Does Cognitive Limitation Affect Investor Behavior and Performance? Evidence from Limit Order Clustering

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Abstract

We investigate the effect of cognitive limitation on investment behavior and investor performance. We hypothesize that the cognitive limitation of investors could be manifested by disproportional large amount of limit orders submitted at round numbers if they use these numbers as cognitive shortcut to save energy from extensive algorithmic processing. Analyzing over 200 million detailed records of trades and quotes in Taiwan Futures Exchange, we document a strong and persistent pattern of limit order clustering at round number prices. The most frequent limit order prices are multiples of a hundred, followed by multiples of fifty, and then multiples of ten. The limit order clustering phenomenon is more pronounced among individual investors. Moreover, using the proportion of orders submitted at round number prices as a proxy for the level of an investor's cognitive limitation, we find that individual investors that are cognitively more constrained suffer from greater losses in their investments. Finally, we find that past trading experience, proxied by number of limit orders submitted, helps to mitigate the cognitive limitation.

Keywords: cognitive limitation, limit order clustering, investor performance, individual investors

JEL Classifications: G02, G15

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1. Introduction

Although economic theories usually assume full rationality of the agents, economists have long recognized that individuals are constrained by their cognitive limitations on decision making (Simon, 1955). One type of cognitive limitation discussed by Lacetera, Pope, and Sydnor (2011) is that, when making purchase decisions, customers in the used car market often use round numbers as cognitive shortcuts to save energy from extensive algorithmic processing. If investors carry on the same heuristics to financial markets, their cognitive limitations would be manifested in their limit order submission behavior, and we would observe a disproportional large amount of limit orders submitted at round number prices.

In this paper, we investigate the effect of cognitive limitation on investors' order submission behavior and their investment performance. Taking advantage of the complete records in Taiwan Futures Exchange (TAIFEX) with detailed information for investor type and identity, we first examine whether limit orders cluster at round number prices, and whether the pattern is more pronounced among individual investors. If investors are not cognitively constrained, their limit orders should be submitted at any given index points, resulting in uniformly distributed limit order prices. However, if investors rely on heuristic shortcuts, they would submit more limit orders at round number prices. Consequently, we would observe that the proportion of orders submitted at multiples of a hundred, i.e., a price of which the last two digits are "00", is significantly larger than 1%.

We then investigate whether higher cognitive limitation leads to lower investment performance. Intuitively, cognitively constrained investors could have poor investment performance because either they have less ability to access and interpret information or they are more affected by behavioral biases. [1] Since the overrepresentation of round-numbered limit orders largely stems from the cognitive accessibility of those numbers, a higher ratio indicates a larger degree of cognitive limitation at investor level. If cognitive limitation is indeed harmful to investor profitability, we would observe that higher submission ratio at round number prices is

[1] According to Subrahmanyam (1991), the effect of information asymmetry and adverse selection costs are lower in index futures market than in markets for individual securities. Hence, in our setting, the lack of private information is less likely the channel through which cognitive limitation affects investment performance.

associated with lower returns at investor level.

We also examine whether trading experience helps to reduce investors' inclination to submit limit orders at round number prices. Seru, Shumway, and Stoffman (2009) show that some individual investors become better at trading with experience, while others stop trading after learning that their ability is poor. In our context, if investors learn from past experience and become less affected by round-number heuristics, we would observe a negative correlation between the number of limit orders submitted in the past and the submission ratio at round number prices later on.

Employing over 100 million limit order quotes in TAIFEX from January 2003 to September 2008, we document a strong and persistent limit order clustering pattern. The average submission ratio at multiples of a hundred (the last two digits of the limit order prices are "00") is 3.1% during our sample period. Limit order clustering at multiples of a hundred is strongest, followed by multiples of fifty and multiples of ten. Furthermore, we find that limit order clustering is more pronounced among individual investors. They submit 4.1% of their limit orders at "00". This ratio is substantially higher than 1%, and is almost five times of the submission ratio at "99" and "01" (the last two digits of order prices are "99" and "01", respectively). Institutional investors also exhibit round-number heuristics, but with much smaller magnitude (1.4% of their limit orders are submitted at "00").

The results also show that limit order clustering is prevalent among various product types and persistent over time for individual investors. The submission ratio at "00" for the major two products, Taiwan Stock Exchange Futures and Mini-Taiwan Stock Exchange Futures, is 3.0% and 3.3%, respectively. The proportion of orders submitted at "00" is above 3.5% each year throughout our sample period for individual investors. For institutional investors, in contrast, the submission ratio at "00" decreased from 2.7% to 1.3% from 2003 to 2008. For them, limit order clustering phenomenon seems to subdue over time.

Moreover, we document a large cross-sectional heterogeneity in the submission ratio at round number prices. When sorting investors based on the proportion of orders submitted at round numbers, we find that the top-quintile individual investors submit over 60% of their limit orders at multiples of ten (the last two digits of the order prices are "X0", where X is an integer ranging from 0 to 9) while those in the bottom quintile submit only 10% at "X0".

We then use the submission ratio at "X0" as a proxy for the level of cognitive limitation, and test whether higher level of cognitive limitation would lead to inferior investment performance.[2] Individual investors with higher submission ratio at "X0" suffer from significantly lower intraday, 1-day as well as 5-day index returns of their limit orders. Individuals in the top quintile (where the submission ratio at "X0" is highest) underperform those in the bottom quintile by 5.5 basis points within the trading day (13.8% annualized). For institutional investors, the underperformance is significant only for intraday return.

To further substantiate the validity of using submission ratio at round number prices to represent the level of cognitive limitation, we examine whether the underperformance for the top-quintile investors concentrates only on limit orders with round number prices. If investors rationally pay for the energy they save by using round numbers as cognitive shortcuts, they would sacrifice a certain proportion of their profits at round number prices. In that case, the inferior performance for top-quintile investors should only appear for round-numbered limit orders. However, if the submission ratio at round numbers serves as a valid proxy for cognitive limitation, the inferior performance would be observed for limit orders submitted at any given price, and for market orders as well as round-trip trades.

We reexamine the index returns by grouping the limit orders within each quintile according to the last two digits of the order prices. If the inferior performance of top-quintile investors, compared with bottom-quintile ones, concentrates on limit orders with the ten round price points (the "X0"s), it would be consistent with the "pay-for-cognitive-shortcuts". However, out of a hundred different "XX"s, we find that, at 95 price points, the top-quintile individual investors have significantly lower intraday returns than the bottom-quintile ones. For institutional investors, the underperformance is significant at 30 out of a hundred different price points. The prevalent inferior relative performance at most price points corroborates our hypothesis that submitting orders substantially at round number prices is an indicator for cognitive limitation, which leads to poor investment performance.

The negative relationship between cognitive limitation and investor performance

[2] We do not use submission ratio at "00" as the proxy for cognitive limitation because, for some investors, the submission ratio at "00" cannot sufficiently reflect their round number heuristics. Especially for inactive investors, it is possible that they submit limit orders at prices other than "00" simply because the current market price happens to be far away from multiples of a hundred. To ensure reasonable submission ratio at round numbers, therefore, we employ "X0" instead of "00" to indicate round number prices.

is further strengthened when we look at the returns of market orders and round-trip trades. For individual investors, the market orders from top-quintile investors underperform those from bottom-quintile investors by 5.4 basis points within the trading day. The difference of realized round-trip daily index return is 30.2 basis points between top- and bottom-quintile individual investors. In addition to investor performance, we also find that investors, individual or institutional, have lower order execution ratio and longer order execution duration if they submit disproportionally large number of orders at round numbers.

To test whether investors learn to mitigate the cognitive limitation, we divide each investor's trade and quote records into former and later half of her trading history, and regress the submission ratio at "X0" in the later period on the investor's number of limit orders submitted in the former period. We find that trading experience helps to reduce the propensity to submit round-numbered limit orders. One standard deviation's increase in the number of limit orders submitted in the former period will lead to 6.8% fewer limit orders submitted at "X0" in the latter period for individual investors, after controlling for past submission ratio at "X0", past round-trip performance, and disposition effect.

We contribute to the literature by providing direct evidence for limit order clustering at round number prices among both individual and institutional investors for the entire exchange record which spans a long period of time. We also document high heterogeneity in the propensity to submit limit orders at round numbers within each investor type. Moreover, we propose a new proxy for the cognitive limitation, and find a strongly negative relationship between the level of cognitive limitation and investor performance. In addition, we document new evidence for investor learning by trading, and show that cognitive limitation could be mitigated by trading experience.

This paper is mostly related to Grinblatt, Keloharju, and Linnainmma (2012) who find high-IQ investors outperform low-IQ investors. Our paper differs from theirs in the following key ways, and yet complements their study. First, our proxy is a revelation of cognitive limitation from limit order submission behavior, instead of mathematical, verbal, and logical ability which are shown in the IQ test. In other words, we are directly linking investors' cognitive limitation, revealed in their financial decisions, to the investment performance. Second, we employ the entire records of Taiwan Futures Exchange with more than 200 million quotes and trades, irrespective of age, gender, and investor type, while Grinblatt et al. (2012) study the

middle-aged male individual investors with IQ data. Third, using futures index data in Taiwan provides a cleaner laboratory to study investor cognitive limitation, as there is no capital gain tax, no short-sales constraint, and there is only one underlying index price.

The rest of the paper is organized as follows. Section 2 provides the literature review. Section 3 introduces the data on Taiwan futures market. Section 4 presents the results on limit order clustering at round number prices. Section 5 investigates the relationship between cognitive limitation and investor performance. Section 6 examines the effects of trading experience on limit order submission ratio at round number prices. Section 7 provides the robustness checks. We conclude in Section 8.

2. Psychological Foundations and Related Literature

Originated primarily from psychology, an extensive literature has shown that people often use cognitive shortcuts when processing information and making decisions (see Gilovich, Griffin, and Kahneman, 2002 for a review). Generally, people are "bounded rational", and they usually cannot perform purely rational optimizations when faced with complex situations.

One type of cognitive limitation identified by Rosch (1975) is that people rely on round numbers, such as multiples of ten, as cognitive reference point. Schindler and Kirby (1997) analyze of the rightmost digits of selling prices in a sample of retail price advertisements and show that the overrepresentation of the digits 0, 5 can be explained by their high cognitive accessibility. More recently, Lacetera, Pope, and Sydnor (2011) study the heuristic information processing in the used-car market, and find that the tendency to focus on the left-most digit of a number affects customers' purchase decisions.

In the context of financial market, an extensive literature has shown that trade prices cluster at round numbers.[3] Aitken, Brown, Buckland, Izan, and Walter (1996) interpret the trade price clustering as investors have a natural "attraction" to round number prices. Using trade records, Bhattacharya, Holden, and Jacobsen (2011) document abnormal buy-sell imbalance when stock price approaches to or crosses round numbers. They propose that this is due to a combination of limit order

[3]See Neiderhoffer (1965, 1966), Ball et. al. (1985), Harris (1991), Goodhart and Curcio (1991), Christine and Schultz (1994a, 1994b), Ley and Variance (1994), Booth et. al. (2000), Palmon, Smith and Sopranzetti (2004), Sonnemans (2005), etc.

clustering and undercutting. The rationales from the above mentioned literatures are based on a common assumption: limit orders cluster at round number prices. Due to data availability, it is only recently that scholars are able to utilize limit orders to directly study investors' order submission behavior. Using five queues on the limit order book from Stock Exchange of Hong Kong, Ahn, Cai, and Yan (2005) find that the preference of prices are in the order of integer, halves and quarters. Osler (2003) investigates full records of currency orders submitted to a specific dealer and find similar results. However, none of the above literatures are able to distinguish among investor types, nor can they provide solid behavioral-based explanations for limit order clustering.

This paper offers several important distinctions. First, we are able to differentiate the limit order clustering patterns between individual and institutional investors. This is meaningful because, if investors are indeed affected by the round-number heuristics, the effect should be larger for individuals who generally do not specialize in trading. Therefore, the pattern of limit order clustering should be more pronounced among individual investors. Previous studies generally are not able to distinguish investor types, and they usually use small volume trades to proxy for individual investors. Second, in addition to the limit order clustering on aggregate level, we document heterogeneity in the submission ratio at round number prices within investor type. Furthermore, we propose to use the proportion of orders submitted at round number prices as a proxy for the level of cognitive limitation, and we are able to investigate the relationship between the level of cognitive limitation and investor performance. Last, the richness of our data provides more comprehensive picture of limit order clustering. Our sample covers five years and nine months quotes and trades, which enables us to examine whether limit order clustering pattern is persistent over time.

This paper is also related with the recent wave of research studying investor inattention and trading. For example, Barber and Odean (2008) argue that stock-specific attention-grabbing events have strong effects on the stock selection of individual investors. The recent work by Yuan (2011) shows that market-wide attention-grabbing events also affect investors' trading behavior. Investor inattention is one type of cognitive limitation where investors focus on attractive events when processing exogenous information. In comparison, the round-number heuristics discussed in this paper is a different type of cognitive limitation. Investors submit limit orders more at round number prices might simply because they find round

numbers easier to remember and type in the Electronic Trading System. The round-number heuristics is more likely to be an internal inclination to save cognitive energy, and is less about exogenous information processing. Furthermore, while Barber and Odean (2008) and Yuan (2011) documents limited cognitive capability at market level, our results indicates that there is heterogeneity in cognitive limitation at investor level.

