Informational\_Volatility_{t-1}$, $Spread_{t-1}$, $Same\_Side\_Depth_{t-1}$, $Opposite\_Side\_Depth_{t-1}$, and $Limit\_Size_t$) on net limit order submission by institutional and individual traders.

In the analysis of intraday variation patterns of order choices by trader types, we follow two principles to select the length of the time interval. First, we are interested in short time variations in limit and market order submissions. Second, the time interval must be sufficient to provide reliable estimates of intraday patterns. Balancing these two guidelines, we select a 15-minute interval.

The one-way analysis of variance regression model is specified as follows:

$$Y_t = \delta_0 + \sum_{j=0}^{19} \beta_j D_{j,t} + e_t. \tag{1}$$

The dependent variable Y_t is equal to the sum of limit orders in a 15-minute time interval, the sum of market orders in a 15-minute time interval, or the limit order submission ratio in a 15-minute interval. The value of intercept δ_0 is equal to the daily average as the basis of comparison. For this reason, we impose the restriction $\sum_{j=0}^{20} \beta_j = 0$. $D_{j,t}$ is a dummy variable that equals 1 if it is in jth interval, $j = 0,1,2,\ldots,19$; zero, if it is not in the jth interval; and equal to -1 if it is in 20th time interval.[9] The error term is e_t. The coefficient of β_j is equal to the difference between the mean of jth time interval and the value of δ_0, the daily average. The sample mean of jth time interval is equal to the sum of the values of $\beta_j + \delta_0$. This model allows us to examine the influences of the role of the time interval on order submissions by trader type.

The regression model used to examine the influence of characteristics of market conditions lagged one period (i.e., $Transitory\_Volatility_{t-1}$, $Informational\_Volatility_{t-1}$,

[6]In 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 traders only accounts 3.69% of average daily trade volume. 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.

[7]Goettler et al. (2009, p. 68) suggest institutional traders are informed traders who view the current expected value of cash flow on the instrument. This finding implies that informed traders perform research on the value of the instrument while uninformed agents estimate the value of the instrument based on market observables.

[8]*Day 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.

[9]The estimated $\beta_{20} = -(\sum_{j=1}^{19} \beta_j)$.

$Spread_{t-1}$, $Same\_Side\_Depth_{t-1}$, and $Other\_Side\_Depth_{t-1}$) and order size on liquidity provision by institutional and individual traders is

$$\begin{aligned} NLM_t = {} & \alpha + \beta_1 Spread_{t-1} + \beta_2 Transitory\_Volatility_{t-1} \\ & + \beta_3\, Informational\_Volatility_{t-1} + \beta_4\, Same\_Side\_Depth_{t-1} \\ & + \beta_5\, Other\_Side\_Depth_{t-1} + \beta_6\, Limit\_Size_t + \sum_{j=1}^{19} \beta_{7,j} D_j + \varepsilon_t. \end{aligned} \tag{2}$$

The dependent variable, the net sum of limit order (NLM_t), denotes the sum of limit orders minus market orders and marketable limit orders during the 15-minute interval.[10] $Spread_{t-1}$ is the average of all dollar quote spreads during $t-1$ time period. $Same\_Side\_Depth_{t-1}$ ($Other\_Side\_Depth_{t-1}$) is measured as the average number of limit orders at the best bid (ask) just prior to a buy order's submission and as the number at the best ask (bid) just prior to a sell order's submission at a given time in the $t-1$ time interval.

Previous literature has reported a positive relation between total price volatility and submissions of limit orders by traders. Handa and Schwartz (1996) hypothesize that an increase in transitory volatility will attract new limit orders and that an increase in informational volatility will discourage the submission of new limit orders due to an increase in adverse selection risk. Conversely, Foucault (1999) argues that when informational volatility increases, traders will submit more limit orders even though they face increasing adverse selection risk. During periods of increased informational volatility, traders face higher trading costs due to higher bid–ask quotes. Thus, market order trading is even more expensive than limit order trading, and more traders find it optimal to implement their trades using limit orders.

To test these two competing hypotheses, we decompose total volatility into transitory volatility and informational volatility. To estimate transitory variance and informational variance, we assume transaction price follows a random walk model with transitory noise. The local-level model is specified as[11]

$$\begin{aligned} P_t &= m_t + \xi_t \qquad \xi_t \sim NID\left(0, \sigma_\xi^2\right) \\ m_t &= m_{t-1} + \upsilon_t \quad \upsilon_t \sim NID\left(0, \sigma_\upsilon^2\right) \end{aligned}, \tag{3}$$

where P_t is transaction price; m_t is unobserved equilibrium (efficient) price that follows a random walk model; and ξ_t is transitory component. We use the Kalman filter technique to estimate the parameters of the Model (3) for each 15-minute interval.

We use σ_ξ as our measure of transitory volatility in each 15-minute interval and σ_υ as our measure of informational volatility in each 15-minute interval. Bae et al. (2003) use Model (3) to estimate intraday-efficient price and transitory price for each day and then employ high–low price range in 30-minute intervals to estimate the transitory and informational volatility, respectively, for each time interval. In our case, we obtain the estimates of transitory volatility and informational volatility from the empirical results of Model (3) applied to each 15-minute interval. We employ $Transitory\_Volatility_{t-1}$ (transitory volatility lagged one period) and $Informational\_Volatility_{t-1}$ (informational volatility lagged one period) to approximate a trader's view on expected transitory and informational volatility in next time period.

[10]Marketable limit orders are limit orders that come with better quotes than the current best quotes in the order book.
[11]See Harvey (1989) for further discussion on this unobserved component (local level) model. Hasbrouck (1996) discusses this type of model with application to finance, and Bae et al. (2003) apply this model to decompose the transactions into efficient and transitory price components.

We measure $Limit\_Size_t$ as the average size of all limit orders for all traders during the tth time interval. The dummy variable $D_{i,t,}$ as defined in the Equation (1), controls intraday variation of limit order submission patterns with respect to time.

We estimate both Equations (1) and (2) for each type of traders using ordinary least squares. Newey and West (1987) heteroskedasticity and autocorrelation covariance procedure is used to calculate the consistent standard errors of estimates.

5. EMPIRICAL RESULTS

5.1. Intraday Variation of Limit and Market Orders by Trader Types

Panels A–C of Table II present the average daily market and limit order submissions by trader type for whole sample period, for the prefinancial crisis period (January 2007 to July 2007) and for the financial crisis period (August 2007 to December 2008), respectively.[12] We sort all orders into pure market order, marketable limit order, and limit order. The numbers in parentheses for each row represent the percentages of order types for individual day traders, individual nonday traders, foreign institutional traders, and futures proprietary firm traders. For example, for the whole sample period, the total daily average order submissions of day traders is composed of 17.26% of pure market orders, 8.94% of marketable limit order and 73.80% of limit orders. The numbers in brackets represent the total number of average trades by each trader type.

Panel A (whole sample) provides several interesting observations: (a) the sum of the average pure market order and marketable limit order submissions is only 16.76%, compared to 83.24% for limit order submissions; (b) individual day traders and nonday traders submit 73.80% and 73.09%, respectively, of their total orders in limit orders whereas 94.08% and 92.62% of the total order submission of foreign institutional traders and futures proprietary firms, respectively, are limit orders. These results confirm that, in general, institutional traders use more limit orders than market orders. Our results are consistent with Kaniel and Liu (2006) and Bloomfield et al. (2005) but do not support Harris (1998) who predicts that informed traders use more market orders than limit orders.

Panel C of Table II shows that the order submissions by trader types during the financial crisis period are very similar to the order submissions by trader types during whole sample period. This result is not surprising because the time period of financial crisis period accounts for three-fourths of the whole sample period. Panel B shows that during the prefinancial crisis period (January 2001 to July 2007) individual day traders use slightly less market orders and marketable limit orders and relatively more limit orders than during the financial crisis period. Also, during the prefinancial crisis period, the sum of foreign institutional traders and futures proprietary firm accounts for 33% of total average daily order submission, and yet the sum of their daily trading volume accounts for total average daily order submission during financial crisis period. These results suggest that individual traders are trading more active during the prefinancial crisis period and that institutional traders are more active during the financial crisis period.

In Table III, we present the regression analysis of the intraday variation of limit and market orders by trader types on 15-minute time intervals. See Appendix for further details.[13]

[12]Following Brunnermeier (2009) as well as Melvin and Taylor (2009), we define the beginning of the subprime crisis period as August 2007. We thus divide our sample period into prefinancial crisis period (January 2007 to July 2007) and financial crisis period (August 2007 to December 2008).

[13]Appendix is a supplement to Table III. It presents the means of the numbers of limit and market orders submitted by trader type on a 15-minute time interval. Limit order submission ratio in the Appendix is the ratio of the mean of the number of limit orders to the sum of limit orders, market orders, and marketable limit orders.

