Title	Cognitive Limitation and Investment Performance: Evidence from Limit Order Clustering
Author(s)	Kuo, WY; Lin, TC; ZHAO, J
Citation	Review of Financial Studies, 2015, v. 28 n. 3, p. 838-875
Issued Date	2015
URL	http://hdl.handle.net/10722/199292
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Cognitive Limitation and Investment Performance: Evidence from Limit Order Clustering

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Abstract

We hypothesize that cognitive limitation may be manifested in a disproportionately large volume of limit orders submitted at round-number prices if investors use these numbers as cognitive shortcuts. Using detailed limit order data in the Taiwan Futures Exchange, we find that investors with lower cognitive abilities, defined as higher limit order submission ratios at round numbers, suffer greater losses in their round-numbered and non-round-numbered limit orders, market orders, and round-trip trades. The positive correlation between cognitive ability and investment performance is monotonic and robust across futures and options markets. In addition, past trading experience helps to mitigate the cognitive limitation.

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

JEL Classifications: G02, G15

The suggestions and advice of David Hirshleifer (the editor) and the two anonymous referees are gratefully acknowledged. We thank Gurdip Bakshi, Sreedhar Bharath, Utpal Bhattacharya, Dion Bongaerts, Darwin Choi, Zhi Da, Joost Driessen, Yael Hochberg, Craig W. Holden, Paul Hsu, Jennifer Huang, Zoran Ivkovich, Danling Jiang, Yu-Jane Liu, Mark Seasholes, Johan Sulaeman, Mandy Tham, Chishen Wei, and seminar participants at the University of Hong Kong, Interdisciplinary Workshop in Behavioral and Decision Science, Guanghua School of Management Peking University, European Finance and Management Associations meetings (2012), Asian Finance Association meetings (2012), China International Conference of Finance (2012), and World Finance and Banking Symposium (2012) for helpful comments. Wei-Yu Kuo would like to express his gratitude to the National Science Council of Taiwan for its financial support (project numbers NSC 101-2918-I-004-004). Tse-Chun Lin gratefully acknowledges the research support from the Faculty of Business and Economics and the University of Hong Kong and the Research Grants Council of the Hong Kong SAR government. Any remaining errors are ours.

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Abstract

We hypothesize that cognitive limitation may be manifested in a disproportionately large volume of limit orders submitted at round-number prices if investors use these numbers as cognitive shortcuts. Using detailed limit order data in the Taiwan Futures Exchange, we find that investors with lower cognitive abilities, defined as higher limit order submission ratios at round numbers, suffer greater losses in their round-numbered and non-round-numbered limit orders, market orders, and round-trip trades. The positive correlation between cognitive ability and investment performance is monotonic and robust across futures and options markets. In addition, past trading experience helps to mitigate the cognitive limitation.

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

1. Introduction

Although economic theories usually assume the full rationality of the agents, economists have long recognized that individuals' decision making is limited by their cognitive abilities (Simon, 1955). One type of cognitive limitation discussed by Lacetera, Pope, and Sydnor (2012) is that customers in the used car market tend to adopt round numbers as cognitive shortcuts to save energy spent on extensive algorithmic processing when making purchase decisions. If investors carry the same heuristics over to financial decisions, their cognitive limitation can be manifested in their limit order submission behavior. A disproportionately large volume of limit orders submitted at round numbers by an investor may be indicative of a low level of cognitive ability, and vice versa.

We first investigate the existence of cognitive limitation in investors' order submission behavior. Our data are from the Taiwan Futures Exchange (TAIFEX) and consist of detailed information about orders and transactions. Based on this data, we are able to examine whether the limit orders submitted by investors tend to cluster at round-number prices, and whether this limit order clustering phenomenon is particularly pronounced for individual investors. If investors are not cognitively constrained and hence do not have to rely on round-number heuristics, then their limit orders will be submitted at any given index point, resulting in uniformly distributed limit order prices in the last one or two digits. However, if investors rely on round numbers as heuristic shortcuts, they will submit more limit orders at round-number prices. For example, the proportion of limit orders submitted at multiples of 100 (the last two digits of the index prices are "00") will be larger than 1%.

Next, we explore whether investors with lower cognitive abilities, defined by higher limit order submission ratios at round-number prices, exhibit inferior investment performance. Intuitively, cognitively constrained investors might have poor investment performance either because they have low capability to access and interpret information or because their investment decisions are more likely to be affected by behavioral biases associated with the

cognitive limitation.[1] Because the overrepresentation of round-numbered limit orders largely stems from the ease of the cognitive accessibility of those numbers, a higher submission ratio at round numbers indicates a lower degree of cognitive ability at the investor level. Accordingly, we argue that the submission ratio at round-number prices is negatively associated with investment performance.