Several proxies for investor's cognitive ability have been proposed to study how cognitive limitation generates differences in trading behavior and investment performance. Chevalier and Ellison (1999) and Gottesman and Morey (2006) find that a mutual fund's performance can be predicted by the fund manager's average Scholastic Aptitude Test (SAT) score or average Graduate Management Admission Test (GMAT) score. Grinblatt, Keloharju, and Linnainmma (2012) utilize IQ scores of middle-aged male individual investors in Finland, and find that high IQ investors outperform low IQ investors. This paper proposes an innovative proxy, derived from investment decisions, for cognitive capability. Instead of mathematical, verbal and logical ability measured in the above mentioned tests, submission ratio at round number prices is a direct measure of the degree to which cognitive limitation is revealed in their limit order submission behaviors. Moreover, since submitting limit orders disproportionally more at round numbers reflects round-number heuristics regardless of investor type, we are able to draw implications for both individual and institutional investors.

3. Data Description

This paper employs complete records of quotes and trades in Taiwan Futures Exchange (TAIFEX) with detailed investor type and identity information from January 2003 to September 2008. The detailed quotes data allows us to directly study investors' limit order submission behavior, while the trades data allows us to capture the investor performance.

3.1 The Taiwan Futures Market

Investors are allowed to submit orders to the Electronic Trading System of TAIFEX from 8:30 AM to 13:45 PM, Monday to Friday. Orders submitted before 8:45 AM and after 13:40 PM are matched by open and close auction, respectively.

From 8:45 AM 13:40 PM, orders are matched immediately once they enter the Electronic Trading System (ETS). The matching rules of this continuous auction system are price priority and time priority.

From January 2003 to September 2008, the two major contracts traded in the TAIFEX are the Taiwan Stock Exchange Index Futures (hereafter TXF), and the Mini-Taiwan Stock Exchange Index Futures (hereafter MXF). TXF is based on all listed stocks on the Taiwan Stock Exchange, while MXF is a mini version of TXF with roughly one-quarter of the margin and payoff.

3.2 Limit Order Quotes

In each quote's record, we observe the investor type (individual or institutional) and account number, as well as other relevant information such as order price, quantity, submission time, etc. Since the largest daily price change should be within 7% of previous trading day's closing price in TAIFEX, we exclude limit orders that are submitted out of this range. In total, we have 102 million records of submitted limit orders.

Table I reports the descriptive statistics of limit order quotes in TAIFEX. The first feature worth emphasizing is that individual investors are major participants in TAIFEX. On average, 63.78% of the limit orders are submitted by individual investors, which is substantially more than that of institutional investors from 2003 to 2007. A second feature is that the more preferred futures product is TXF. 63.01% orders are submitted to trade TXF. Additionally, the data also suggests that TAIFEX futures market becomes increasingly more popular during the period. In 2008 we only have data for the first nine months. However, they consist 32.57% of total submitted quotes.

Panel B of Table I shows that the total number of contracts amounts to 313 million, which indicates that investors on average submit about three contracts in each order. Institutional investors submit larger number of contracts in their orders (averagely 4.38 contracts per order).

3.3 Limit Order Trades

The limit order trade data set contains detailed information about each transaction. One limit order can appear in several transaction records because it is matched with

several different orders, perhaps at different points of time as well. It is also possible that some orders are only partly executed. Therefore, to facilitate meaningful comparison with limit order quote data, Table II reports the descriptive statistics for number of contracts executed.

There are 102 million contracts filled overall. The average execution ratio, defined as the number of contracts executed divided by number of contracts submitted, is 33.93%. Again, we want to point out that the futures trading in TAIFEX is dominated by individual investors. On average, 73.16% of the executed contracts are from individual investors. They complete substantially more trades than institutional investors throughout the sample period.

The transaction price in TAIFEX ranges from 4,011 to 9,934 index point. Therefore, in this paper, we look at the last two digits of the order price to identify round number prices. One index point's increase in the transaction price brings about 200 TWD profit for one TXF contract. MXF contracts have one quarter of the payoff for TXF contracts per index point change.

3.4 Investors in TAIFEX

Table III presents the descriptive statistics of investors in TAIFEX. In total, there are over 290 thousand investors participating in futures trading from January 2003 to September 2008. Among them, over 283 thousand are individual investors. Although institutional investors comprise only 2% of the entire population, they contribute to about 36% of order submission. Among all the investors, only a small proportion plays an active part during our sample period. 62% (34%) of all the investors submit more than 25 (75) orders. Those investors are major participants in TAIFEX, contributing to 99% (96%) of all limit order quotes during the time.

4. Limit Order Clustering at Round Number Prices

Using detailed records of limit order quotes, this section addresses the following questions: Do investors submit disproportionally large amount of limit orders at round number prices? Does the limit order clustering pattern differ between various investor types and products? Is limit order clustering phenomenon persistent over time?

4.1 Limit Order Clustering at Round Number Prices

To indentify round number prices, we focus on the last two digits in the limit order prices. For example, if a limit buy order price is 4,500, we characterize the order as "submitted at 00". Limit order prices can end with a hundred different "XX"s (where X is an integer ranging from 0 to 9). In this paper, round number prices are referred to the prices with XX=00, 10, 20, …, 90.

We calculate the submission ratio as:

$$SR_{XX} = \frac{Number\ of\ limit\ orders\ submitted\ at\ "XX"}{\sum_{XX=00}^{99} Number\ of\ limit\ orders\ submitted\ at\ "XX"} \quad (1)$$

The submission ratio directly measures the proportion of orders submitted with the last two digits of the order prices being "XX". Theoretically, if investors are not cognitively constrained, their limit orders should be submitted at any given prices. However, if investors are affected by round-number heuristics, they would submit more limit orders at round number prices.[4] Consequently, for example, we would observe that the submission ratio at "00" is significantly larger than 1%.

The submission ratio is plotted by the last two digits of the order prices in Figure 1. It shows that limit order clustering is evident in TAIFEX. The submission ratio is 3.1% at "00", which is 2.2% higher than that of "99" and "01". The most favored prices are those that end with "00", followed by those end with "50", and then "20", "80", etc. This indicates that when investors submit limit orders, they have higher tendency to choose a round number order price, and the submission ratio at "XX" is increasing in its roundness.[5]

4.2 Limit Order Clustering for Different Order Types

To take a closer look at limit order clustering, we report the submission ratios separately for individual and institutional investors, and TXF and MXF orders. This allows us to investigate whether limit order clustering is prevalent among various order types.

The takeaway from Figure 2 is that limit order clustering pattern is substantially

[4] One may hypothesize that the limit order clustering phenomenon is driven by the hedging strategies where the order prices of futures contracts are anchored at the index options strike prices. However, the basic findings remain unchanged when we restrict our sample to investors that do not trade options during our sample period. Therefore, in this paper we incorporate the entire records of futures orders in TAIFEX market regardless of whether or not the investor has position in index options market.

[5] Although not reported in Figure 1, the submission ratio is highest at "000" if we look at the last three digits of the quote prices.

more pronounced for individual investors. The submission ratio is 4.1% at “00”, which is almost five times of that of “99” and “01”. Limit orders cluster most at multiples of a hundred, then at multiples of fifty and then at other round numbers. For example, 3.1% (2.6%) orders are submitted with the last two digits of order prices being “50” (“80”). This is in line with our argument that individual investors submit round-numbered limit orders as a shortcut to save cognitive energy. The more roundness of a number, the higher likelihood the number is chosen for the limit order price.

For institutional investors, on the other hand, this pattern is with much smaller magnitude. The submission ratio at “00” is 1.4%, which is only 0.4% larger than the uniform distribution benchmark. The results indicate that individual investors exhibit more round-number heuristics when submitting limit orders.

Figure 3 plots the submission ratio separately for TXF and MXF orders. For TXF, 3.0% orders are submitted at “00”, while for MXF the number is 3.3%. The similar proportion of orders submitted at round number prices for TXF and MXF suggests that the limit order clustering phenomenon exists regardless of the product type.

4.3 Limit Order Clustering is Persistent over Time

To further confirm that limit order clustering documented in this paper is not driven by unusual price movements during a particular period, we look at submission ratio at round number prices in different years. For illustration, we plot the proportion of orders submitted at “00” and “50”, respectively, from 2003 to 2008. Figure 4 shows that, as futures trading becomes increasingly more popular from 2003 to 2008, individual investors are consistently affected by the round-number heuristics when submitting the limit orders. The submission ratio at “00” is above 3.5% throughout our sample period. For institutional investors, in contrast, limit order clustering phenomenon seems to subdue over time. For them, the submission ratio at “00” decreased from 2.7% to 1.3%. This suggests that institutional investors overcome the cognitive limitation over time. It might also be due to the increasing popularity of program trading among institutional investors.

4.4 Multivariate Regression Analysis

In this subsection, we formally test the existence and prevalence of limit order

clustering through regressions on dummy variables indicating round number prices and order types. In each quote's record, we are able to recognize whether it is submitted by individual or institutional investor, and whether it is to trade MXF or TXF. For each year and for each order type, we calculate the proportion of orders submitted at "XX", and run the following regression:

$$SR_{XX} = a_{XX} + \beta_1 D_{00} + \beta_2 D_{50} + \beta_3 D_{X0} + \beta_4 D_{00} \times D_{indv} + \beta_5 D_{50} \times D_{indv} + \beta_6 D_{X0} \times D_{indv} + \beta_7 D_{00} \times D_{MXF} + \beta_8 D_{50} \times D_{MXF} + \beta_9 D_{X0} \times D_{MXF} + \varepsilon_{XX} \quad (2)$$

where SR_{XX} is the submission ratio at "XX" for a specific order type. D_{00}, D_{50} and D_{X0} are dummy variables for price point "00", "50" and "X0", where X≠0 or 5. D_{indv} and D_{MXF} are indicators for orders submitted by individual investors, and MXF orders, respectively. β_1, β_2, and β_3 measure the extent to which submission ratios increase at round numbers. The coefficients of the interaction terms, β_4 to β_9, measure the marginal effect of a specific order type. For example, if β_4 is significantly larger than 0, it means that the submission ratio at "00" is higher for individual investors, which indicates that they are more affected by round-number heuristics. Table IV reports the parameter estimates for this regression, and shows the F-tests for the difference between β_1, β_2 and β_3 in the last three rows.

When we ignore the interaction terms, the coefficients for D_{00}, D_{50} and D_{X0} are all significantly positive with p-values smaller than 0.01. The parameter estimate is decreasing from D_{00} to D_{50} and to D_{X0}, and the difference of the coefficients is considerable. For example, the submission ratio at "00" is averagely 0.6% larger than that of "50", where the submission ratio is again 0.5% larger than that of "X0". The proportion of orders submitted at "XX" is increasing in its roundness.

The results indicate that individual investors play a major role in limit order clustering at round number prices. The proportion of limit orders submitted at "00" is 3.2% higher than non-round "XX"s (i.e. "XX"s that are not equal to "00", "10", "20",…, "90"). The submission ratios at "50" and "X0" are also higher than non-round "XX"s by 2.3% and 1.4%, respectively. Although with smaller magnitude, institutional investors submit more orders at round number prices, too. The submission ratio at "00" is 0.9% higher than non-round "XX"s, which is also significant with p-value smaller than 0.01. This is consistent with Locke and Mann (2005) who show that institutional investors also exhibit behavioral bias like

disposition effect. Liu et. al. (2009) also document trading patterns consistent with prospect theory for market makers as well as other types of investors. Although institutional investors are generally better educated and more specialized in trading, it is still possible for them to exhibit certain level of cognitive limitation and round-number heuristics when deciding the order price. The lower submission ratio at round numbers than that of individual investors indicates lower level of cognitive limitation for institutional investors in general.

When we incorporate all the interaction terms, the most influential factor is the individual investor dummy. MXF orders cluster slightly more than TXF orders. The submission ratio for MXF orders is 0.2% higher than TXF orders at "00" price point. To sum up, it is the individual investors that exhibit more round-number heuristics, and this is true no matter when they submit MXF or TXF orders. For both individual and institutional investors, and both TXF and MXF, the limit order clustering phenomenon is increasing from "X0" to "50" and "00".

5. Cognitive Limitation and Investor Performance

In this section, we take submission ratio at round number prices as a proxy for cognitive limitation, and test whether higher degree of cognitive limitation would lead to worse performance at investor level.

With investor account number, we are able to identify each investor and keep track of both her submission behavior and investment performance. For each investor, we calculate the proportion of orders submitted at multiples of ten as well as the performance of all investments, and we then investigate whether a larger submission ratio at "X0" is correlated with lower returns. To make sure that investors have reasonable submission ratio at "X0", we require that investors must submit at least fifty limit orders during our sample period. As is shown in Table III, this subsample of investors comprises 49% of the entire population but accounts for 98% of all the limit orders. For robustness sake, in Section 7 we also check whether our results remain when we look at investor performance by submission ratio at "00" only (or "00" and "50") and when we expand (restrict) our sample to investors with more than 25 (or 75) limit orders submitted.

For each investor that has more than fifty records of limit order quotes from January 2003 to September 2008, we calculate the submission ratio at "X0" and sort

the investors accordingly. As is shown in Table V, the number of individual investors is quite spread out among different quintiles. For example, the bottom quintile individual investors where submission ratio at "X0" is only 10%. For top-quintile investors, on the other hand, both and institutional investors, submit 60% of their orders at "X0", which signals for great round-number heuristic effects. The huge difference in the submission ratio at round number prices indicates considerable heterogeneity in the degree of cognitive limitation.