TABLE II
Daily Order Book Statistics by Trader-Type Categories

	Individual Trader				
	Day Trader (%)	*Nonday Trader (%)*	*Foreign Institutional Traders (%)*	*Futures Proprietary Firm Traders (%)*	*Total Daily Average Orders*
Panel A: Full Sample Period (January 2007 to December 2008)					
Pure market order	49.15	47.15	1.57	2.13	100
	(17.26)	(17.48)	(0.57)	(0.82)	(9.17)
					[22,465.46]
Marketable limit order	30.80	30.74	17.75	20.71	100
	(8.94)	(9.43)	(5.35)	(6.56)	(7.59)
					[18,581.06]
Limit order	23.16	21.73	28.48	26.63	100
	(73.80)	(73.09)	(94.08)	(92.62)	(83.24)
					[203,841.30]
Total daily order average	26.13	24.74	25.20	23.93	100
	(100)	(100)	(100)	(100)	(100)
	[63,981.86]	[60,590.68]	[61,705.38]	[58,609.91]	[244,887.84]
Panel B: Prefinancial Crisis—January 2007 to July 2008					
Pure market order	38.87	56.41	1.50	3.22	100
	(12.73)	(15.53)	(0.95)	(1.80)	(9.95)
					[14,278.45]
Marketable limit order	22.93	37.36	17.16	22.54	100
	(5.81)	(7.95)	(8.43)	(9.73)	(7.69)
					[11,040.01]
Limit order	30.04	33.58	17.23	19.14	100
	(81.46)	(76.52)	(90.62)	(88.47)	(82.36)
					[118,185.89]
Total daily order average	30.38	36.15	15.66	17.82	100
	(100)	(100)	(100)	(100)	(100)
	[43,589.69]	[51,871.18]	[22,472.08]	[25,571.40]	[143,504.35]
Panel C: During Financial Crisis—August 2007 to December 2008					
Pure market order	51.48	45.06	1.57	1.89	100
	(18.37)	(18.13)	(0.52)	(0.67)	(9.01)
					[25,818.09]
Marketable limit order	32.44	29.36	17.88	20.32	100
	(9.72)	(9.92)	(4.98)	(6.10)	(7.57)
					[21,673.68]
Limit order	21.77	19.32	30.76	28.15	100
	(71.91)	(71.95)	(94.49)	(93.22)	(83.42)
					[238,950.09]
Total daily order average	25.25	22.40	27.16	25.19	100
	(100)	(100)	(100)	(100)	(100)
	[72,340.28]	[64,164.67]	[77,785.05]	[72,151.86]	[286,441.86]

Note. In this table, we present a daily order book statistics by trader type in the futures contract FITX from whole sample period, prefinancial crisis, and during financial crisis periods. We divide all order books into the pure market order, marketable limit order, and limit order and give the percentages of order types by individual day traders, individual nonday traders, foreign institutional traders, and futures proprietary firm traders. The numbers in parentheses represent the percentages of order types by each trader types. For example, during whole sample period, the total daily average orders of day traders, 17.26% are pure market orders, 8.94% are marketable limit order, and 73.80% are limit orders. The numbers in brackets are the total number of average trades by trader type.

TABLE III

Regression Analysis of Intraday Variation Patterns of Limit and Market Orders by Type of Traders

	Individual Day Traders			*Individual Nonday Traders*			*Foreign Institutional Traders*			*Futures Proprietary Firm Traders*		
Time Interval	*Limit*	*Market*	*Limit Order Submission Ratio (%)*	*Limit*	*Market*	*Limit Order Submission Ratio (%)*	*Limit*	*Market*	*Limit Order Submission Ratio (%)*	*Limit*	*Market*	*Limit Order Submission Ratio (%)*
0. 08:30–08:45 hours	−1,168.70*** (−21.13)	−684.71*** (−25.36)	0.1485*** (46.70)	−655.68*** (−14.37)	−414.46*** (18.04)	0.0700*** (23.09)	−2,628.85*** (−18.84)	−116.95*** (−12.27)	−0.2364*** (−47.42)	−2,155.82*** (−20.06)	−149.27*** (17.44)	−0.0348*** (−13.93)
1. 08:45–09:00 hours	152.44*** (2.75)	−152.80*** (−5.64)	0.0415*** (13.00)	1,102.33*** (24.06)	539.62*** (23.39)	−0.0256*** (−8.41)	−298.62** (−2.13)	79.55*** (8.31)	−0.0166*** (−3.31)	403.85*** (3.74)	100.71*** (11.72)	−0.0155*** (−6.19)
2. 09:00–09:15 hours	805.39*** (14.52)	295.95*** (10.93)	−0.0118*** (−3.71)	649.68*** (14.20)	406.30*** (17.63)	−0.0407*** (−13.38)	1,031.12*** (7.37)	128.31*** (13.42)	0.0021 (0.43)	964.08*** (8.95)	133.07*** (15.50)	−0.0154*** (−6.16)
3. 09:15–09:30 hours	664.03*** (11.97)	227.12*** (8.39)	−0.0050 (−1.58)	451.81*** (9.87)	215.21*** (9.34)	−0.0194*** (−6.37)	1,035.06*** (7.40)	57.47*** (6.01)	0.0157*** (3.14)	687.73*** (6.38)	66.97*** (7.80)	−0.0056** (−2.23)
4. 09:30–09:45 hours	401.64*** (7.25)	125.80*** (4.65)	−0.0022 (−0.67)	225.18*** (4.92)	49.37** (2.14)	−0.0019 (−0.61)	723.01*** (5.17)	16.76* (1.75)	0.0204*** (4.09)	406.30*** (3.77)	20.00** (2.33)	−0.0030 (−1.19)
5. 09:45–10:00 hours	333.06*** (6.01)	119.52*** (4.41)	−0.0033 (−1.05)	164.06*** (3.58)	39.79* (1.73)	−0.0035 (−1.16)	491.88*** (3.52)	−0.71 (−0.07)	0.0180*** (3.60)	246.97** (2.29)	15.78* (1.84)	0.0006 (0.24)
6. 10:00–10:15 hours	177.62*** (3.20)	84.70*** (3.12)	−0.0075** (−2.36)	27.14 (0.59)	−28.82 (−1.25)	0.0039 (1.27)	240.23* (1.72)	−11.49 (−1.20)	0.0165*** (3.29)	42.28 (0.39)	−3.77 (−0.44)	0.0038 (1.52)
7. 10:15–10:30 hours	65.48 (1.18)	48.80* (1.79)	−0.0074** (−2.32)	−85.27* (−1.86)	−88.19*** (−3.81)	0.0108*** (3.52)	−20.64 (−0.15)	−28.78*** (−3.00)	0.0179*** (3.57)	−40.80 (−0.38)	−19.85** (−2.30)	0.0065*** (2.58)
8. 10:30–10:45 hours	−146.42*** (−2.63)	−24.76 (−0.91)	−0.0070** (−2.20)	−272.59*** (−5.94)	−158.27*** (−6.85)	0.0127*** (4.18)	−149.69 (−1.07)	−39.72*** (−4.15)	0.0231*** (4.62)	−148.53 (−1.38)	−50.27*** (−5.85)	0.0139*** (5.54)

continued

TABLE III
(Continued)

	Individual Day Traders			*Individual Nonday Traders*			*Foreign Institutional Traders*			*Futures Proprietary Firm Traders*		
Time Interval	*Limit*	*Market*	*Limit Order Submission Ratio (%)*	*Limit*	*Market*	*Limit Order Submission Ratio (%)*	*Limit*	*Market*	*Limit Order Submission Ratio (%)*	*Limit*	*Market*	*Limit Order Submission Ratio (%)*
9. 10:45–11:00 hours	−139.04** (−2.50)	1.99 (0.07)	−0.0104*** (−3.25)	−224.96*** (−4.91)	−133.88*** (−5.80)	0.0134*** (4.39)	−157.45 (−1.12)	−46.67*** (−4.87)	0.0246*** (4.90)	−69.53 (−0.64)	−31.88*** (−3.71)	0.0115*** (4.59)
10. 11:00–11:15 hours	−231.09*** (−4.15)	−53.07** (−1.96)	−0.0072** (−2.23)	−335.43*** (−7.30)	−181.31*** (−7.84)	0.0168*** (5.51)	−313.47** (−2.23)	−43.35*** (−4.52)	0.0183*** (3.64)	−223.57** (−2.07)	−50.84*** (−5.90)	0.0132*** (5.25)
11. 11:15–11:30 hours	−125.02** (−2.24)	8.82 (0.32)	−0.0146*** (−4.55)	−218.28*** (−4.75)	−112.19*** (−4.84)	0.0095*** (3.10)	−281.79** (−2.00)	−35.50*** (−3.70)	0.0200*** (3.99)	−93.56 (−0.86)	−24.74*** (−2.87)	0.0092*** (3.64)
12. 11:30–11:45 hours	24.15 (0.43)	35.66 (1.31)	−0.0084*** (−2.61)	−176.89*** (−3.85)	−99.71*** (−4.31)	0.0089*** (2.91)	−127.11 (−0.91)	−32.63*** (−3.40)	0.0203*** (4.05)	9.33 (0.09)	−20.99** (−2.44)	0.0081*** (3.24)
13. 11:45–12:00 hours	−4.42 (−0.08)	41.34 (1.52)	−0.0123*** (−3.84)	−186.26*** (−4.05)	−81.67*** (−3.52)	0.0023 (0.76)	−15.58 (−0.11)	−37.59*** (−3.91)	0.0214*** (4.25)	−36.41 (−0.34)	−21.67** (−2.51)	0.0108*** (4.30)
14. 12:00–12:15 hours	−66.85 (−1.20)	13.64 (0.50)	−0.0074** (−2.29)	−304.69*** (−6.61)	−114.73*** (−4.94)	0.0050* (1.65)	82.20 (0.58)	−38.12*** (−3.96)	0.0234*** (4.66)	−97.33 (−0.90)	−28.90*** (−3.34)	0.0134*** (5.29)
15. 12:15–12:30 hours	16.67 (0.30)	26.51 (0.97)	−0.0048 (−1.50)	−165.60*** (−3.59)	−73.01*** (−3.15)	0.0066** (2.17)	142.17 (1.01)	−26.35*** (−2.74)	0.0190*** (3.77)	9.45 (0.09)	−11.88 (−1.37)	0.0084*** (3.31)
16. 12:30–12:45 hours	−52.80 (−0.95)	−4.79 (−0.18)	−0.0026 (−0.82)	−213.02*** (−4.63)	−113.49*** (−4.90)	0.0081*** (2.66)	30.09 (0.21)	−42.21*** (−4.39)	0.0265*** (5.27)	−12.47 (−0.11)	−31.65*** (−3.67)	0.0106*** (4.21)
17. 12:45–13:00 hours	37.86 (0.68)	6.68 (0.24)	−0.0026 (−0.80)	−95.13** (−2.06)	−56.68** (−2.44)	0.0008 (0.24)	123.99 (0.88)	−37.12*** (−3.85)	0.0239*** (4.74)	34.81 (0.32)	−15.28* (−1.76)	0.0068*** (2.67)