Last, we examine how "learning-by-trading" affects investors' tendencies to submit limit orders at round-number prices. The investor learning literature is still debating whether trading experience helps investors to make better investment decision. On the one hand, investors could learn from past trading experience and make better subsequent investment decisions (e.g., Feng and Seasholes, 2005). On the other hand, investors could also learn in a naive and reinforcement way such that they invest less effectively in the future (e.g., Chiang, Hirshleifer, Qian, and Sherman, 2011). In our context, we test how the round-numbered limit order submission behavior is influenced by investors' past trading frequency and the past returns of round-numbered limit orders to shed light on the debate.

Using over 100 million limit orders 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 100 (the last two digits of the limit order prices are "00") is 3.1% during our sample period. The limit order clustering at multiples of 100 is the strongest, followed by those at multiples of 50 and 10. Furthermore, limit order clustering is more pronounced for individual investors who submit 4.1% of their limit orders at "00." Institutional investors also exhibit round-number heuristics, but in a much smaller magnitude (1.6% of their limit orders are submitted at "00"). The results also show that limit order clustering is prevalent among various product types. Moreover, the limit order clustering is persistent across years for individual investors.

In addition, we document a large cross-sectional heterogeneity in the submission ratio at

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

round-number prices. After sorting investors into five groups based on the proportion of orders submitted at round numbers, we find that the top-quintile individual investors submit over 62.5% 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 9.2% at "X0."

This limit order clustering phenomenon cannot be explained by the existing hypotheses on price clustering, which involve market makers or dealers specifying the prices in quote-driven markets. For example, Harris (1991) argues that price clustering reduces the cost of negotiating between traders and dealers (negotiation hypothesis). Christie and Schultz (1994) argue that the price clustering at NASDAQ may be attributed to dealers' implicitly collusion for maintaining wide spreads (collusion hypothesis). Neither can the limit order clustering be driven by investors' need to hedge their index options positions through index futures contracts for the following two reasons. First, we find similar results using a subsample of investors with no index options trading. Second, the option strike prices are only set in multiples of 100 while the documented limit order clustering pattern is also prevalent at other round numbers.

Next, we use the submission ratio at multiples of 10 as an indicator of the level of cognitive limitation to test whether the ratio is related to investment performance.[2] We find that individual investors with higher submission ratios at "X0" in the previous year have significantly lower intraday, 1-day, and 5-day mark-to-market index returns of their limit orders in the current year. After sorting investors into five groups based on the proportion of orders submitted at round numbers, we find a negative correlation between round-numbered limit order submission ratio and investment performance in a monotonic fashion. The individuals with lower cognitive abilities (the top-quintile proportion of orders submitted at round numbers) underperform the investors with higher cognitive abilities (the

[2] We do not use the submission ratio at multiples of 100 because this ratio cannot fully reflect the round-number heuristics of investors who trade less actively. It is possible that less active investors submit limit orders at prices other than multiples of 100 simply because the current market price does not happen to be around those levels. However, the results are qualitatively the same if the submission ratio at multiples of 100 is used as the indicator for the level of cognitive limitation.

bottom-quintile proportion of orders submitted at round numbers) by 3.9 basis points within a trading day. This underperformance is also significant for institutional investors.

For the multivariate analyses, we regress the intraday, 1-day, or 5-day mark-to-market returns for each investor in the current year on the submission ratio at round-number prices in the previous year and several control variables, such as the logged number of limit orders submitted in the previous year and a proxy for the disposition effect. Furthermore, we use the block bootstrapping at the annual level to estimate the empirical p-values for the estimated coefficients of the submission ratios to address the concern that each investor might not represent an independent observation within a sample year. The results remain that the investment performance is positively associated with the cognitive abilities of individual investors.

One alternative explanation that might be consistent with the documented negative relation between the limit order submission ratio at round numbers and the investment performance is that investors rationally pay for the cognitive convenience. Intuitively, if investors pay for the cognitive energy they save by using round numbers as heuristic shortcuts, they are intentionally sacrificing a certain proportion of their profits for the limit orders submitted at round-number prices. This “pay-for-cognitive-shortcut” hypothesis implies that the inferior performance for top-quintile investors should only appear in the limit orders with round-number prices. However, if the submission ratio at round numbers reveals an investor’s cognitive limitation, the inferior performance could also be observed for the limit orders submitted at other prices, the market orders, and the round-trip trades.