We also report in Table V whether there is a larger friction for investors with higher level of cognitive limitation when executing their limit orders. Specifically, we look at the average execution ratio and average time-to-execution of limit orders for investors with different submission ratio at "X0". The execution ratio is defined as the number of contracts executed divided by the total number of contracts submitted by each investor from January 2003 to September 2008. Time-to-execution is the interval between submission time and execution time.

The result shows that investors in the top quintile have significant lower execution ratio and longer duration than those in the bottom quintile. For top-quintile individual investors, the execution ratio is 56.2%, which is 4.0% lower than that of bottom-quintile investors. The execution duration for investors in the top quintile is 701 seconds, which is 365 seconds longer than that of bottom-quintile investors. Similar pattern also holds for institutional investors. The results indicate that it is more difficult for investors, individual or institutional, to execute their orders if they are more cognitively constrained and submit substantially large number of orders at round number prices.

5.1 Submission Ratio at "X0" and Hypothetical Index Return of Limit Orders

The first aspect of investor performance we look at is the hypothetical index return of limit orders. The intraday return is calculated as the pseudo return assuming that the initiating limit order is settled at the closing price of the day. For each investor, we first calculate the average intraday return, and then average them up among all the investors in each quintile with equal weights. For robustness sake, 1-day and 5-day returns are also reported.

Figure 5 plots the hypothetical returns against the quintile ranks of investors. A monotonic decrease of intraday return by the submission ratio at "X0" is documented for individual investors. Similar monotonic decreasing pattern also exists for 1-day and 5-day returns. For institutional investors, however, no persistent decreasing hypothetical index return can be observed. The result indicates that individual investors with higher level of cognitive limitation suffer from inferior performance of their investments.

Table VI presents the statistical tests formally. Individual investors with higher submission ratio at "X0" suffer from significantly lower intraday, 1-day as well as 5-day returns. The top-quintile investors perform worse than those in the bottom quintile by 5.5 basis points within the trading day. The annualized underperformance amounts to 13.8%. The inferior performance of top-quintile investors persists from intraday to 5 days after the transaction. For institutional investors, on the other hand, the underperformance of top-quintile investors is significant only for intraday returns.

Another interesting finding is that individual investors in all quintiles experience negative returns, while for institutional investors, only those that submit substantially more limit orders at "X0" endure loss in their investments. This is consistent with Barber et. al. (2006) who find that individual investor trading results in systematic and economically large losses. Since individual and institutional investors in the bottom quintile have similar submission ratio at "X0", it seems that the difference of investor performance between different investor types cannot be fully explained by the level of cognitive limitation. This is because, unlike professionally trained institutional investors, individuals are generally less informed and most of them are not specialized in futures trading. The heterogeneity in trading skills and information between individual and institutional investors may explain the difference in profitability of these two types of investors with similar submission ratio at round number prices. Nevertheless, our result indicates that submission ratio at "X0" serves as a valid proxy for the level of cognitive limitation among individual investors.

In addition to the univariate sorting, we provide the formal analysis by performing cross-sectional regression at investor level:

$$Return_i = a_i + \beta_1 SR_{X0,i} + \beta_2 Ln(N_i) + \beta_3 Disposition_i + \varepsilon_i \quad (3)$$

where $Return_i$ is the average hypothetical index return for investor i. $SR_{X0,i}$ is

investor i's submission ratio at "X0" price points. $Ln(N_i)$ is the log of number of limit orders submitted, which is a proxy for trading experience.[6] $Disposition_i$ measures the extent to which investor i is affected by disposition effect, and it is calculated as the difference between the duration of losing and winning round-trip trades, scaled by the average of the two. Odean (1998) shows that the tendency to hold losing investments too long and sell winning investments too soon leads to lower after tax returns. Therefore, controlling for disposition effect helps us to focus on the pure effect of cognitive limitation. The coefficient of particular interest is β_1 as it measures how cognitive limitation affects investment performance.[7]

The first three columns of Table X show significantly negative coefficients of the submission ratio at "X0" for both individual and institutional investors. One standard deviation increase in the submission ratio at "X0" (18.1%) leads to a 1.7 basis points decrease in intraday return for individual investors, after controlling for trading experience and disposition effect. Similar results hold for 1-day or 5-day index returns. Notice that the coefficients for $Disposition_i$ are all significantly negative, suggesting that the more an investor is affected by disposition effect, the lower return of the investment, which is consistent with the findings in Odean (1998). Overall, the multivariate regression analysis yields similar result to that of the univariate sorting and is consistent with our hypothesis.

5.2 Submission Ratio at "X0" and Hypothetical Index Return of Limit Orders at "XX"

The conclusion we draw from previous subsection is based on that the submission ratio at round number prices is a valid proxy for the level of cognitive limitation. However, by looking merely at the average return of limit orders, we cannot rule out the possibility that the underperformance is driven by limit orders with round prices only.

Consider the case where cognitive energy is in the utility function of the investors. When making investment decisions, investors face a tradeoff between the benefit of

[6] We also perform the regression analysis using the account age as the indicator for trading experience. The results are basically the same.

[7] However, one needs to be cautious when interpreting of the coefficients for $Ln(N_i)$ due to survivorship bias. Investors may outperform others because they accumulate experience from previous trading. However, investors may submit more limit orders and remain in the market simply because their investment performance is satisfying.

executing orders at the optimal price and the cost of energy spent on determining the order price. They may rationally pay for the cognitive energy they save from deciding an optimal order price by simply relying on round number heuristics. However, if investors are able to submit the accurate optimal prices, the return for orders submitted at non-round numbers will remain unaffected. In that case, the underperformance should concentrate on orders submitted at round number prices. Note that in the "pay-for-cognitive-shortcut" channel, it is submitting orders at round number prices that directly leads to poor profitability.

To substantiate the validity of using submission ratio at round number prices as a proxy for cognitive limitation, and to rule out the explanation of "pay-for-cognitive-shortcut", we test whether the underperformance of top-quintile investors is concentrated on limit orders with round prices. In the following three subsections, we examine whether the inferior performance for top-quintile investors exists for limit orders at non-round prices, and also for market orders and round-trip trades as well.

In this subsection, we reexamine the hypothetical index return of limit orders by grouping the limit orders within each quintile according to the last two digits of the order prices. If the submission ratio at "X0" is a good proxy for the level of cognitive limitation, the underperformance of top-quintile investors would appear for limit orders at any given price. Figure 6 presents the hypothetical intraday, 1-day as well as 5-day index returns for investors in the top and bottom quintiles. It appears that the underperformance of investors in the top quintile comes not only from the orders with round prices. Individual investors in the top quintile tend to underperform those in the bottom when they submit orders at most price points. The patterns are similar for hypothetical intraday, 1-day as well as 5-day index returns.

For formal statistical analysis, we report in Table VII the number of price points where top-quintile investors (significantly) underperform those in the bottom quintile. If the inferior performance of top-quintile investors, compared with bottom-quintile ones, concentrates on orders with the ten round price points (the "X0"s), it would be consistent with the "pay-for-cognitive-shortcut" explanation. However, out of a hundred different last two digits of the order prices, we find that at 98 price points, the top-quintile investors have lower intraday returns than the bottom-quintile ones. Among them, at 95 price points the underperformance is significant at 0.01 level. For

institutional investors, the underperformance is significant at 30 out of 100 price points. Similar results hold for 1-day and 5-day returns, too.

The prevalent inferior relative performance at almost every price point corroborates our hypothesis that submitting disproportionally large number of orders at round number prices is an indicator for cognitive limitation.

5.3 Submission Ratio at "X0" and Hypothetical Index Return of Market Orders

The Hypothetical intraday index return is calculated as the pseudo return assuming that the initiating market order is settled at the closing price of the day. For each investor, we first calculate the average intraday return, and then average them up among all the investors in each quintile with equal weights. 1-day and 5-day returns are also reported for robustness sake.

Panel A of Table VIII shows that individual investors with higher submission ratio at "X0" have significantly lower intraday, 1-day as well as 5-day returns of their market orders. The intraday underperformance of investors in the top quintile compared to those in the bottom quintile is 5.4 basis points, which is quite similar in magnitude with the underperformance calculated using limit order intraday index return. The underperformance enlarges to 8.0 (9.0) basis points one (five) day(s) after the transaction. For institutional investors, on the other hand, the top-quintile investors' performance is not significantly inferior.

We find similar results using multivariate regressions reported in the middle three columns of Table X. The parameter estimates on submission ratio at "X0" are significantly negative for individual investors. One standard deviation increase in submission ratio at "X0" (18.1%) leads to a 1.5 basis points decline in intraday return of market orders, which is quite similar in magnitude to the result for intraday return of limit orders. Same results hold for 1-day or 5-day index returns. For institutional investors, however, we do not observe a consistent relationship between market order returns and submission ratio at "X0", which might be partly due to the much smaller number of observations.

The results indicate that, at least for individual investors, the underperformance for investors with higher submission ratio at round number prices is not restricted only

to limit orders. Investors with higher level of cognitive limitation suffer from inferior performance when they submit market orders as well.

5.4 Submission Ratio at "X0" and Investor Performance of Round-trip Trades

In addition to hypothetical index returns, we examine the performance of round-trip trades in this subsection. To adjust for the cross-sectional variation in round-trip duration, and facilitate comparison with the hypothetical index returns, we look at the round-trip daily profit and daily index return for investors with various submission ratios at "X0".

Round-trip trades are identified in a way similar to Jordan and Diltz (2003) and Feng and Seasholes (2005). Essentially, a round-trip trade is accomplished when an initiated position, long or short, is covered. The profit of a round-trip trade can therefore be calculated when the net position of an investor is back to zero again, and the round-trip duration is the interval between the initiating position and the back-to-zero position. We calculate the round-trip index return as the profit divided by the average execution price of all limit buy orders within a round-trip trade. The round-trip daily profit (index return) is defined as the average round-trip profit (index return) divided by average round-trip duration.[8] Similar as hypothetical index returns, all items are first calculated for each investor and then averaged up for each quintile with equal weights.

Panel A of Table IX shows that the underperformance is substantial for individual investors with higher submission ratio at "X0". Investors in the top quintile have significantly lower round-trip daily profit than those in the bottom quintile. The realized underperformance is about 2,469 TWD per trading day. If we multiply the daily underperformance per round-trip trade by round-trip duration, number of round trips for each investor and number of investors in the top quintile, we can roughly calculate the economic loss caused due to cognitive limitation. The top-quintile individual investors lose about 12.7 trillion TWD more than the bottom-quintile ones

[8] The effect of extreme outliers can be a serious issue if we calculate the daily performance per round-trip. A number of round-trip trades have very short duration, leading to extremely large daily profit and daily index return for those round-trip trades. Therefore, in the paper we first calculate the average round-trip duration and profit for each investor, and then calculate the investor's daily profit as average round-trip profit divided by average duration. Round-trip daily index return is defined similarly.

during our sample period, which is about 387 million USD.[9] The result also shows that individual investors that submit more orders at round number prices experience substantially lower round-trip daily index return. Investors in the top quintile significantly underperform those in the bottom by 30 basis points per day.

Panel B of Table IX shows that institutional investors in the top quintile also have lower round-trip daily profit and daily index return than those in the bottom quintile, but the difference is less significant. This might be partly due to the smaller number of institutional investors in the bottom quintile.

The last two columns of Table X present the result from multivariate regressions. The coefficients of the submission ratio at "X0" are significantly negative for individual investors. One standard deviation increase in submission ratio at "X0" (18.1%) leads to 461 TWD lower round-trip daily profit and 5.6 basis points lower daily index return. For institutional investors, we do not find the significant relationship, again, which might be due small number of observations.

Both lower hypothetical return and realized round-trip return of investors with higher submission ratio at "X0" corroborate the negative correlation between investor's cognitive limitation and their investment performance.

6. Trading Experience and Submission Ratio at "X0"

In this section, we examine whether trading experience helps to reduce the propensity to submit limit orders at "X0". For each investor, we divide the quote and trade records into former and later periods of the investor's trading history. To mitigate outlier issue, we require that the investors must have their account for more than two years, and that they must submit more than 50 limit orders in both periods.[10] We perform the following regression:

$$SR_{X0,later,i} = a_i + \beta_1 Ln(N_{former,i}) + \beta_2 \ SR_{X0,former,i} + Controls_i + \varepsilon_i \qquad (4)$$

where $SR_{X0,later,i}$ and $SR_{X0,former,i}$ are investor i's submission ratio at "X0" price points in her later and former periods, respectively. $Ln(N_{former,i})$ is the natural log of the number of limit orders submitted, and it measures the trading experience accumulated in the former period for investor *i*. As for controls, we include measures for

[9] The exchange rate is averagely 0.0305 USD/TWD from January 2003 to September 2008.
[10] The results are qualitatively the same when we use two months as the threshold.

disposition effect, round-trip daily index return, and daily index return of round-trips where the initiating order is a limit order submitted at "X0". The extent to which an investor is affected by disposition effect is calculated as the difference between the duration of losing and winning round-trips in the former period, divided by the average of the two.

Panel A of Table XI shows that trading experience significantly reduces the submission ratio at "X0" for individual investors. The parameter estimates for $Ln(N_{former,i})$ are significantly negative at 0.01 level, both before and after controlling for past submission ratio at "X0" and other control variables. A one standard deviation increase in the number of limit orders submitted in the former period (1,881) will reduce submission ratio at "X0" by 6.8% later on. This indicates that individual investors learn from their past trading experience and become less affected by round-number heuristics in their subsequent investments. Panel B shows that for institutional investors, however, the effect of trading experience is smaller and insignificant.