continued

TABLE III
(Continued)

Time Interval	*Individual Day Traders*			*Individual Nonday Traders*			*Foreign Institutional Traders*			*Futures Proprietary Firm Traders*		
	Limit	*Market*	*Limit Order Submission Ratio (%)*	*Limit*	*Market*	*Limit Order Submission Ratio (%)*	*Limit*	*Market*	*Limit Order Submission Ratio (%)*	*Limit*	*Market*	*Limit Order Submission Ratio (%)*
18. 13:00–13:15 hours	97.15*	30.12	−0.0016	31.86	0.94	−0.0007	361.89***	9.41	0.0138***	123.85	3.79	0.0017
	(1.74)	(1.10)	(−0.50)	(0.69)	(0.04)	(−0.24)	(2.56)	(0.98)	(2.74)	(1.14)	(0.44)	(0.68)
19. 13:15–13:30 hours	−333.42***	−164.84***	0.0063**	−89.07*	−57.83**	0.0029	254.02*	70.92***	−0.0051	−236.23**	−33.69***	0.0081***
	(−5.95)	(−6.03)	(1.96)	(−1.93)	(−2.48)	(0.95)	(1.80)	(7.34)	(−1.01)	(−2.17)	(−3.89)	(3.22)
C	2,272.27***	807.00***	0.7555***	2,129.46***	780.19***	0.7466***	2,800.14***	1,74.91***	0.9066***	2,615.02***	205.30***	0.9168***
	(182.53)	(132.77)	(1,055.38)	(207.29)	(150.82)	(1,093.45)	(89.15)	(81.51)	(807.97)	(108.11)	(106.56)	(1,630.38)
Observation	10,042	10,042	10,042	10,042	10,042	10,042	10,042	10,042	10,042	10,042	10,042	10,042
Adj. R^2	0.090	0.082	0.225	0.119	0.155	0.132	0.048	0.084	0.203	0.050	0.102	0.078
F-test	50.88***	46.07***	146.51***	68.72***	93.27***	77.14***	26.14***	47.25***	128.82***	27.37***	58.28***	43.39***

Note. In this table, we present one-way analysis of variance model (see Equation (1) to estimate intraday submission patterns of limit order, market order, and limit order submission ratio by all types of traders in the futures contract FITX from January 1, 2007 to December 31, 2008. The limit and market order are divided into four types of traders: individual day traders, individual nonday traders, foreign institutional traders, and futures proprietary firm traders. The dependent variable is the mean of limit order sum, market order sum, or limit order submission ratio sum for each trader types during the 15-minute intraday interval, which is regressed on the time-of-day dummy variables for each 15-minute interval (i.e., 8:30–8:45 a.m. to 13:15–13:30 p.m.). The value of intercept *C* is daily average and is used as the basis for comparison. The *t*-statistic is reported in parentheses for each estimate. The preopen trading period for each trading day is denoted by 0. The preopen session is from 8:30 a.m. to 8:45 a.m.

***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

The intercept is the daily average, which is used as the basis of comparison. The results show that during the preopening session (i.e., 8:30 a.m. to 8:45 a.m.), individual day traders and nonday traders actively submit limit orders whereas foreign institutional traders and futures proprietary firms are relatively inactive in submitting limit orders. The second time interval (9:00–9:15 a.m.) has the highest average number of order submissions for all type of traders. Given the results in Table III, Figure 1 shows that the intraday average numbers of order submissions for all trader types is V-shaped for both market and limit orders. Our intraday pattern of order submissions is very similar to the patterns reported by Biais et al. (1995) and Bae et al. (2003).

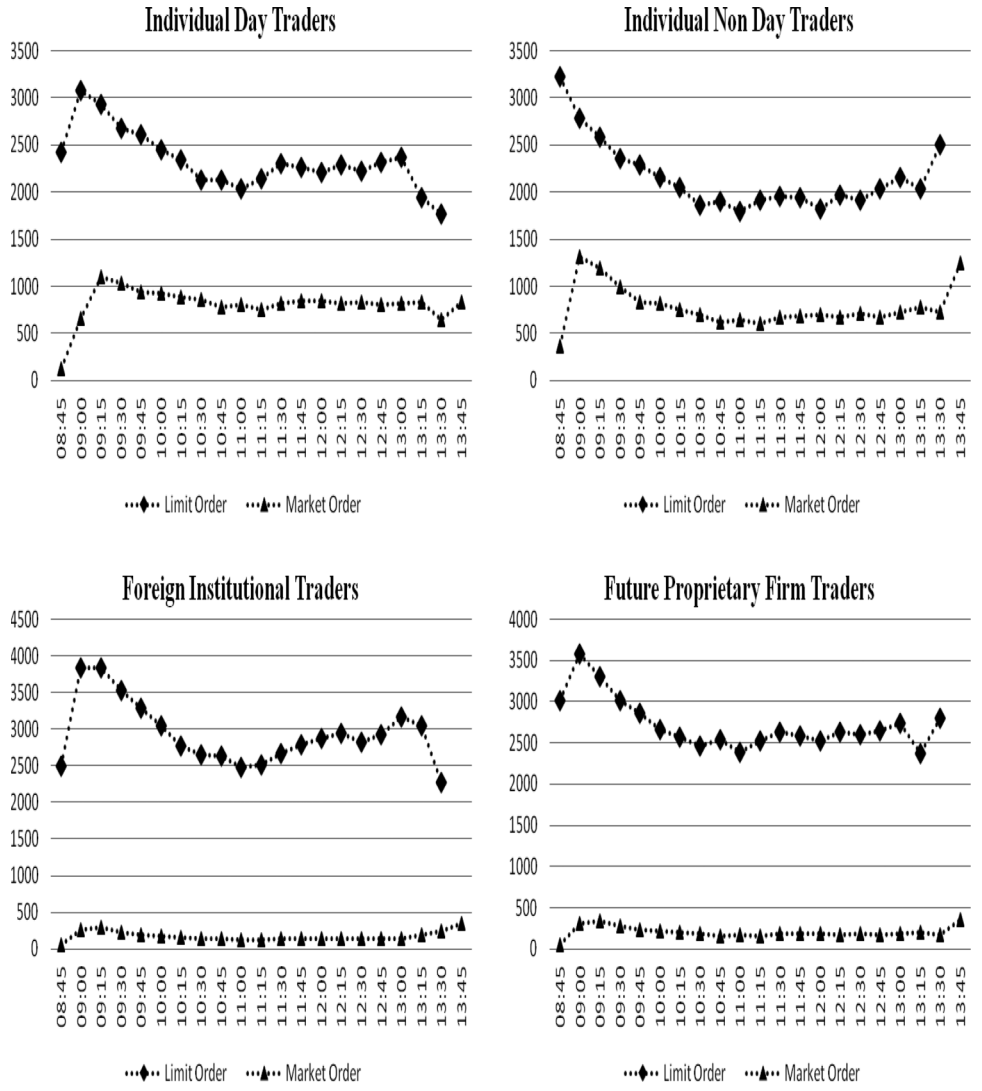


FIGURE 1

Intraday average numbers of limit and market order submission by four types of traders. The graph depicts the average number of orders submitted during the 15-minute intervals for each trading day for the futures contract FITX from January 1, 2007 to December 31, 2008. The limit and market order are divided into four types of traders: individual day traders, individual nonday traders, foreign institutional traders, and futures proprietary firm traders.