Table XI also shows that an investor's propensity to submit limit orders at round numbers is quite persistent over time. The parameter estimates of $SR_{X0,former,i}$ are significantly positive. For individual investors, previous submission ratio at "X0" explains 49% variation of submission ratio at "X0" in the later period. A one standard deviation increase in past submission ratio at "X0" (17.5%) will lead to 13.3% increase in the investor's later submission ratio at "X0". For institutional investors, the explanatory power of $SR_{X0,former,i}$ is 38%. The persistency of submission ratio at "X0" is consistent with our argument that it serves as a valid proxy for cognitive limitation.

The coefficients for disposition effect and past round-trip performance are not significant, suggesting little influence of these factors on submission ratio at round number prices.

7. Robustness Check

In Section 5 we sort investors that submit more than 50 limit orders into quintiles based on the proportion of limit orders submitted at "X0" price points, and test whether submission ratio at round numbers is correlated with investor performance. To further confirm that our results are not driven by the sorting or filtering criterion,

in this section, we check whether our results persist when we sort investors by submission ratio at “00” (or “00” and “50”), and when we expand (restrict) our sample to investors with more than 25 (or 75) limit orders submitted.

In Figure 7 we plot the hypothetical index returns of limit orders by quintile ranks of individual investors. The main results from previous section still hold when we modify the sorting criterion. When we group investors according to the proportion of orders submitted at “00”, both the hypothetical intraday, 1-day and 5-day returns are monotonically decreasing in the quintile ranks of individual investors. Similar pattern persists when we consider submission ratio at “00” and “50”. The magnitude of underperformance for top-quintile investors is quite similar when we sort investors based on submission ratio at “00”, at “00” and “50”, and at all “X0” price points. Although not reported in Figure 7, the underperformance for investors in the top quintile appears not only at round number prices. Over 90 out of all “XX”s witness significantly lower index returns of limit orders when we sort investors by submission ratio at “00” (or “00” and “50”).

Table XII reports the difference in performance between top- and bottom-quintile individual investors that submit more than 25 (or 75) limit orders. This difference is persistently negative when we sort investors according to the submission ratio at "00" only, "00" and "50", as well as all "X0" price points, and the magnitudes of the underperformance are similar for investors with 25, 50 or 75 limit orders submitted. These results indicate that the negative relationship between cognitive limitation and investor performance documented in the previous sections is not driven by the sorting or filtering criterion.

8. Conclusion

We investigate whether cognitive limitation would affect investor limit order submission behavior and performance. We document a strong and persistent limit order clustering pattern by employing detailed records of limit order quotes in Taiwan Futures Exchange. Specifically, we find that limit orders cluster most at multiples of a hundred, followed by multiples of fifty, and then multiples of ten. Individual investors are more affected by the round-number heuristics. They submit 4.1% of their orders at “00”, which is almost five times of that of price point “99” and “01”. For institutional investors, the limit order clustering pattern still exists, but with much smaller

magnitude. Limit order clustering phenomenon is prevalent among different products (TXF and MXF) and persistent over time for individual investors. Moreover, we document cross-sectional heterogeneity in the submission ratio at round number prices. Individual investors in the top (bottom) quintile submit about 60% (10%) of their limit orders at "X0".

We then propose a new proxy for the level of cognitive limitation, and document a monotonic relationship between cognitive limitation and investor performance. Individual investors with higher submission ratio at "X0" have significantly lower intraday, 1-day as well as 5-day returns. We document an annualized underperformance of 13.75% for top-quintile individual investors, compared to those in the bottom. For institutional investors, the underperformance is also significant for intraday and 1-day returns. It appears that the inferior performance of investors in the top quintile is not restricted to limit orders with round prices. The underperformance appears for limit orders at most price points, for market orders, and for realized round-trips of individual investors with higher submission ratio at "X0". This is supportive of our hypothesis that submission ratio at round number prices serves as a valid proxy for cognitive limitation, which is associated with poor investment performance.

Finally, we also show new evidence of investor learning by trading. We find that trading experience, proxied by number of limit orders submitted in the former period, helps to improve cognitive capability and reduce round-numbered limit orders.

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Table I. Descriptive Statistics of Limit Order Quotes

This table reports the summary statistics of the submitted limit orders for two major Taiwan index futures in Taiwan Futures Exchange from January 2003 to September 2008. The number of limit orders submitted is reported in panel A, while number of limit-order contracts is reported in panel B.

Panel A: Descriptive Statistics of Number of Limit Orders Submitted

	Total number of	Investor type		Product type	
Time	orders submitted	Individual	Institutional	TXF	MXF
2003/01-2003/12	8,324,617	7,874,288	450,329	5,864,147	2,460,470
2004/01-2004/12	11,618,064	10,436,137	1,181,927	7,801,525	3,816,539
2005/01-2005/12	9,037,562	7,171,025	1,866,537	6,558,268	2,479,294
2006/01-2006/12	15,248,910	10,088,540	5,160,370	10,306,766	4,942,144
2007/01-2007/12	24,743,232	13,019,752	11,723,480	14,409,222	10,334,010
2008/01-2008/09	33,316,148	16,650,693	16,665,455	19,515,005	13,801,143
Total	102,288,533	65,240,435	37,048,098	64,454,933	37,833,600
Ratio	100.00%	63.78%	36.22%	63.01%	36.99%

Panel B: Descriptive Statistics of Number of Limit-order Contracts Submitted

	Total number of	Investor type		Product type	
Time	contracts submitted	Individual	Institutional	TXF	MXF
2003/01-2003/12	19,594,573	16,859,030	2,735,543	16,183,318	3,411,255
2004/01-2004/12	29,925,687	22,720,915	7,204,772	23,356,530	6,569,157
2005/01-2005/12	27,189,022	18,980,375	8,208,647	22,243,999	4,945,023
2006/01-2006/12	47,711,888	25,136,643	22,575,245	33,453,316	14,258,572
2007/01-2007/12	82,947,178	27,342,689	55,604,489	44,628,091	38,319,087
2008/01-2008/09	95,249,384	29,437,784	65,811,600	50,658,874	44,590,510
Total	302,617,732	140,477,436	162,140,296	190,524,128	112,093,604
Ratio	100.00%	46.42%	53.58%	62.96%	37.04%

Table II. Descriptive Statistics of Limit Order Trades

This table reports the summary statistics of the executed limit orders for two major Taiwan index futures in Taiwan Futures Exchange from January 2003 to September 2008. The number of executed limit-order contracts is reported separately for individual investors and institutional investors, Taiwan Stock Exchange Futures (TXF) and Mini-Taiwan Stock Exchange Futures (MXF). The maximum and minimum execution prices are also reported in the last two columns.

	Total number of	Investor type		Product type		Transaction price (index point)	
Time	contracts executed	Individual	Institutional	TXF	MXF	minimum	maximum
2003/01-2003/12	11,586,280	9,783,808	1,802,472	9,699,767	1,886,513	4,011	6,302
2004/01-2004/12	16,115,999	12,754,376	3,361,623	13,257,865	2,858,134	5,010	7,312
2005/01-2005/12	12,201,640	8,893,996	3,307,644	10,548,372	1,653,268	5,438	6,647
2006/01-2006/12	17,552,416	12,509,174	5,043,242	14,964,327	2,588,089	6,005	7,972
2007/01-2007/12	20,769,713	14,270,920	6,498,793	16,577,207	4,192,506	7,057	9,934
2008/01-2008/09	24,451,351	16,903,809	7,547,542	17,156,739	7,294,612	5,387	9,389
Total	102,677,399	75,116,083	27,561,316	82,204,277	20,473,122	4,011	9,934
Ratio	100.00%	73.16%	26.84%	80.06%	19.94%		

Table III. Descriptive Statistics of Investors

This table reports the summary statistics of the investors in Taiwan Futures Exchange from January 2003 to September 2008. We report the number of investors that submit at least 1, 25, 50 and 75 limit orders, and the corresponding total number of orders and contracts they submit. Individual investors and institutional investors are reported separately.

Panel A: Number of Investors

Restrictions on investors	Individual	Institutional	Total	Ratio
Submitted ≧ 1 order	283,617	6,493	290,110	100.00%
≧ 25 orders	176,886	3,029	179,915	62.02%
≧ 50 orders	138,346	2,469	140,815	48.54%
≧ 75 orders	114,679	2,082	116,761	40.25%

Panel B: Number of Orders Submitted

Restrictions on investors	Individual	Institutional	Total	Ratio
Submitted ≧ 1 order	65,240,435	37,048,098	102,288,533	100.00%
≧ 25 orders	64,283,012	37,030,183	101,313,195	99.05%
≧ 50 orders	62,903,929	37,010,069	99,913,998	97.68%
≧ 75 orders	61,454,641	36,986,648	98,441,289	96.24%

Panel C: Number of Contracts Submitted

Restrictions on investors	Individual	Institutional	Total	Ratio
Submitted ≧ 1 order	140,477,436	162,140,296	302,617,732	100.00%
≧ 25orders	139,163,728	162,086,246	301,249,974	99.55%
≧ 50 orders	137,207,851	162,017,106	299,224,957	98.88%
≧ 75 orders	135,092,379	161,953,530	297,045,909	98.16%

Table IV. Limit Order Clustering at Round number prices

This table reports the parameter estimates of the following regression:

$$SR_{XX} = a_{XX} + \beta_1 D_{00} + \beta_2 D_{50} + \beta_3 D_{X0} + \beta_4 D_{00} \times D_{indv} + \beta_5 D_{50} \times D_{indv} + \beta_6 D_{X0} \times D_{indv} + \beta_7 D_{00} \times D_{MXF} + \beta_8 D_{50} \times D_{MXF} + \beta_9 D_{X0} \times D_{MXF} + \varepsilon_{XX}$$

The dependent variable is the proportion of limit orders submitted at "XX" price point. Submission ratios are calculated separately for individual and institutional investors and MXF and TXF orders each year. D_{00}, D_{50} and D_{X0} are dummy variables for price points "00", "50" and "X0" where X≠0 and 5. D_{indv}, and D_{MXF}, are indicators for orders submitted by individual investors and for Mini-Taiwan Stock Exchange Futures orders, respectively. In the last three rows we report results for the F-tests for $\beta_1 = \beta_2 = \beta_3$. *, ** and *** indicates significance level of 0.1, 0.05 and 0.01, respectively.

Independent	Parameter Estimates			
Variables	Model 1	Model 2	Model 3	Model 4
D00	0.0206***	0.0090***	0.0197***	0.0081***
	(0.000)	(0.000)	(0.000)	(0.000)
D50	0.0143***	0.0054***	0.0128***	0.0038***
	(0.000)	(0.000)	(0.000)	(0.000)
Dx0	0.0090***	0.0040***	0.0080***	0.0030***
	(0.000)	(0.000)	(0.000)	(0.000)
D00 ×Dindv		0.0231***		0.0231***
		(0.000)		(0.000)
D50 ×Dindv		0.0180***		0.0180***
		(0.000)		(0.000)
Dx0 ×Dindv		0.0101***		0.0101***
		(0.000)		(0.000)
D00 ×DMXF			0.0018	0.0018*
			(0.146)	(0.053)
D50 ×DMXF			0.0031**	0.0031***
			(0.014)	(0.001)
Dx0 ×DMXF			0.0020***	0.0020***
			(0.000)	(0.000)
Intercept	0.0089***	0.0089***	0.0089***	0.0089***
	(0.000)	(0.000)	(0.000)	(0.000)
D00-Dx0	0.0116***	0.0050***	0.0117***	0.0051***
	(0.000)	(0.000)	(0.000)	(0.000)
D50-Dx0	0.0053***	0.0014*	0.0048***	0.0008
	(0.000)	(0.053)	(0.000)	(0.334)
D00-D50	0.0063***	0.0036***	0.0069***	0.0043***
	(0.000)	(0.000)	(0.000)	(0.000)

Table V. Submission Ratio at "X0" and Investors' Descriptive Statistics

In this table we report the descriptive statistics for investors with different submission ratio at "X0". We sort investors into quintiles by the proportion of limit orders submitted at "X0", where X is an integer ranging from 1 to 9. Quintile 5 investors have higher submission ratio. Execution ratio is the proportion of limit orders executed. Time-to-execution is the interval from submission time to execution time for those executed orders. Account age is calculated as the number of days between the investor's first and last trading record. All items are first calculated for each investor and then averaged up in each quintile. Results for individual and institutional investors are reported separately. Satterthwaite p-value assumes unequal variances of investor performance in quintile 1 and 5. *, ** and *** indicates significance level of 0.1, 0.05 and 0.01, respectively.