In Table III, we also show that the limit order submission ratio ranges in the regular trading period from 83.97% to 93.12% for foreign institutional traders and from 86.45% to 93.07% for futures proprietary firm traders. The limit order submission ratio of individual day (noonday) traders is in the range from 67.53% to 79.7% (66.67–76.34%). These results support Bloomfield et al. (2005) and Kaniel and Liu (2006) who find that informed traders use more limit orders than market orders and do not support Harris (1998) who predicts that informed traders use relatively more market than limit orders.

Panel A of Figure 2 shows that the limit order submission ratio of institutional traders is an inverted U-shaped during whole sample period; that is, institutional traders use relatively more market orders at the beginning and closing time intervals.[14] This finding is expected, in that institutional traders use more market orders to capture the value of private information in the early trading process and use relatively more market orders to close their positions as trading comes to an end. Limit order submission ratios of individual day and nonday traders are somewhat L-shaped with a sudden drop in the last two time intervals, suggesting that individual traders (i.e., uninformed traders) use relatively more limit orders in the early trading and relatively more market orders in late trading. These results suggest that individual traders provide relatively greater liquidity in the early session and consume relatively greater liquidity toward the end of trading session. Panel B shows that limit order submission ratios of all types traders during the prefinancial crisis are very similar to limit order submission ratios of all trader types for whole sample period. Our data clearly show that limit orders are preferred to market orders for all types of traders. Relatively, some trader may submit more market orders during certain time of the day versus other time of the day (but not versus limit orders), but by and large, the order type used is predominantly limit orders.

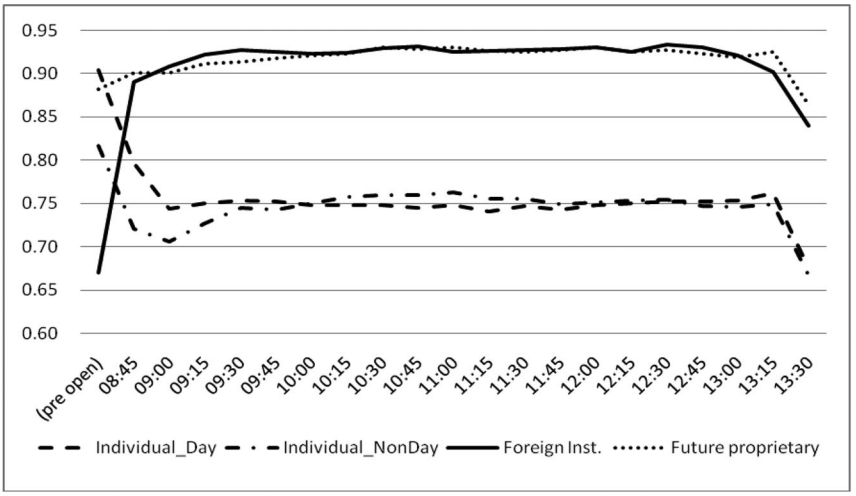
In Table IV, we report regression results on intraday variation of the size of limit orders and market orders submitted by all types of traders over a trading day.[15] Panels A and B of Figure 3 show the time-series patterns of the limit order size and market order size by trader type, respectively. First, we find that limit orders submitted by individual day traders, individual nonday traders, and foreign institutional traders are larger in size than their corresponding market orders. These results affirm the results for all traders reported by Bae et al. (2003). Futures proprietary firms however show the exact reverse pattern on submission of limit order size versus market order size.

Second, we find that the limit order size and market order size intraday patterns for both foreign institutional traders and futures proprietary firms are clearly L-shaped and that the same patterns are flat for individual traders. The larger order sizes of institutional traders suggest that they try to capture as much value as possible from their market information in the early stage of the trading process. These differences in intraday order size submission between institutional and individual traders are new to the limit order market literature. In general foreign institutional traders, compared to the other three trader types, use larger limit and market orders.

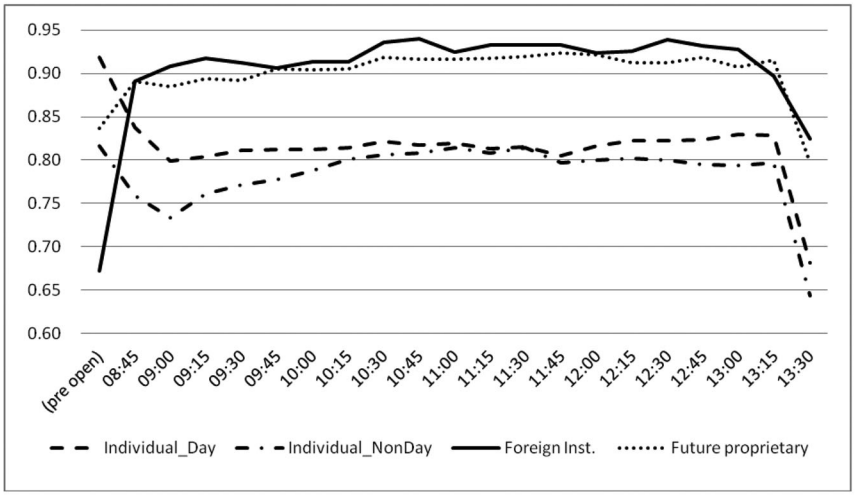
In sum, we find that institutional traders use relatively more market orders in the early stage of trading process and switch to relatively more limit orders as the trading process progresses. Individual traders submit relatively more limit orders in the early trading and use relatively more market orders as trading come to a close.

[14]Limit order submission ratio is defined as the ratio of the number of limit orders to the sum of limit and market orders during each 15-minute interval.

[15]Based on the regression results of Table 4, we can estimate the means of the size of limit and market orders submitted by trader types on a 15-minute interval. For example, the mean of limit order size at 8:45–9:00 a.m. time interval submitted by individual day trader is equal to 2.2791 (intercept) − 0.0347 (the coefficient of limit order size regression of individual day trader at 8:45–9:00 a.m.) = 2.244.



Panel A. The intraday day patterns of limit order submission ratios by trader types during full sample period (January 2007 to December 2008).



Panel B. The intraday day patterns of limit order submission ratios by trader types in the prefinancial crises period (January 2007–July 2007).

FIGURE 2

The means of limit order submission ratios during the 15-minute intervals of each trading day for the futures contract FITX for full sample period and prefinancial crisis period in Panels (A) and (B), respectively. The preopen session is from 8:30 a.m. to 8:45 a.m. Submission ratio is defined as the ratio of the number of limit order to the sum of his limit and market orders during each 15-minute interval. The four types of traders are individual day traders, individual nonday traders, foreign institutional traders, and futures proprietary firm traders.

5.2. Regression Analysis

We report the regression analysis of the influences of market conditions on liquidity provision by trader types in Table V. To conserve space, we do not present the results of dummy variables. For all traders (see column 2), the coefficient of $Spread_{t-1}$ is positive and highly significant at the 1% level. This result confirms that when the spread is wide, traders place

TABLE IV
Regression Analysis of Limit and Market Order Size Regression by Trader Type