Panel A: Individual Investors

Quintile ranks	1	2	3	4	5	Diff (5-1)	Satterthwaite p
Submission ratio at "X0"	0.108	0.206	0.294	0.404	0.606		
Number of investors	27,662	27,676	27,672	27,672	27,664		
Number of contracts submitted	60,682,264	31,398,072	18,180,326	16,025,413	10,921,776		
Number of contracts executed	29,977,838	18,063,313	10,754,632	8,590,628	5,852,703		
Execution ratio	0.602	0.635	0.622	0.601	0.562	-0.040***	0.000
Time-to-execution (s)	336.491	286.167	345.450	453.887	701.338	364.874***	0.000
Account age (day)	647.220	690.529	700.278	688.089	655.566	8.346*	0.096

Panel B: Institutional Investors

Quintile ranks	1	2	3	4	5	Diff (5-1)	Satterthwaite p
Submission ratio at "X0"	0.092	0.155	0.216	0.301	0.494		
Number of investors	493	494	495	493	494		
Number of contracts submitted	157,474,636	1,792,824	1,459,799	806,012	483,835		
Number of contracts executed	24,560,338	1,249,558	952,895	515,641	286,454		
Execution ratio	0.626	0.666	0.682	0.647	0.589	-0.037***	0.006
Time-to-execution (s)	248.643	200.905	174.532	218.072	416.825	168.182***	0.000
Trading experience (day)	415.286	492.479	516.496	453.185	403.092	-12.194	0.651

Table VI. Submission Ratio at "X0" and Hypothetical Index Return of Limit Orders

In this table we report the relationship between investors' submission ratio at "X0" and hypothetical intraday, 1-day and 5-day index returns of limit orders. We sort investors into quintiles by the proportion of limit orders submitted at "X0", where X is an integer ranging from 1 to 9. Quintile 5 investors have higher submission ratio. Hypothetical index return of limit orders is the return assuming that the initiating limit orders are covered at the closing price of a trading day. All items are first calculated for each investor and then averaged up in each quintile. Results for individual and institutional investors are reported separately. Satterthwaite p-value assumes unequal variances of investor performance in quintile 1 and 5. *, ** and *** indicates significance level of 0.1, 0.05 and 0.01, respectively.

Panel A: Individual Investors

Quintile ranks	1	2	3	4	5	Diff (5-1)	Satterthwaite p
Intraday return (%)	-0.052	-0.061	-0.072	-0.087	-0.107	-0.055***	0.000
1-day return (%)	-0.068	-0.089	-0.108	-0.130	-0.157	-0.089***	0.000
5-day return (%)	-0.109	-0.142	-0.174	-0.211	-0.237	-0.126***	0.000

Panel B: Institutional Investors

Quintile ranks	1	2	3	4	5	Diff (5-1)	Satterthwaite p
Intraday return (%)	0.005	0.007	0.018	0.003	-0.041	-0.045***	0.004
1-day return (%)	-0.034	-0.008	-0.054	-0.052	-0.053	-0.019	0.661
5-day return (%)	-0.108	0.010	-0.094	-0.233	-0.107	0.001	0.995

Table VII. Number of "XX"s Where Top-Quintile Investors Underperform

In this table, we report the number of "XX"s where top-quintile investors (significantly) underperform those in the bottom quintile. The underperformance is determined by looking at the hypothetical index return of limit orders. Investors are sorted into quintiles according to the submission ratio at "X0", where X is an integer ranging from 1 to 9. The intraday index return for limit orders is defined as the difference between execution price and the same day's closing price divided by the execution price. 1-day and 5-day index returns are defined similarly. The significance level is indicated by Satterthwaite p-value, which assumes unequal variances of investor performance in quintile 1 and 5.

Panel A: Individual Investors

Significance	Hypothetical index return of limit orders		
Level	Intraday return	1-day return	5-day return
$p \leq 1$	98	99	98
$p<0.1$	97	96	89
$p<0.05$	97	95	88
$p<0.01$	95	92	77

Panel B: Institutional Investors

Significance	Hypothetical index return of limit orders		
Level	Intraday return	1-day return	5-day return
$p \leq 1$	75	57	60
$p<0.1$	47	27	22
$p<0.05$	40	21	18
$p<0.01$	30	15	10

Table VIII. Submission Ratio at "X0" and Hypothetical Index Return of Market Orders

In this table we report the relationship between investors' submission ratio at "X0" and hypothetical intraday, 1-day and 5-day index returns of market orders. We sort investors into quintiles by the proportion of limit orders submitted at "X0", where X is an integer ranging from 1 to 9. Quintile 5 investors have higher submission ratio. Hypothetical index return of market orders is the return assuming that the initiating market orders are covered at the closing price of a trading day. All items are first calculated for each investor and then averaged up in each quintile. Results for individual and institutional investors are reported separately. Satterthwaite p-value assumes unequal variances of investor performance in quintile 1 and 5. *, ** and *** indicates significance level of 0.1, 0.05 and 0.01, respectively.

Panel A: Individual Investors

Quintile ranks	1	2	3	4	5	Diff (5-1)	Satterthwaite p
Intraday return (%)	-0.019	-0.040	-0.047	-0.057	-0.073	-0.054***	0.000
1-day return (%)	-0.057	-0.087	-0.095	-0.118	-0.137	-0.080***	0.000
5-day return (%)	-0.131	-0.165	-0.168	-0.200	-0.221	-0.090***	0.000

Panel B: Institutional Investors

Quintile ranks	1	2	3	4	5	Diff (5-1)	Satterthwaite p
Intraday return (%)	-0.042	0.034	-0.041	-0.061	0.030	0.072	0.114
1-day return (%)	-0.037	-0.072	-0.219	-0.067	0.122	0.159	0.089
5-day return (%)	0.041	-0.262	-0.227	-0.130	-0.066	-0.107	0.564

Table IX. Submission Ratio at "X0" and Investor Performance of Round-trip Trades

In this table we report the relationship between investors' submission ratio at "X0" and investor performance of round-trip trades. We sort investors into quintiles by the proportion of limit orders submitted at "X0", where X is an integer ranging from 1 to 9. Quintile 5 investors have higher submission ratio. Round-trip duration is the number of trading days between the initiating and closing position of a round-trip. For each investor, we calculate the round-trip daily profit and daily index return are calculated as the average round-trip profit or index return divided by the average round-trip duration. All items are first calculated for each investor and then averaged up in each quintile. Results for individual and institutional investors are reported separately. Satterthwaite p-value assumes unequal variances of investor performance in quintile 1 and 5. *, ** and *** indicates significance level of 0.1, 0.05 and 0.01, respectively.

Panel A: Individual Investors

Quintile ranks	1	2	3	4	5	Diff (5-1)	Satterthwaite p
Number of round-trips	166.695	129.963	103.851	90.574	75.726	-90.968***	0.000
Round-trip duration (day)	1.562	1.644	1.759	1.941	2.440	0.877***	0.000
Daily profit (TWD)	-75.841	-1642.255	-2067.727	-2672.346	-2544.507	-2468.666***	0.000
Daily index return (%)	0.060	-0.145	-0.178	-0.236	-0.242	-0.302***	0.000

Panel B: Institutional Investors

Quintile ranks	1	2	3	4	5	Diff (5-1)	Satterthwaite p
Number of round-trips	145.640	124.016	68.986	58.305	54.796	-90.844***	0.003
Round-trip duration (day)	4.150	4.799	4.494	3.643	3.346	-0.804**	0.013
Daily profit (TWD)	2165.574	3363.657	-227164.127	17370.177	11781.199	9615.625	0.678
Daily index return (%)	0.776	0.626	-12.187	1.714	1.417	0.641	0.677

Table X. Multivariate Regression Analysis for Submission Ratio at "X0" and Investor Performance

In this table we report the parameter estimates for the following regression: $Return_i = a_i + \beta_1 SR_{X0,i} + \beta_2 Ln(N_i) + \beta_3 Disposition_i + \varepsilon_i$, where $Return_i$ is the average hypothetical index return or round-trip performance for investor i. $SR_{X0,i}$ is investor i's submission ratio at "X0" price points. $Ln(N_i)$ is the log of number of limit orders submitted. $Disposition_i$ is the difference between the duration of losing and winning round-trips, divided by the average of the two. Hypothetical index return of limit (market) orders is the return assuming that the initiating limit (market) orders are covered at the closing price of a trading day. The round-trip daily profit and daily index return are calculated as the average round-trip profit or index return divided by the average round-trip duration for each investor. *, ** and *** indicates significance level of 0.1, 0.05 and 0.01, respectively. Standard errors are adjusted for heteroskedasticity.

Panel A: Individual Investors

	Hypothetical index return of limit orders (%)			Hypothetical index return of market orders (%)			Performance of round-trip trades	
Independent variables	Intraday return	1-day return	5-day return	Intraday return	1-day return	5-day return	Daily profit (TWD)	Daily index return (%)
$SR_{X0,i}$	-0.093***	-0.140***	-0.193***	-0.084***	-0.124***	-0.119***	-2,275.164***	-0.275***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)
$Ln(N_i)$	0.015***	0.031***	0.058***	0.014***	0.027***	0.043***	1,978.080***	0.216***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$Disposition_i$	-0.036***	-0.067***	-0.155***	-0.029***	-0.058***	-0.136***	-4,728.421***	-0.441***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Intercept	-0.113***	-0.205***	-0.358***	-0.086***	-0.184***	-0.322***	-9,808.519***	-1.043***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Number of obs.	137,644	137,644	137,598	99,532	99,382	97,573	137,709	137,709
Adjusted R^2	0.034	0.026	0.018	0.004	0.003	0.003	0.006	0.007

Panel B: Institutional Investors

	Hypothetical index return of limit orders (%)			Hypothetical index return of market orders (%)			Performance of round-trip trades	
Independent variables	Intraday return	1-day return	5-day return	Intraday return	1-day return	5-day return	Daily profit (TWD)	Daily index return (%)
$SR_{X0,i}$	-0.138***	-0.170**	-0.468***	0.073	0.330	-0.026	19,571.419	2.186
	(0.000)	(0.011)	(0.005)	(0.454)	(0.108)	(0.948)	(0.344)	(0.176)
$Ln(N_i)$	0.010***	0.022***	0.011	0.009	0.027	0.078*	7,672.500	0.937**
	(0.001)	(0.000)	(0.419)	(0.315)	(0.169)	(0.093)	(0.204)	(0.015)
$Disposition_i$	-0.041***	-0.088***	-0.178***	-0.075***	0.015	-0.043	-31,420.831***	-2.463***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.745)	(0.663)	(0.000)	(0.000)
Intercept	-0.014	-0.095**	-0.004	-0.071	-0.305**	-0.562*	-36,786.654	-4.708**
	(0.502)	(0.042)	(0.973)	(0.268)	(0.030)	(0.079)	(0.281)	(0.029)
Number of obs.	2,325	2,325	2,323	1,449	1,447	1,412	2,328	2,328
Adjusted R^2	0.037	0.028	0.020	0.009	0.000	0.001	0.015	0.019

Table XI. Trading Experience and Submission Ratio at "X0"

In this table we report the parameter estimates for the following regression: $SR_{X0,later,i} = a_i + \beta_1 Ln(N_{former,i}) + \beta_2\ SR_{X0,former,i} + \beta_3\ Disposition_{former,i} + \beta_4\ Return_{former,i} + \beta_5\ Return_{X0,former,i} + \varepsilon_i$ where $SR_{X0,later,i}$ and $SR_{X0,former,i}$ are investor *i*'s submission ratio at "X0" price point in the later and former period of the trading history. $Ln(N_{former,i})$ is natural log of the number of limit orders submitted in the former period. $Disposition_{former,i}$ is the difference between duration of losing and winning round-trips, divided by the average of the two. $Return_{former,i}$ is the round-trip daily index return, calculated as the average round-trip index return divided by the average round-trip duration for each investor. $Return_{X0,former,i}$ is the daily index return for round-trips that are initiated by limit orders submitted at "X0" price point. *, ** and *** indicates significance level of 0.1, 0.05 and 0.01, respectively. Standard errors are adjusted for heteroskedasticity.

Panel A: Individual Investors

Independent variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
$Ln(N_{former,i})$	-0.039***		-0.009***	-0.009***	-0.009***	-0.009***
	(0.000)		(0.000)	(0.000)	(0.000)	(0.000)
$SR_{X0,former,i}$		0.764***	0.753***	0.753***	0.753***	0.751***
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$Disposition_{former,i}$				0.001	0.001	0.001
				(0.530)	(0.510)	(0.679)
$Return_{former,i}$					0.000	
					(0.674)	
$Return_{X0,former,i}$						-0.000
						(0.840)
Intercept	0.525***	0.077***	0.128***	0.127***	0.127***	0.129***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Number of obs.	28,137	28,137	28,137	28,012	28,012	27,559
Adjusted R^2	0.040	0.488	0.490	0.487	0.487	0.484

Panel B: Institutional Investors

Independent variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
$Ln(N_{former,i})$	-0.017***		-0.000	-0.001	-0.001	-0.002
	(0.000)		(0.920)	(0.799)	(0.805)	(0.698)
$SR_{X0,former,i}$		0.627***	0.625***	0.598***	0.599***	0.587***
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$Disposition_{former,i}$				0.009	0.008	0.009
				(0.281)	(0.309)	(0.275)
$Return_{former,i}$					-0.000	
					(0.748)	
$Return_{X0,former,i}$						0.000
						(1.000)
Intercept	0.335***	0.090***	0.093***	0.100***	0.100***	0.106***
	(0.000)	(0.000)	(0.004)	(0.002)	(0.002)	(0.002)
Number of obs.	351	351	351	326	326	309
Adjusted R^2	0.028	0.383	0.381	0.338	0.336	0.325

Table XII. Robustness Check for Difference in Performance of Top- and Bottom-quintile Individual Investors

In this table we report the difference in performance of individual investors in the top and bottom quintile. Quintile 5 investors have higher submission ratio at round number prices. Diff (5-1) is reported separately for the occasions when we sort investors according to the submission ratio at "00" only, "00" and "50", as well as all "X0" price points, where X is an integer ranging from 1 to 9. The first three columns show the Diff (5-1) for investors who submit more than 25 limit orders, while the last three columns present the result for investors with more than 75 limit orders from January 2003 to September 2008. For each investor, we calculate the execution ratio as the proportion of limit orders executed. Time-to-execution is the interval from submission time to execution time for those executed orders. Hypothetical index return of limit (market) orders is the return assuming that the initiating limit (market) orders are covered at the closing price of a trading day. The round-trip daily profit and daily index return are calculated as the average round-trip profit or index return divided by the average round-trip duration for each investor. All items are first calculated for each investor and then averaged up in each quintile. *, ** and *** indicates significance level of 0.1, 0.05 and 0.01, respectively, according to Satterthwaite p-value which assumes unequal variances of investor performance in quintile 1 and 5.

Investment performance	Diff (5-1)					
	For investors submit more than 25 limit orders			For investors submit more than 75 limit orders		
	"00"	"00" and "50"	"X0"	"00"	"00" and "50"	"X0"
Execution ratio	-0.054***	-0.075***	-0.071***	-0.058***	-0.077***	-0.072***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Time-to-execution (s)	278.712***	366.176***	422.777***	284.247***	363.130***	409.627***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Hypothetical index return of limit orders						
Intraday return (%)	-0.043***	-0.048***	-0.050***	-0.034***	-0.041***	-0.044***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
1-day return (%)	-0.079***	-0.083***	-0.082***	-0.055***	-0.060***	-0.061***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
5-day return (%)	-0.101***	-0.112***	-0.122***	-0.071***	-0.077***	-0.086***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Hypothetical index return of market orders						
Intraday return (%)	-0.036***	-0.033***	-0.032***	-0.036***	-0.033***	-0.032***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
1-day return (%)	-0.066***	-0.055***	-0.062***	-0.053***	-0.032***	-0.042***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
5-day return (%)	-0.092***	-0.078***	-0.083***	-0.065**	-0.034***	-0.052***
	(0.001)	(0.000)	(0.000)	(0.032)	(0.006)	(0.000)
Performance of round-trip trades						
Daily profit (TWD)	-1361.9**	-1247.1***	-822.07***	-1574.1**	-1498.4***	-936.62***
	(0.011)	(0.000)	(0.000)	(0.011)	(0.000)	(0.000)
Daily index return (%)	-0.158***	-0.147***	-0.088***	-0.175***	-0.167***	-0.097***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Figure 1. Limit Order Clustering at Round Number Prices

In this figure, we report the submission ratio against the last two digits of the order price. The submission ratio at "XX" is defined as the number of orders submitted at "XX" divided by total number of orders submitted at all different "XX"s. We report the submission ratio for all orders in this figure.

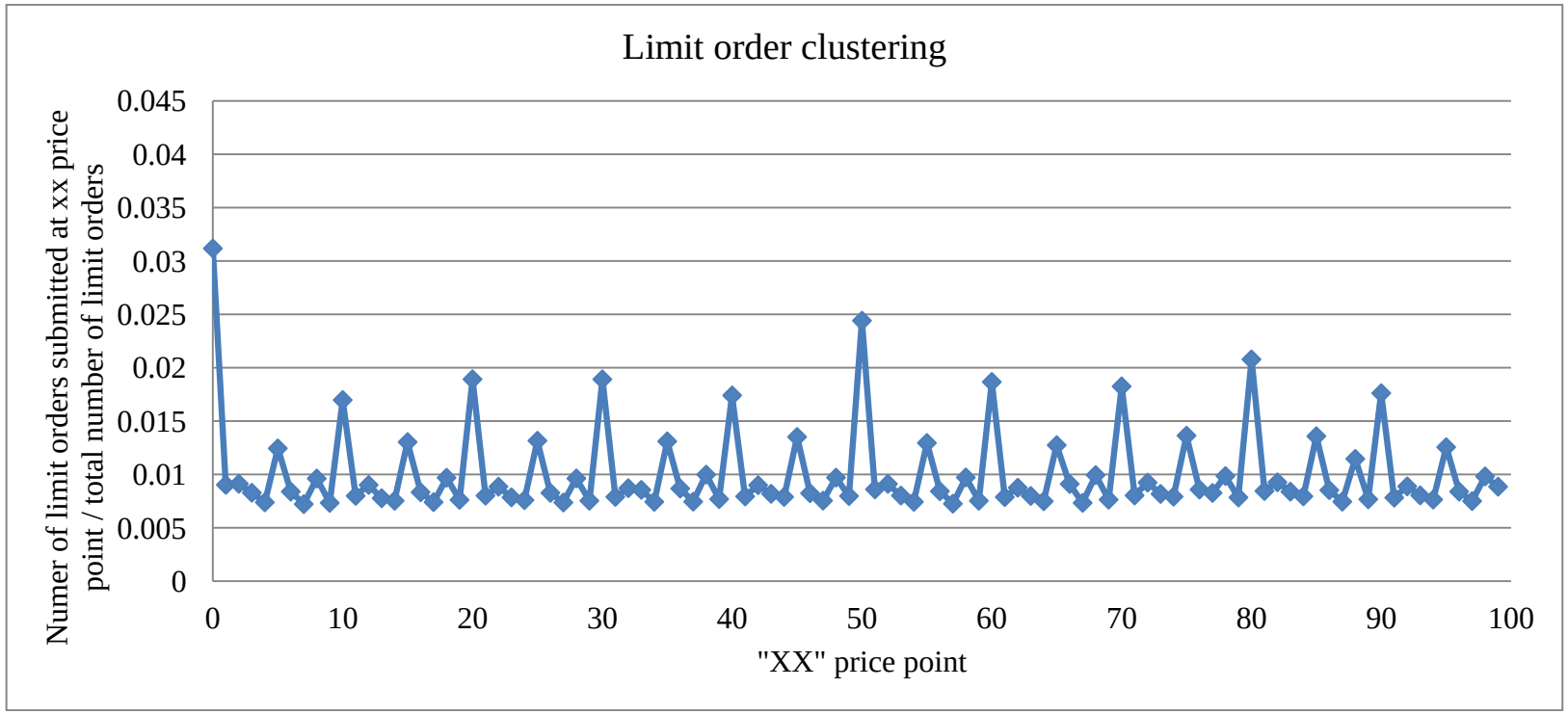
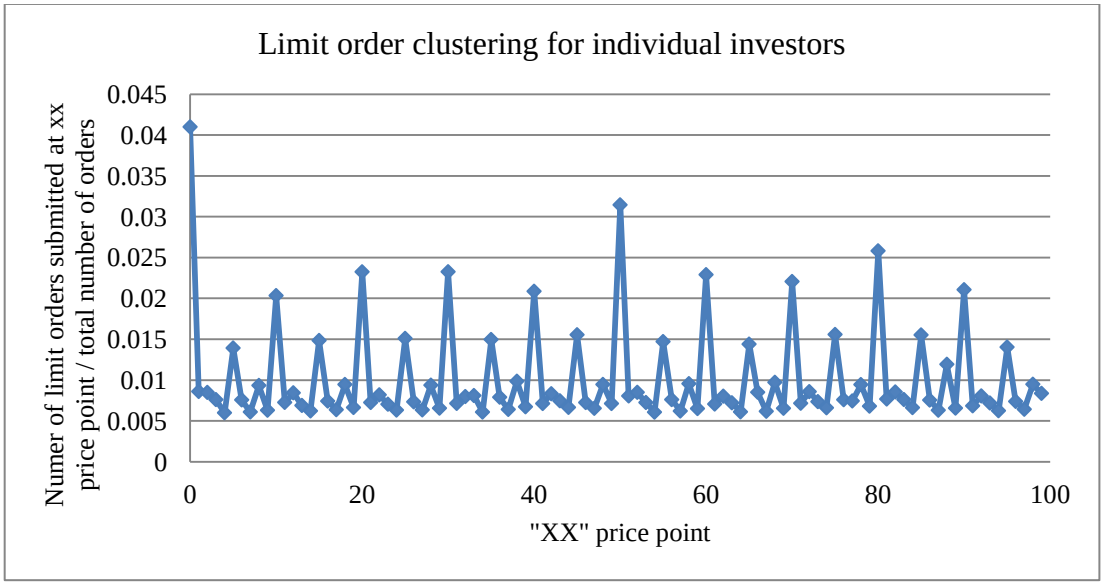


Figure 2. Limit Order Clustering for Different Investor Types

In this figure, we report the submission ratio against the last two digits of the order price separately for individual investors and institutional investors. Submission ratio at "XX" is defined as the number of orders submitted at "XX" divided by total number of orders submitted at all different "XX"s.



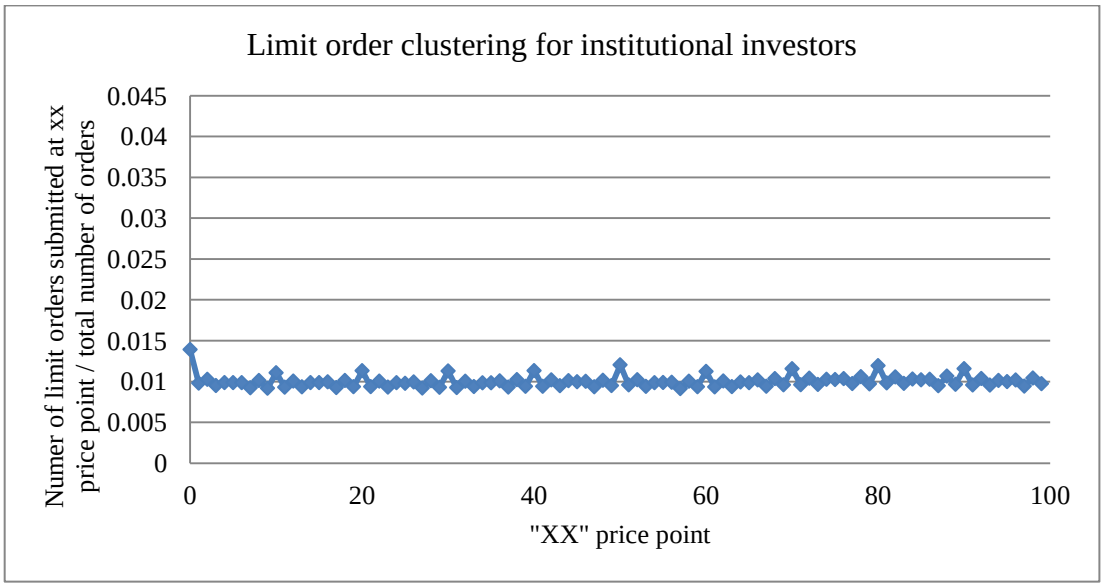
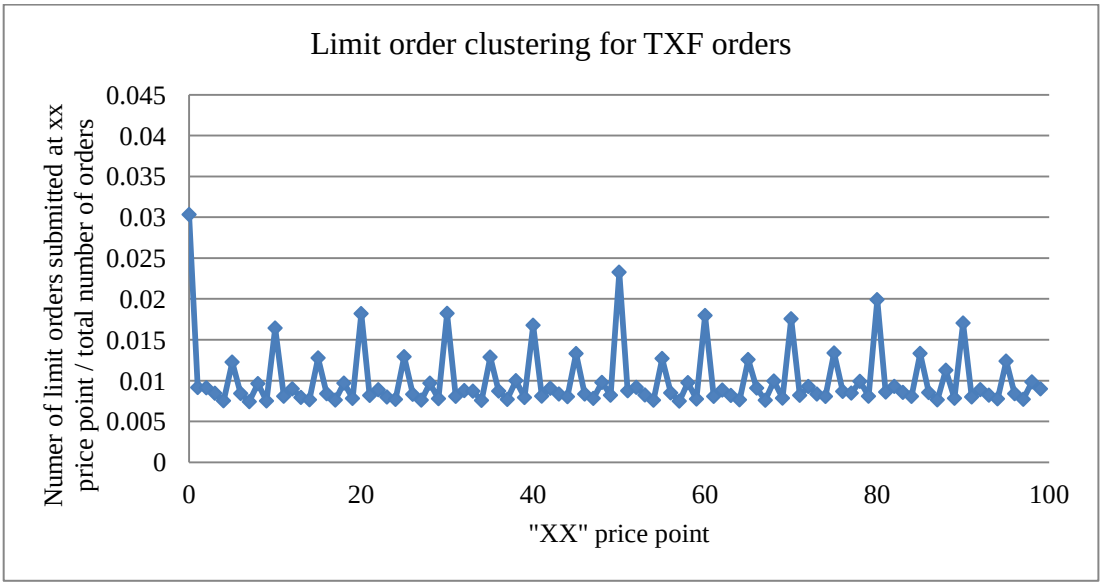


Figure 3. Limit Order Clustering for Different Products

In this figure, we plot the submission ratio against the last two digits of the order price separately for Taiwan Stock Exchange Futures (TXF) and Mini-Taiwan Stock Exchange Futures orders (MXF). Submission ratio at "XX" price point for TXF (MXF) orders is defined as the number of orders submitted at "XX" divided by total number of TXF (MXF) orders submitted at all different "XX"s.