	Individual Day Trader		*Individual Nonday Trader*		*Foreign Institutional Traders*		*Futures Proprietary Firm Traders*	
Time Interval	*Limit*	*Market*	*Limit*	*Market*	*Limit*	*Market*	*Limit*	*Market*
0. 08:30–08:45 hours	−0.1170***	0.0084	0.1954***	0.1300***	5.7214***	24.6161***	3.3099***	3.1426***
	(−12.40)	(0.49)	(19.87)	(9.42)	(91.90)	(71.05)	(190.26)	(29.04)
1. 08:45–09:00 hours	−0.0347***	−0.1662***	−0.0902***	−0.1687***	0.0757***	1.7080***	0.2423***	0.1143***
	(−5.25)	(−22.77)	(−14.01)	(−23.80)	(6.26)	(18.96)	(49.43)	(3.09)
2. 09:00–09:15 hours	0.1385***	0.0305***	−0.0895***	−0.0740***	−0.3852***	−0.1752**	−0.0528***	−0.3530***
	(22.66)	(5.08)	(−12.96)	(−9.76)	(−39.84)	(−2.36)	(−12.22)	(−10.49)
3. 09:15–09:30 hours	0.0402***	0.0066	−0.0970***	−0.0536***	−0.3218***	−0.8310***	−0.1208***	−0.1510***
	(6.57)	(1.07)	(−13.57)	(−6.48)	(−33.12)	(−10.38)	(−27.30)	(−3.98)
4. 09:30–09:45 hours	0.0156**	−0.0163**	−0.0675***	−0.0571***	−0.2670***	−0.7203***	−0.1442***	−0.1114***
	(2.45)	(−2.53)	(−9.01)	(−6.36)	(−26.42)	(−8.19)	(−31.45)	(−2.68)
5. 09:45–10:00 hours	0.0154**	−0.0115*	−0.0226***	−0.0205**	−0.3376***	−0.9115***	−0.1676***	−0.0289
	(2.39)	(−1.78)	(−2.95)	(−2.25)	(−32.61)	(−10.06)	(−35.79)	(−0.68)
6. 10:00–10:15 hours	−0.0345***	−0.0182***	0.0031	−0.0062	−0.3094***	−0.9704***	−0.2368***	−0.0522
	(−5.24)	(−2.78)	(0.40)	(−0.65)	(−28.78)	(−10.44)	(−49.47)	(−1.18)
7. 10:15–10:30 hours	−0.0635***	−0.0367***	−0.0056	−0.0188*	−0.3653***	−1.3504***	−0.2497***	−0.2025***
	(−9.49)	(−5.52)	(−0.69)	(−1.90)	(−32.77)	(−14.21)	(−51.41)	(−4.47)
8. 10:30–10:45 hours	−0.1311***	−0.0593***	−0.0579***	−0.0123	−0.5853***	−1.3928***	−0.2643***	−0.2525***
	(−19.03)	(−8.59)	(−6.88)	(−1.19)	(−52.52)	(−14.20)	(−53.62)	(−5.17)
9. 10:45–11:00 hours	−0.1473***	−0.0304***	−0.0106	−0.0077	−0.5099***	−1.6362***	−0.2198***	−0.0565
	(−21.51)	(−4.44)	(−1.27)	(−0.76)	(−45.37)	(−16.61)	(−44.90)	(−1.19)
10. 11:00–11:15 hours	−0.1186***	−0.0236***	0.0039	0.0086	−0.5268***	−1.2922***	−0.2321***	−0.1532***
	(−16.81)	(−3.32)	(0.45)	(0.81)	(−45.62)	(−12.88)	(−46.04)	(−3.08)
11. 11:15–11:30 hours	−0.0905***	−0.0025	0.0346***	0.0374***	−0.5282***	−1.6840***	−0.2288***	−0.1734***
	(−13.05)	(−0.36)	(4.09)	(3.67)	(−46.02)	(−17.82)	(−46.42)	(−3.84)
12. 11:30–11:45 hours	−0.0232***	0.0096	0.0164**	0.0419***	−0.4300***	−1.5553***	−0.2023***	−0.7042***
	(−3.41)	(1.42)	(1.96)	(4.15)	(−38.15)	(−16.45)	(−41.67)	(−17.25)
13. 11:45–12:00 hours	−0.0313***	0.0271***	−0.0252***	0.0482***	−0.3033***	−1.7834***	−0.2335***	−0.4007***
	(−4.57)	(3.98)	(−3.03)	(4.82)	(−27.03)	(−18.87)	(−47.89)	(−9.55)

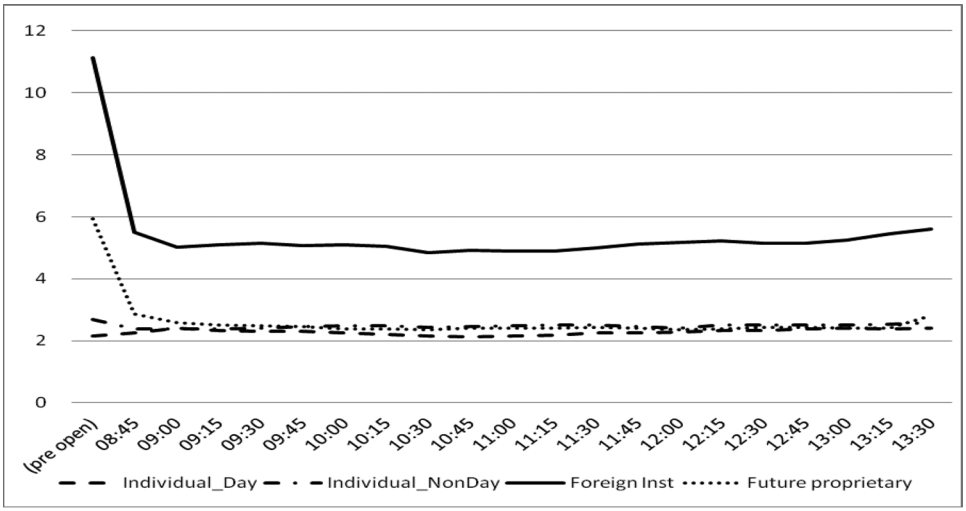
continued

TABLE IV
(Continued)

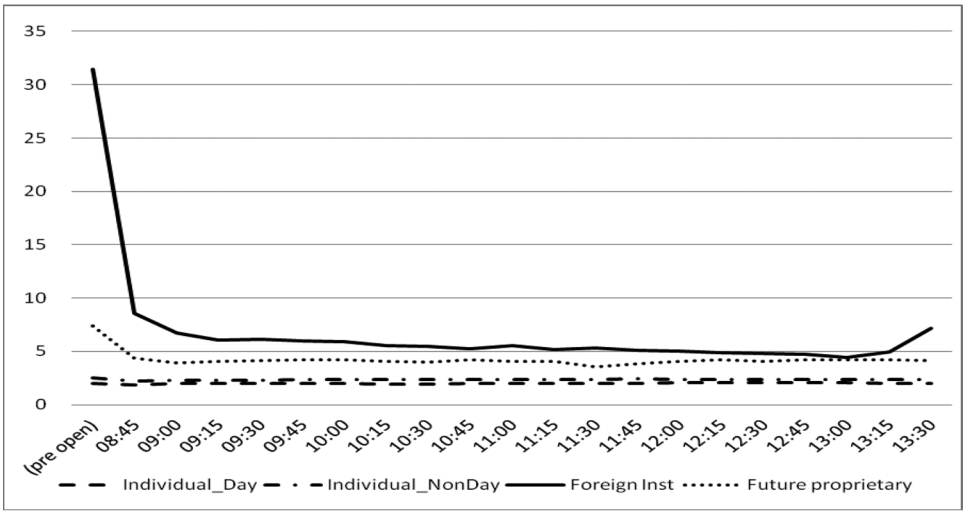
	Individual Day Trader		*Individual Nonday Trader*		*Foreign Institutional Traders*		*Futures Proprietary Firm Traders*	
Time Interval	*Limit*	*Market*	*Limit*	*Market*	*Limit*	*Market*	*Limit*	*Market*
14. 12:00–12:15 hours	0.0078	0.0490***	−0.0618***	0.0364***	−0.2338***	−1.8204***	−0.2815***	−0.1933***
	(1.11)	(7.05)	(−7.25)	(3.56)	(−21.01)	(−19.36)	(−57.56)	(−4.15)
15. 12:15–12:30 hours	0.0489***	0.0459***	0.0179**	0.0411***	−0.1981***	−1.9944***	−0.2556***	−0.0222
	(7.03)	(6.65)	(2.14)	(4.14)	(−17.92)	(−22.33)	(−53.00)	(−0.49)
16. 12:30–12:45 hours	0.0597***	0.0491***	0.0167**	0.0149	−0.2677***	−2.0648***	−0.1987***	−0.1621***
	(8.45)	(6.99)	(1.97)	(1.47)	(−23.94)	(−22.10)	(−40.66)	(−3.44)
17. 12:45–13:00 hours	0.0915***	0.0609***	0.0297***	0.0374***	−0.2730***	−2.1274***	−0.2054***	−0.0548
	(13.11)	(8.67)	(3.61)	(3.82)	(−24.73)	(−23.30)	(−42.33)	(−1.20)
18. 13:00–13:15 hours	0.1281***	0.0607***	0.0412***	0.0289***	−0.1729***	−2.3978***	−0.2105***	−0.0644
	(18.42)	(8.77)	(5.13)	(3.08)	(−16.06)	(−30.74)	(−44.04)	(−1.48)
19. 13:15–13:30 hours	0.1063***	0.0076	0.0516***	−0.0033	0.0245***	−1.9318***	−0.2189***	−0.0391
	(13.96)	(0.98)	(6.23)	(−0.34)	(2.20)	(−26.84)	(−42.95)	(−0.81)
C	2.2791***	1.9928***	2.4798***	2.3579***	5.4160***	6.8632***	2.6302***	4.2399***
	(1,455.77)	(1,165.16)	(1,367.98)	(1,083.70)	(1,395.77)	(265.65)	(1,944.13)	(389.84)
Observation	10,039,866	4,078,962	8,690,712	3,374,647	5,489,755	305,877	10,624,149	511,533
Adj. R^2	0.0003	0.0002	0.0002	0.0003	0.0026	0.0239	0.0048	0.0023
F-test	157.68***	48.71***	70.26***	44.43***	710.04***	376.18***	2544.45***	59.72***

Note. In this table, we present one analysis of variance model (see Equation (1) to estimate intraday variance pattern of limit order size and market order size submitted by trader types over a trading day in the futures contract FITX from January 1, 2007 to December 31, 2008. The trader types are classified by individual day traders, individual nonday traders, foreign institutional traders, and proprietary firm traders. The dependent variable is the tick-by-tick limit orders by trader types, which is regressed on the time-of-day dummy variables for each 15-minute interval (i.e., 08:30–08:45 a.m. to 13:15–13:30 p.m.). The value of intercept *C* represents daily average and is used as the basis for comparison. The *t*-statistic is reported in parentheses for each estimate. The preopen trading period from 8:30 a.m. to 8:45 a.m. for each trading day is denoted by 0.

***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.



Panel A: The intra-day patterns of the size of limit orders by trader types



Panel B: The intra-day patterns of the size of market orders by trader types.

FIGURE 3

These figures plot the means of order sizes of limit and market order by trader type during the 15-minute intervals of each trading day for the futures contract FITX from January 1, 2007 to December 31, 2008. The preopen session is from 8:30 a.m. to 8:45 a.m. The four trader types are individual day traders, individual nonday traders, foreign institutional traders, and futures proprietary firm traders.

more limit orders either because submission of market orders is costly or because compensation is higher if limited orders are executed (e.g., Bae et al., 2003; Chung et al., 1999). The coefficient of *Transitory_Volatility* lagged one period has a positive sign and the coefficient of the *Informational_Volatility* has a negative sign; both of these coefficients are highly significant at the 1% level. Our empirical evidence is consistent with the prediction Handa and Schwartz's (1996) theoretical model but does not support the implications of the model proposed by Foucault (1999).

TABLE V

Regression Analysis on the Influences of Market Conditions on Liquidity Provision by Trader Types

Time Interval	*All*	*Individual Day Trader*	*Individual Nonday Trader*	*Foreign Institutional Traders*	*Futures Proprietary Firm Traders*
$Spread_{t-1}$	16.76*	0.03	0.34	8.20*	5.12*
	(4.87)	(0.06)	(1.04)	(5.38)	(3.71)
$Transitory\_Volatility_{t-1}$	13.99*	2.34*	1.66*	4.36*	5.94*
	(4.70)	(5.46)	(4.77)	(3.64)	(4.41)
$Informational\_Volatility_{t-1}$	−60.13*	−8.34*	−5.52*	−22.27*	−19.77*
	(−2.96)	(−3.78)	(−3.44)	(−2.78)	(−3.04)
$Same\_Side\_Depth_{t-1}$	−875.05*	−104.67*	−87.19*	−353.73*	−256.46*
	(−8.46)	(−7.46)	(−7.12)	(−8.51)	(−7.18)
$Other\_Side\_Depth_{t-1}$	630.84*	85.39*	86.99*	211.12*	187.72*
	(7.19)	(6.64)	(7.84)	(6.00)	(6.46)
$Limit\_Size_t$	1,355.56*	–	–	–	–
	(5.89)				
Day_t	–	233.54*	–	–	–
		(10.77)			
Non_Day_t	–	–	454.38*	–	–
			(13.36)		
$Foreign_t$	–	–	–	911.26*	–
				(157.74)	
$Proprietary_t$	–	–	–	–	−143.69**
					(−2.41)
Observation	9,204	9,204	9,204	9,204	9,204
Adj. R^2	0.13	0.19	0.28	0.37	0.09
F-test	55.49*	87.94*	147.57*	215.71*	36.13*

Note. In this table, we present the regression analysis results that examine whether the lagged spread, lagged volatility, lagged same side depth, lagged other side depth, or limit order size by the trader-type variables affect limit orders in the futures contract FITX. The regression analysis model is specified as

$$NLM_t = \alpha + \beta_1 Spread_{t-1} + \beta_2 Transitory\_Volatility_{t-1} + \beta_3 Informational\_Volatility_{t-1} + \beta_4 Same\_Side\_Depth_{t-1} + \beta_5 Other\_Side\_Depth_{t-1} + \beta_6 Limit\_Size_t + \sum_{j=1}^{19} \beta_{7,j} D_j + \varepsilon_t.$$

The dependent variable NLM_t is equal to the sum of limit orders minus market orders and marketable limit orders for each trader types during each 15-minute interval. The trader types are classified as individual day traders, individual nonday traders, foreign institutional traders, and proprietary firm traders. $Spread_{t-1}$ is the average of dollar quote spread during time interval $t-1$; $Transitory\_Volatility_{t-1}$ denotes transitory volatility lagged one period; $Informational\_Volatility_{t-1}$ represents informational volatility lagged one period; $Same\_Side\_Depth_{t-1}$ ($Other\_Side\_Depth_{t-1}$) is measured as the average number of limit orders at the best bid (ask) just prior to a buy order's submission, and as the average number of limit order at the ask (bid) just prior to a sell order's submission during time interval $t-1$; $Limit\_Size_t$ is the average of limit orders during time interval t for all traders, individual day traders, individual nonday traders, foreign institutional traders, and proprietary firm traders; D_j *is* the time-of-day dummy variables for each 15-minute interval (i.e., 8:45–9:00 a.m. to 13:15–13:30 p.m.). The specification of D_j is discussed in Equation (1). To save the space, we do not report the dummy variables results. The *t*-statistics are reported in parentheses.

* and **, indicate significance at the 1% and 5%, levels, respectively.

In Handa and Schwartz's (1996) model, traders lose when they execute orders with informed traders due to adverse selection risk and profit when they execute limit orders with uninformed (liquidity) traders. Thus, traders will submit more limit orders than market orders when the expected (one period lagged) transitory volatility increases, and they will submit fewer limit orders when expected informational volatility increases. Bae et al. (2003) also report that traders will increase their submission of limit orders when transitory volatility is

expected to increase, but the impact of informational volatility on submission of limit order is inconclusive.[16]

In Table V, we also show that the parameter of same side depth at best bid (ask) lagged one period has a negative sign and is significant at the 1% level, and the parameter of opposite side depth lagged one period has a positive sign and is also significant at 1% level. As we expect, this result confirms that all traders will submit fewer limit orders when the state of the same side order book is thicker and more limit orders when the book is thinner. The impact of the state of the opposite side order book on limit order submissions by all traders has exactly the reverse effect of the state of the same side order book. This result confirms the theoretical prediction of Parlour (1998) and is also consistent with the experimental results obtained by Bloomfield et al. (2005). The positive and significant coefficient of the limit order size confirms that traders prefer to use more limit orders to minimize their trading cost when order sizes are relatively large.

In columns 3–6 of Table V, we report the regression results of the influence of market conditions on the liquidity provision by each type of traders. We summarize their differing provision of liquidity given changes in market conditions as follows. First, the coefficients of the spread lagged one period of individual day traders and individual nonday traders are positive but not significant. The coefficients of $Spread_{t-1}$ of institutional traders (i.e., both foreign institutional traders and futures proprietary firms) have positive signs and are significant at the 1% level or greater. The insignificant impact of change in spreads on the decision of individual day traders may be due to individual traders typically engaging in quick turn-around trading.

Second, the coefficient of the limit order size of for futures proprietary firms is negative and significant at the 1% level. One possible explanation is that because futures proprietary firms often have access to order flow information, they may use market orders to capture the value of short-lived information.[17] Third, the coefficients of $Transitory\_Volatility_{t-1}$, $Informational\_Volatility_{t-1}$, $Same\_Side\_Depth_{t-1}$, and $Opposite\_Side\_Depth_{t-1}$ of all four trader types have the same expected signs and are significant at the 1% level. However, their responses to the net submission of limit orders differ due to changes in these market variables. Based on empirical results of Table 5, we estimate the elasticity of the limit order submission with respect to market condition variables and limit order size variable; these results are reported in Table VI.

In general, in Table V, we show that institutional traders are more elastic to changes in these four lagged one-period variables (i.e., $Transitory\_Volatility_{t-1}$, $Informational\_Volatility_{t-1}$ $Spread_{t-1}$, $Same\_Side\_Depth_{t-1}$, and $Other\_Side\_Depth_{t-1}$) than individual day and nonday traders. For example, the elasticity of spreads lagged one period of foreign institutional traders and futures proprietary firms is 0.99 and 0.69, respectively. The elasticity of spreads lagged one period is less than 0.01 and 0.08 for individual-day and nonday traders, respectively. The elasticity of *Informational_Volatility* is −0.17 for both foreign institutional traders and futures proprietary firms while the same elasticity for individual day and nonday traders is −0.12 and −0.008, respectively. As expected, the elasticity of these market variables

[16]We use *Transitory_Volatility* and *Informational_Volatility* as explanatory variables in the regression model, whereas Bae et al. (2003) use dummy variables to denote four combination cases of high and low transitory versus informational volatility cases.

[17]We interviewed several traders from futures proprietary futures firms. They report that they often hire a large number of traders to monitor order flow from the order book and use relative large market order size to capture the instant trading opportunity. Traders from futures proprietary firms often use relatively larger market order size than limit order size to implement their momentum trading strategy. The anonymous referee suggests the difference in the submission of limit and market order size between foreign institutional investor and futures proprietary firms may be due to difference in information in nature. Further research will be required to resolve this issue.