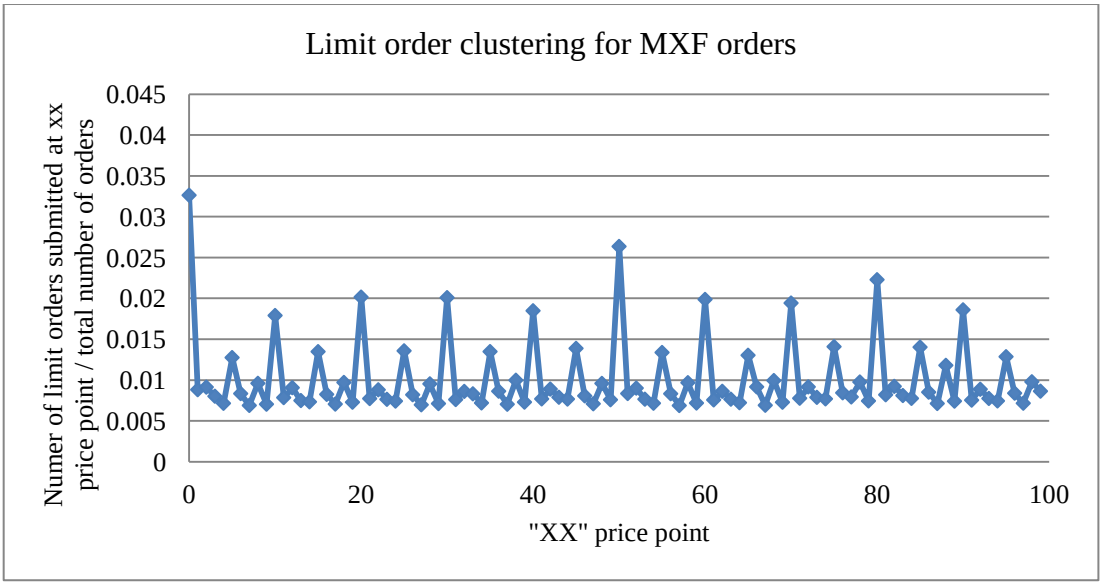
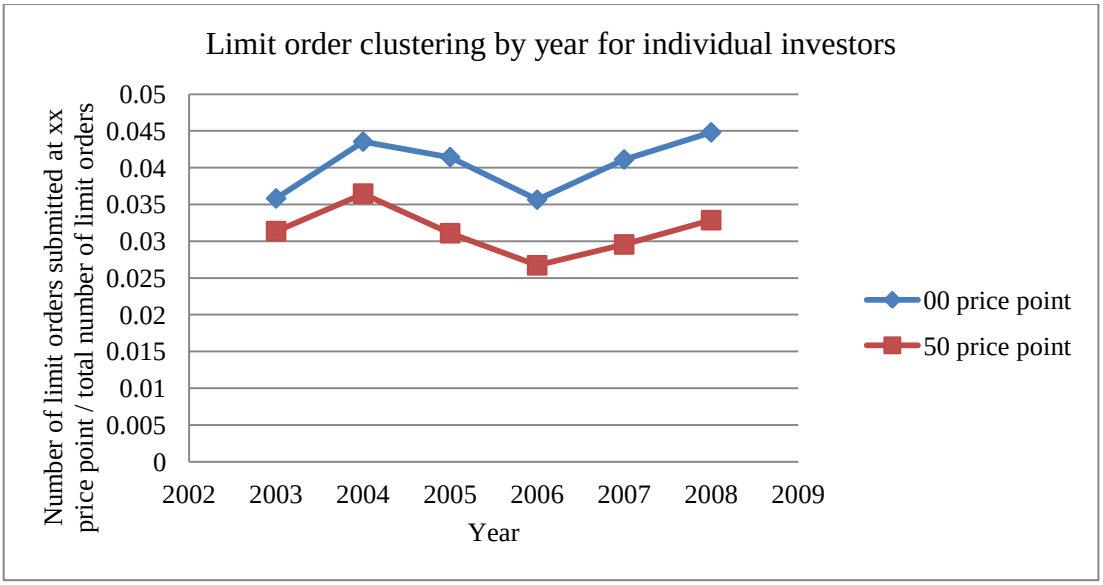


Figure 4. Limit Order Clustering over Time

In this figure we plot the ratio of orders submitted at "00" and "50", respectively, from 2003 to 2008. In 2008, we have access to data from January to September only. The submission ratios are calculated for individual investors and institutional investors separately.



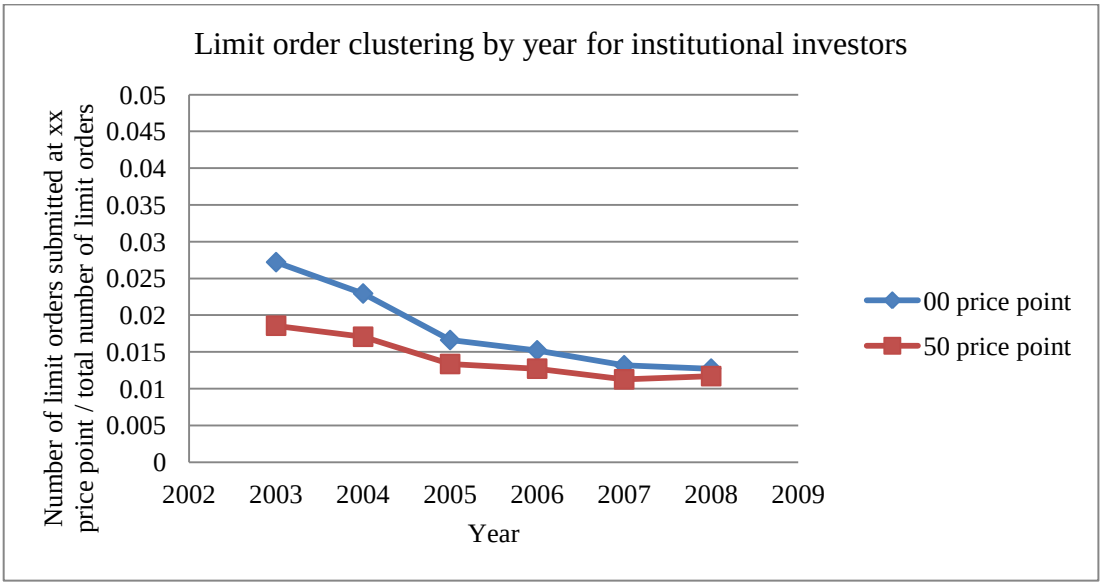
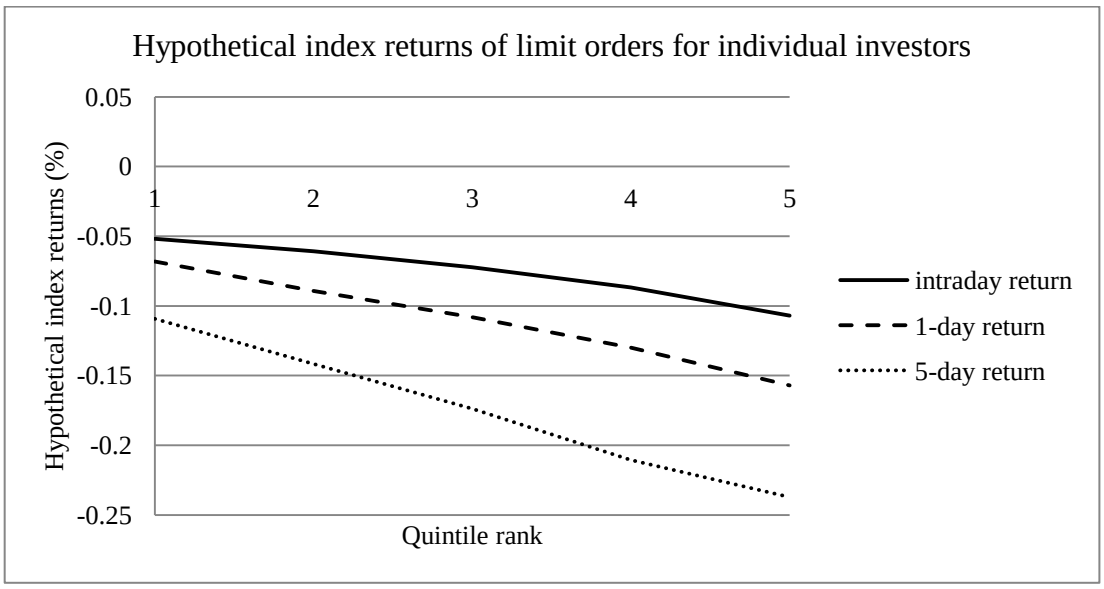


Figure 5. Submission Ratio at "X0" and Hypothetical Index Return

In this figure we plot the hypothetical index return for initiating limit orders against the quintile ranks of the investors. We sort individual investors into quintiles by the proportion of limit orders submitted at "X0", where X is an integer ranging from 1 to 9. Quintile 5 investors have higher submission ratio. The hypothetical intraday index return is defined as the difference between execution price and the same day's closing price divided by the execution price. 1-day and 5-day index returns are defined similarly. The hypothetical returns are calculated for individual investors and institutional investors separately.



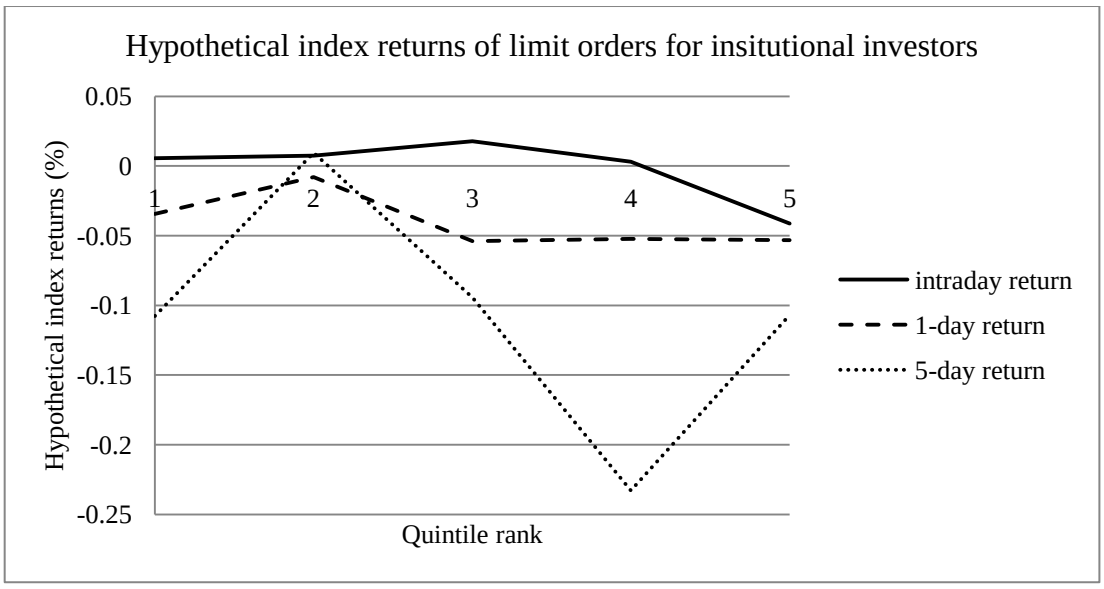
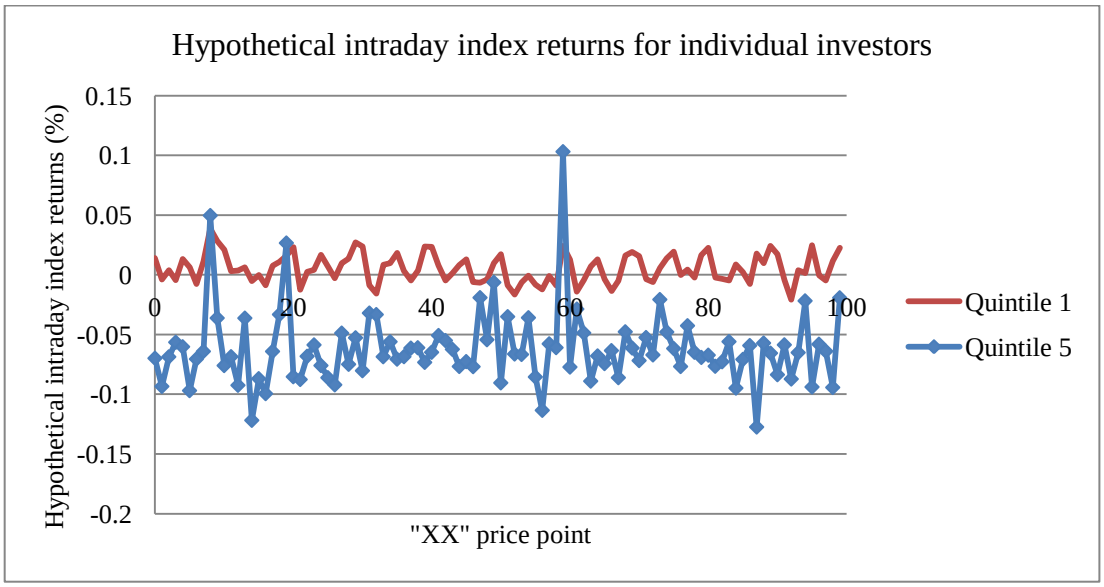
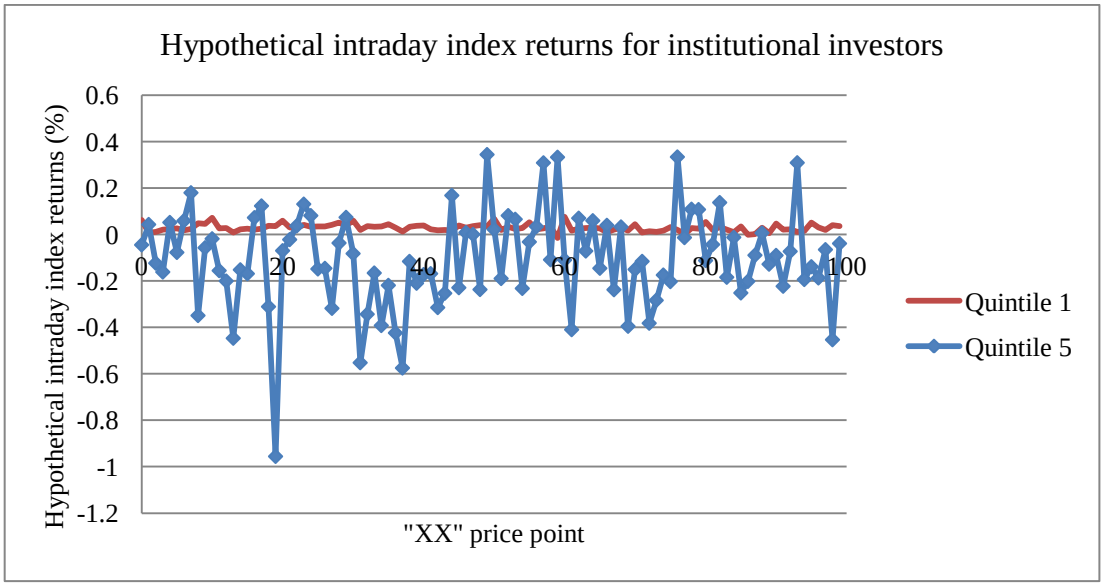
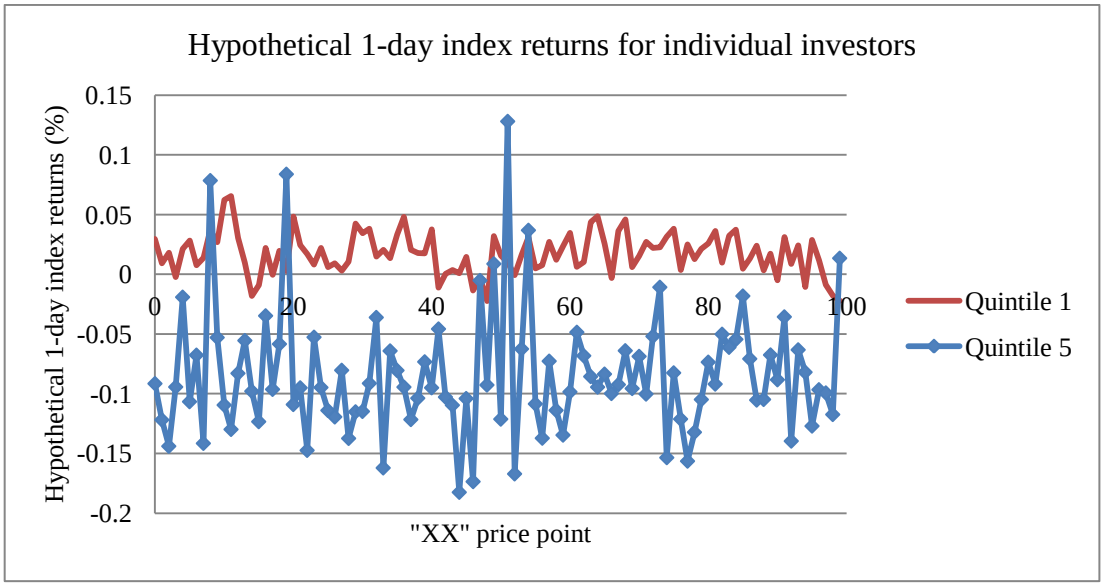