TABLE VI

Elasticity of Net Limit Order Submissions with Respect to Market Condition Variables and Limit Order Size

	All	*Individual Day Trader*	*Individual Nonday Trader*	*Foreign Institutional Traders*	*Futures Proprietary Firm Traders*
$Spread_{t-1}$	0.69	0.01	0.08	0.99	0.69
$Transitory\_Volatility_{t-1}$	0.12	0.11	0.09	0.11	0.17
$Informational\_Volatility_{t-1}$	−0.15	−0.12	−0.08	−0.17	−0.17
$Same\_Side\_Depth_{t-1}$	−1.05	−0.68	−0.62	−1.24	−1.00
$Other\_Side\_Depth_{t-1}$	0.77	0.57	0.64	0.76	0.75
$Limit\_Size_t$	0.50	–	–	–	–
Day_t	–	0.40	–	–	–
Non_Day_t	–	–	0.85	–	–
$Foreign_t$	–	–	–	1.58	–
$Proprietary_t$	–	–	–	–	−0.18

Note. In this table, we present the estimates of the elasticity of $Spread_{t-1}$, $Transitory\_Volatility_{t-1}$, $Informational\_Volatility_{t-1}$, $Same\ Side\ Depth_{t-1}$, $Other\ Side\ Depth_{t-1}$, and *Limit Order Size* from regression model on the influences of the market conditions on liquidity provision by trader type (see Table V). The elasticity is measured as each regression coefficient multiplies the average of independent variable and divides by the average of dependent variable. The trader types are classified by individual day traders, individual nonday traders, foreign institutional traders, and proprietary futures firm traders. The regression model is specified as

$$NLM_t = \alpha + \beta_1 Spread_{t-1} + \beta_2 Transitory\_Volatility_{t-1} + \beta_3 Informational\_Volatility_{t-1} + \beta_4 Same\_Side\_Depth_{t-1} + \beta_5 Other\_Side\_Depth_{t-1} + \beta_6 Limit\_Size_t + \sum_{j=1}^{19} \beta_{7,j} D_j + \varepsilon_t.$$

The dependent variable, NLM_t is equal to the sum of limit orders minus market orders and marketable limit orders for each trader types during 15-minute interval. $Spread_{t-1}$ is the average of dollar quote spread during time interval $t-1$; $Transitory\_Volatility_{t-1}$ denotes transitory volatility lagged one; $Informational\_Volatility_{t-1}$ represents informational volatility lagged one period; $Same\_Side\_Depth_{t-1}$ ($Other\_Side\_Depth_{t-1}$) is measured as the average number of limit orders at the bid (ask) just prior to a buy order's submission, and as the average number of limit orders at the ask (bid) just prior to a sell order's submission during time interval $t-1$; *Limit_Size* is the average of limit orders during time interval t for all traders, individual day traders, individual nonday traders, foreign institutional traders, and proprietary futures firm traders, respectively; D_j *is* the time-of-day dummy variables for each 15-minute interval (i.e., 08:45–9:00 a.m. to 13:15–13:30 p.m.). The specification of D_j is discussed in Equation (1). To save the space, we do not report the dummy variables results. The *t*-statistics are reported in parentheses.

and limit order size for all (aggregate) traders is in the range of the corresponding elasticity for these four types of traders. Our results support Menkhoff et al. (2010), who demonstrate that the order aggressiveness of informed traders is more responsive to market conditions than uninformed traders in ordered logit models.

5.3. Robustness Tests

Alternative Measures of Spreads and Volatility

To test the robustness of our empirical results for different measures of spread and volatility, we use the percentage spread and two alternative measures of volatility. First, we apply a local-level Model (3) to decompose the transaction price into efficient price and transitory price component for each 15-minute interval, and then we use the absolute values of the difference of the log high and log low efficient and transitory price to estimate informational volatility and transitory volatility, respectively, in each 15-minute time interval. Second, we measure the realized variance. The realized variance is measured as $\sum_{i=1}^{N} r_{i,t}^2$ where $r_{i,t}$ is the

return of ith transaction during time interval t, and N denotes the total number of transaction during the time interval.

The merit of this volatility measure is that it includes both the transitory and asset (informational) volatility components. Furthermore, this measure reflects the cumulative price fluctuation rather than the average price fluctuation during the time interval.[18] We find that the empirical results of the coefficients of the alternative measures of transitory and informational volatility with the remainder of other explanatory variables are qualitatively similar to our previous results. The empirical results of the second measure of volatility are positive and significant at the less than 5% level, and the signs and significance of other explanatory variables in this regression model are qualitatively similar to our previous results.

Alternative Measures of Time Intervals and State of Order Book

We also perform our analysis based on a 30-minute time interval and employ two new measures of states of order book: (a) $Same\_Side\_Depth1{-}5_{t-1}$ denotes the average of limit orders at the same bid (ask) sides from the (best) one to five price quotes during 30-minute interval lagged one period and (b) $Other\_Side\_Depth1{-}5_{t-1}$ is the average of limit orders at the opposite bid (ask) sides from the (best) one to five price quotes during 30-minutes interval lagged one period. In Table VII, we report the regression results of the influence of market conditions on liquidity provision by trader type based on 30-minute time intervals and on two new measures of states of order book. Clearly, these empirical results are quite similar qualitatively to our regression results based on 15-minute time intervals and the states of market depth measured at the best bid (ask) price quotes lagged one period.

6. CONCLUSION

This study uses a unique data set to examine the intraday liquidity provision by institutional traders (i.e., foreign institutional firms and futures proprietary firm traders) and individual traders (i.e., individual day traders and individual nonday traders) in the Taiwan index futures market. The data set consists of trader identification codes, trading activity, and the real-time information in order books. Thus, our study is not subject to the trader-type classification error. The conclusions and contributions we considered as important as follows.

First, in the Taiwan index futures market, foreign institutional traders and futures proprietary firm traders supply about 55% of liquidity in terms of the percentage of total limit orders submitted to the market. Individual day and nonday traders demand 49.15% and 47.15% of liquidity, respectively, in terms of the percentage of the pure market orders. Thus, institutional traders play a relatively important role in providing liquidity. Foreign institutional traders and futures proprietary firm traders submit 94.08% and 92.62%, respectively, of their total order submissions in limit orders. These findings are consistent with previous results reported in Kaniel and Liu (2006) and Bloomfield et al. (2005) that informed traders use more limit orders than market orders.

Second, we find that the intraday average number of order submissions for all trader types is V-shaped for both market and limit orders but that the pattern of the limit order submission ratio of institutional traders is an inverted U-shaped. These results suggest that institutional traders use relatively more market orders at the beginning and closing times of the trading day. In addition, the patterns of the limit order submission ratios of individual day

[18]This measurement was used by Ahn et al. (2001) in their test of the hypothesis proposed by Handa and Schwartz (1996) on the influence of transitory volatility on selection of limit orders versus market orders by traders. It is well recognized that this measure contains both informational volatility and transitory volatility. Thus, it is an imperfect measure of transitory volatility.

TABLE VII

Regression Results on the Influences of Market Conditions on Liquidity Provision by Trader Types on 30-Minute Interval

Time Interval	*All*	*Individual Day Trader*	*Individual Nonday Trader*	*Foreign Institutional Traders*	*Futures Proprietary Firm Traders*
$Spread_{t-1}$	38.15*	0.92	1.52*	18.86*	9.50**
	(7.80)	(1.29)	(2.76)	(8.05)	(4.35)
$Transitory\_Volatility_{t-1}$	48.27*	6.38*	4.61*	17.86*	17.39*
	(9.75)	(8.90)	(8.34)	(7.51)	(7.88)
$Informational\_Volatility_{t-1}$	−190.82*	−25.67*	−16.09*	−78.63*	−52.89*
	(−11.89)	(−11.08)	(−9.02)	(−10.27)	(−7.34)
$Same\_Side\_Depth1-5_{t-1}$	−344.18*	−21.98*	−26.27*	−175.54*	−82.54*
	(−7.60)	(−3.35)	(−5.22)	(−8.14)	(−4.05)
$Other\_Side\_Depth1-5_{t-1}$	330.86*	22.74*	31.20*	159.14*	79.88*
	(7.22)	(3.43)	(6.11)	(7.26)	(3.88)
$Limit\_Size_t$	1,271.11*	–	–	–	–
	(5.52)				
Day_t	–	383.89*	–	–	–
		(18.73)			
Non_Day_t	–	–	830.56*	–	–
			(30.18)		
$Foreign_t$	–	–	–	1,790.47*	–
				(42.63)	
$Proprietary_t$	–	–	–	–	−718.51*
					(−11.46)
Observation	4,422	4,422	4,422	4,422	4,422
Adj. R^2	0.12	0.18	0.28	0.38	0.10
F-test	41.94*	63.36*	112.22*	178.56*	35.32*

Note. In this table, we present the robustness test on regression results by trader-type categories in the futures contract FITX on 30-minute intervals. The regression model is specified as

$$NLM_t = \alpha + \beta_1 Spread_{t-1} + \beta_2 Transitory\_Volatility_{t-1} + \beta_3 Informational\_Volatility_{t-1} + \beta_4 Same\_Side\_Depth1-5_{t-1} + \beta_5 Other\_Side\_Depth1-5_{t-1} + \beta_6 Limit\_Size_t + \sum_{j=1}^{19} \beta_{7j} D_j + \varepsilon_t.$$

The dependent variable NLM_t is equal to the sum of limit orders minus market orders and marketable limit orders for each trader types during 30-minute intervals. The trader types are classified by individual day traders, individual nonday traders, foreign institutional traders, and proprietary firm traders. $Spread_{t-1}$ is the average of dollar quote spread during time interval $t-1$; $Transitory\_Volatility_{t-1}$ denotes transitory volatility lagged one period; $Informational\_Volatility_{t-1}$ represents informational volatility lagged one period; $Same\_Side\_Depth1–5_{t-1}$ ($Other\_Side\_Depth1–5_{t-1}$) is measured as the average number of limit orders at the bid 1–5 (ask 1–5) just prior to a buy order's submission, and as the average number of limit orders at the ask 1–5 (bid 1–5) just prior to a sell order's submission during time interval $t-1$; *Limit_Size* is the average of limit orders during time interval t for all traders, individual day traders, individual nonday traders, foreign institutional traders, and futures proprietary firm traders, respectively; D_j *is* the time-of-day dummy variables for each 15-minute intervals (i.e., 8:45–9:00 a.m. to 13:15–13:30 p.m.). The specification of D_j is discussed in Equation (1). To save the space, we do not report the dummy variables results. The *t*-statistics are reported in parentheses.

*, and **, indicate significance at the 1% and 5%, levels, respectively.

and nonday traders are akin to an L-shaped with a sudden drop at the last two time intervals. These results suggest that individual traders provide relatively greater liquidity in the early session and consume relatively greater liquidity near the end of the trading session. Our results are consistent with Harris's (1998) model prediction and Bloomfield et al.'s (2005) empirical results on the changing trading strategies in an experimental market setting.

Third, in terms of order size, we find that the size of limit orders submitted by individual day traders, individual nonday traders, and foreign institutional traders are larger than those of

their corresponding market orders. The intraday patterns of the size of limit orders and of market orders for both foreign institutional traders and futures proprietary firm traders are clearly L-shaped, whereas the intraday patterns of limit order size and market order size for individual traders are flat. In general, foreign institutional traders use larger sized limit and market orders than those for the other three types of traders. This finding is a new empirical result that adds to the limit order market literature.

Finally, results from the joint regression model indicate that the one-period lagged variables of transitory volatility, informational volatility, spreads, and same side and opposite side market depths, and order size have correct signs and are highly significant statistically for all trader types. The coefficients of these market variables for foreign institutional investors are similar to the coefficients on all trader types. We obtain new interesting results 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. These results are consistent with Handa and Schwartz's (1996) prediction regarding the influence of transitory volatility and informational volatility on trader's selection decision of limit versus market orders by type of trades.

However, differences exist in the coefficients of spreads and the limit order size variables in the net limit order submission regression for each trader type. For example, the one-period lagged spreads variable does not affect the decision of individual day traders. This result is expected because individual traders engage in quick turn-around trading. The coefficient of the limit order size for futures proprietary firm traders is negative and highly significant. One possible explanation is that futures proprietary firm traders, who often have access to order flow information, tend to use market orders to capture the value of the short-lived information.

We also find that institutional traders are more elastic with respect to changes in one period lagged spread, *Transitory_Volatility*, *Informational_Volatility*, same side (opposite side) market depths, and limit order size than individual day and nonday traders. Our results are consistent with Menkhoff et al. (2010). Using ordered logit models, they show that the order aggressiveness of informed traders is more responsive to market conditions than that of uninformed traders.

In sum, we report the differences in impact of market variables on intraday order submission strategy by trader types. Our empirical results also serve as useful input for the developers of theoretical models that predict the differences in liquidity provision by institutional and individual traders in a real-world market setting.

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APPENDIX

Daily Limit and Market Order Statistics by Trader-Type Categories

	Individual Day Traders			*Individual Nonday Traders*			*Foreign Institutional Traders*			*Futures Proprietary Firm Traders*		
Time Interval	*Limit*	*Market*	*Limit Order Submission Ratio (%)*	*Limit*	*Market*	*Limit Order Submission Ratio (%)*	*Limit*	*Market*	*Limit Order Submission Ratio (%)*	*Limit*	*Market*	*Limit Order Submission Ratio (%)*
0. 08:30–08:45 hours	1,103.57	122.29	0.9040	1,473.78	365.73	0.8166	171.29	57.96	0.6702	459.20	56.03	0.8820
1. 08:45–09:00 hours	2,424.71	654.19	0.7970	3,231.79	1,319.81	0.7210	2,501.52	254.46	0.8901	3,018.86	306.01	0.9013
2. 09:00–09:15 hours	3,077.66	1,102.94	0.7436	2,779.15	1,186.48	0.7059	3,831.26	303.22	0.9088	3,579.10	338.37	0.9014
3. 09:15–09:30 hours	2,936.30	1,034.12	0.7504	2,581.28	995.39	0.7272	3,835.20	232.38	0.9223	3,302.74	272.26	0.9112
4. 09:30–09:45 hours	2,673.91	932.80	0.7533	2,354.64	829.55	0.7448	3,523.15	191.67	0.9271	3,021.31	225.30	0.9138
5. 09:45–10:00 hours	2,605.33	926.52	0.7521	2,293.52	819.98	0.7431	3,292.02	174.20	0.9246	2,861.99	221.08	0.9174
6. 10:00–10:15 hours	2,449.89	891.69	0.7479	2,156.60	751.36	0.7505	3,040.37	163.42	0.9231	2,657.30	201.53	0.9206
7. 10:15–10:30 hours	2,337.75	855.79	0.7480	2,044.19	691.99	0.7574	2,779.50	146.13	0.9246	2,574.22	185.44	0.9233
8. 10:30–10:45 hours	2,125.85	782.23	0.7484	1,856.87	621.92	0.7594	2,650.45	135.19	0.9298	2,466.49	155.03	0.9307
9. 10:45–11:00 hours	2,133.24	808.98	0.7451	1,904.51	646.31	0.7600	2,642.69	128.24	0.9312	2,545.49	173.42	0.9283
10. 11:00–11:15 hours	2,041.18	753.93	0.7483	1,794.03	598.87	0.7634	2,486.67	131.56	0.9249	2,391.45	154.46	0.9300
11. 11:15–11:30 hours	2,147.25	815.82	0.7409	1,911.18	667.99	0.7561	2,518.35	139.41	0.9267	2,521.46	180.56	0.9260
12. 11:30–11:45 hours	2,296.42	842.66	0.7471	1,952.57	680.48	0.7555	2,673.03	142.28	0.9269	2,624.35	184.31	0.9249
13. 11:45–12:00 hours	2,267.86	848.34	0.7432	1,943.20	698.52	0.7489	2,784.56	137.32	0.9280	2,578.61	183.63	0.9276
14. 12:00–12:15 hours	2,205.42	820.64	0.7481	1,824.77	665.45	0.7516	2,882.34	136.79	0.9301	2,517.69	176.39	0.9301
15. 12:15–12:30 hours	2,288.94	833.51	0.7506	1,963.87	707.18	0.7533	2,942.31	148.56	0.9256	2,624.47	193.42	0.9251
16. 12:30–12:45 hours	2,219.47	802.21	0.7528	1,916.44	666.70	0.7548	2,830.23	132.70	0.9331	2,602.55	173.64	0.9274
17. 12:45–13:00 hours	2,310.13	813.67	0.7529	2,034.33	723.50	0.7474	2,924.13	137.78	0.9305	2,649.82	190.02	0.9236
18. 13:00–13:15 hours	2,369.42	837.12	0.7539	2,161.32	781.13	0.7459	3,162.03	184.32	0.9205	2,738.87	209.08	0.9185
19. 13:15–13:30 hours	1,938.85	642.16	0.7617	2,040.39	722.36	0.7495	3,054.15	245.83	0.9015	2,378.79	171.61	0.9249
20. 13:30–13:45 hours	1,764.52	825.32	0.6753	2,500.26	1,243.20	0.6667	2,277.69	349.67	0.8397	2,800.64	359.67	0.8645

Note. In this table, we present daily means of limit orders, market orders, and limit order submission ratios during 15-minute interval for individual day traders, individual nonday traders, foreign institutional traders, and futures proprietary firm traders of the futures contract FITX. The limit column is defined as the mean of limit orders sum during the 15-minute intraday interval. The market column is defined as the mean of market orders, which is the sum of pure market orders and marketable limit orders, sum during the 15-minute intraday interval. The limit order submission ratio is defined as the means of the ratio of the limit orders to the sum of the limit, market orders during the 15-minute intraday interval. The preopen trading period from 8:30 a.m. to 8:45 a.m. for each trading day is denoted by 0.

Note