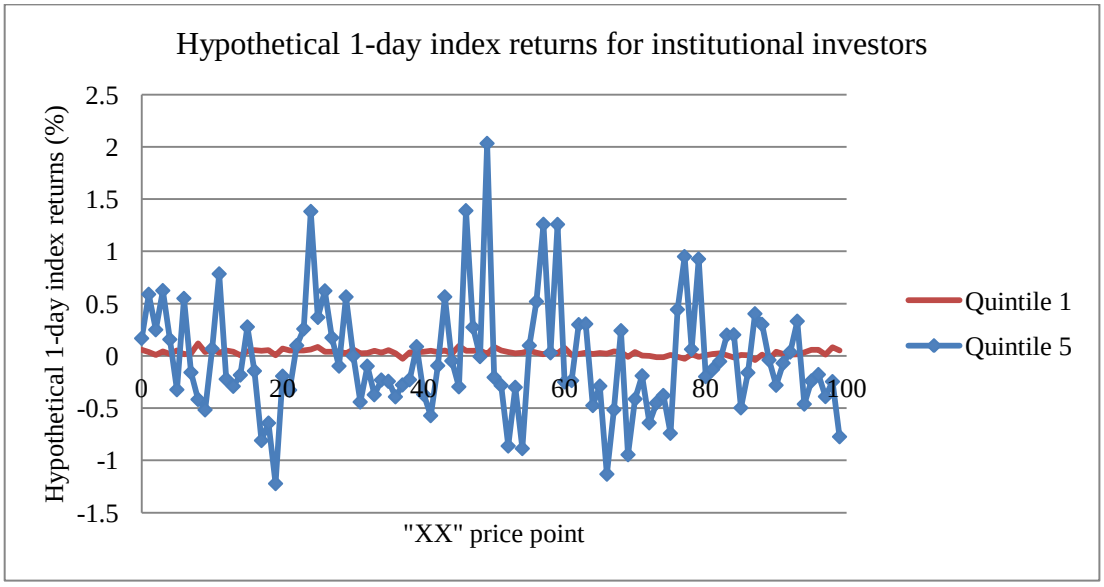
Figure 6. Submission Ratio at "X0" and Hypothetical Index Return of Limit Orders submitted at "XX"

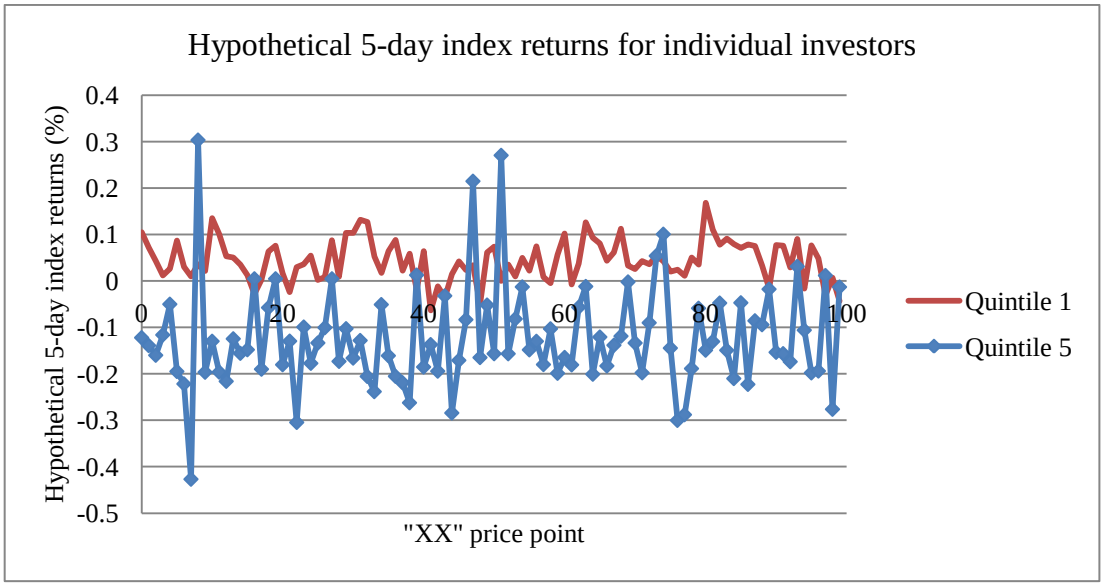
In this figure we plot the hypothetical index return for initiating limit orders against the last two digits of the order price. Investors are sorted into quintiles according to the proportion of limit orders submitted at "X0" price points. Quintile 5 investors have higher submission ratio. The hypothetical intraday index return is defined as the difference between execution price and the same day's closing price divided by the execution price. 1-day and 5-day index returns are defined similarly. Hypothetical index returns for individual investors and institutional investors are reported separately.






Hypothetical 1-day index returns for individual investors
Hypothetical 1-day index returns (%)
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
0
20
40
60
80
100
"XX" price point
Quintile 1
Quintile 5


Hypothetical 1-day index returns for institutional investors
Hypothetical 1-day index returns (%)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
0
20
40
60
80
100
"XX" price point
Quintile 1
Quintile 5


Hypothetical 5-day index returns for individual investors
Hypothetical 5-day index returns (%)
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
20
40
60
80
100
"XX" price point
Quintile 1
Quintile 5

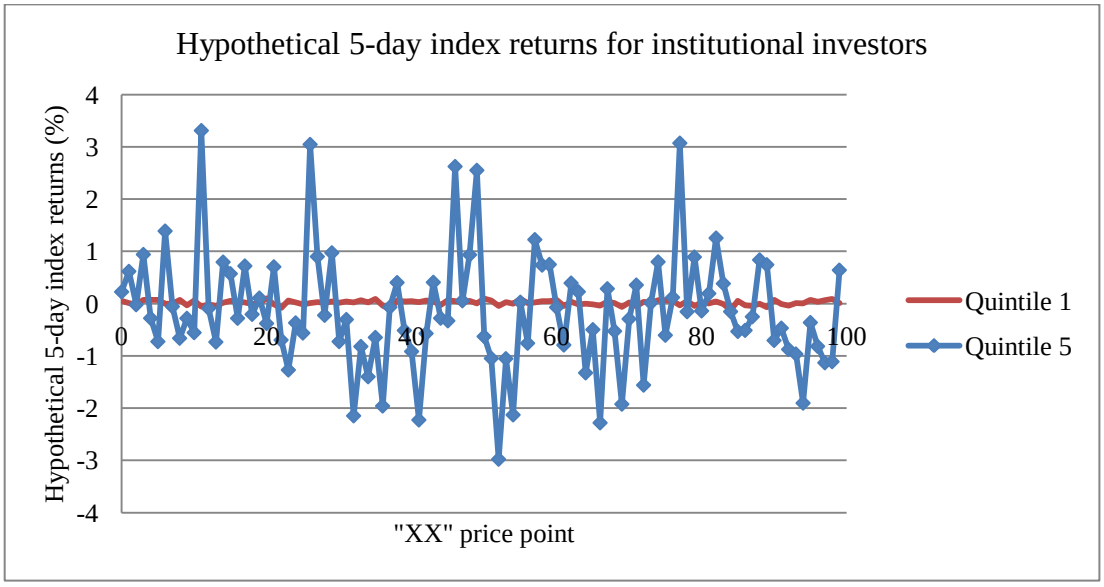

Hypothetical 5-day index returns for institutional investors
Hypothetical 5-day index returns (%)
4
3
2
1
0
-1
-2
-3
-4
0
20
40
60
80
100
"XX" price point
Quintile 1
Quintile 5

Figure 7. Submission Ratio at "00" ("00" and "50") and Hypothetical Index Return of Limit Orders

In this figure we plot the hypothetical index returns of limit orders against the quintile ranks of individual investors. In figure 11.A we sort individual investors into quintiles by the proportion of limit orders submitted at "00" only, while in figure 11.B we sort by the proportion of limit orders submitted at "00" and "50". For each individual investor, we calculate the hypothetical intraday index return as the difference between execution price and the same day's closing price divided by the execution price. 1-day and 5-day index returns are defined similarly.

Figure 11.A Rank by Submission Ratio at "00"

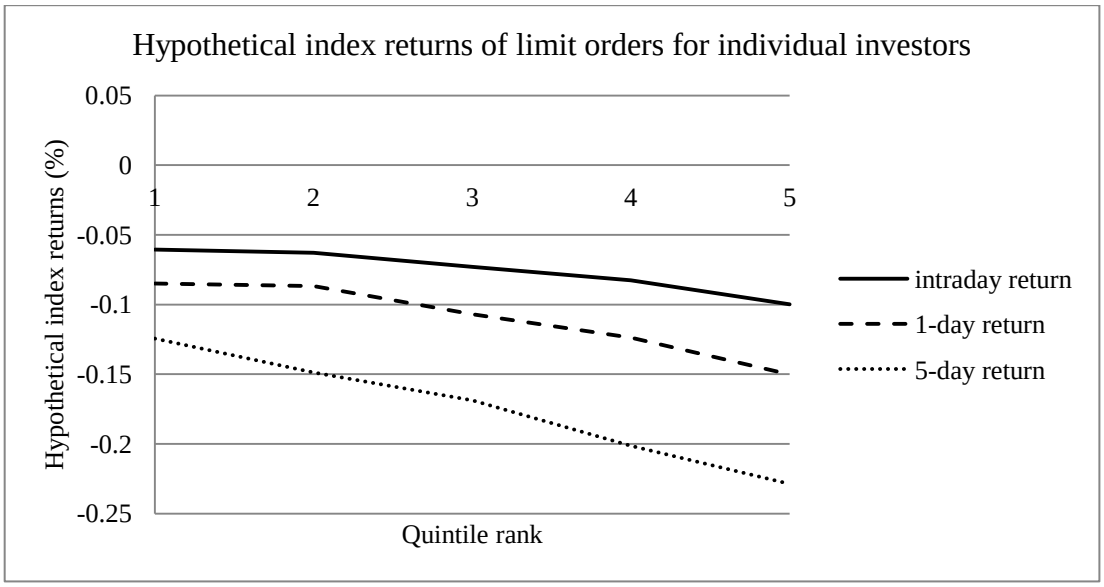


Figure 11.B Rank by Submission Ratio at "00" and "50"