The results show that compared with investors with higher cognitive abilities, the underperformance of individual investors with lower cognitive abilities exists for both their round-numbered limit orders and the limit orders submitted at other prices. When we compare the performance of limit orders submitted at each of the “XY” price points (X and Y are both integers ranging from 0 to 9), we find that for 86 out of 100 different “XY” price points, individual investors with lower cognitive abilities have significantly lower intraday returns

than their counterparts. As for institutional investors, the underperformance is significant only for 17 out of 100 different price points.

Individual investors with lower cognitive abilities also have inferior performance on their intraday, 1-day, and 5-days market orders and round-trip trades. For example, the intraday performance difference in market orders is 4.9 basis points between the investors with higher cognitive abilities and those with lower cognitive abilities. The magnitude of the underperformance is comparable with that of the limit orders and the result is less significant for institutional investors. The results thus do not support the "pay-for-cognitive-shortcut" hypothesis.

Moreover, we adopt the transaction-based calendar time (TBCT) portfolio approach used in Seasholes and Zhu (2010) as an alternative methodology. For each day, we sort investors who trade a specific product into quintiles according to their limit order submission ratios at "X0" in the previous year. We then test whether the cognitive ability is associated with a higher tendency to hold more long positions relative to short positions during market up-turns. This allows us to evaluate the investors' market-timing abilities. The results show that individual investors with lower cognitive abilities tend to hold fewer index futures contracts when prices are rising and more when prices are falling, compared with the investors with higher cognitive abilities. This suggests that the underperformance of individual investors with lower cognitive abilities might be partially attributed to their poor market timing ability.

The economic loss due to cognitive limitation is nontrivial. The total amount of annual loss per individual based on round-trip trades amounts to 85,255 Taiwanese dollars (TWD).[3] This significant amount of loss is not due to investors trading too much, as is documented in Barber and Odean (2000) and Barber, Lee, Liu, and Odean (2009). In fact, the investors with the lowest cognitive abilities trade much less than those with the highest abilities. Collectively, the findings are more in line with the notion that the poor investment performance of the investors who submit more limit orders at round-number prices is due to their low cognitive abilities.

[3] The exchange rate was 0.0305 USD/TWD, on average, during our sample period.

For the final question on the effect of investor learning, we regress the change in submission ratio at "X0" each year on the logged number of limit orders submitted in the previous year, past submission ratio at round numbers, past investment returns of limit orders submitted at round numbers, and difference in the durations of winning and losing round-trip trades. The logged number of limit orders submitted in the previous year helps to reduce individual investors' propensity to submit limit orders with round-number prices. The result is consistent with Feng and Seasholes (2005), Dhar and Zhu (2006), and Seru, Shumway, and Stoffman (2010), all of whom argue that past trading experience improves financial decisions. We do not find significant effect of the past returns of round-numbered limit orders on the subsequent limit order submission behavior, which is not in line with the implications of reinforcement learning.

For robustness checks, we conduct a cross-market analysis of a subsample of investors who trade both index futures and index options to validate the effect of cognitive limitation on individual investor performance. Investors with lower cognitive abilities, identified by their limit order submission ratio at round numbers in the index futures contracts, behave in a similar fashion in their options trading. The results remain the same when we use various definitions of round-number prices and different filters to deal with outlier issues. In addition, we find a similar negative association between the round-number submission ratio and longer-term (monthly) investment performance for individual investors.

This study is related to Bhattacharya, Holden, and Jacobsen (2012), who document buy-sell imbalance, based on the Lee and Ready (1991) method, around round-number prices in the US stock market. Our study complements theirs but differs in relation to the following key features. First, Bhattacharya et al. (2012) argue that the buy-sell imbalance stems from the combination of limit order clustering and sophisticated investors' undercutting. Using the entire limit orders data in TAIFEX, we provide direct evidence of their first assumption and show that limit orders indeed cluster at round-number prices. Second, they show that the order imbalance can explain much of the difference in trade performance at various price points, indicating that the round-number heuristics influence trade performance at the order level.

Complementary to their order-level findings, we investigate the influence of round-number heuristics on investment performance at the investor level. The account identity information allows us to track an investor's limit order submission behavior and investment performance to examine the effect of cognitive limitation at the investor level. Third, we provide cross-market evidence that cognitive ability, as revealed by limit order clustering, is an inner trait of investors in their financial decisions.

This study also complements the work of Grinblatt, Keloharju, and Linnainmaa (2012), who find that high-IQ investors outperform their low-IQ counterparts. Compared with the mathematical, verbal, and logical ability measured by the IQ test, the submission ratio at round-number prices reflects the extent to which investors' cognitive limitation is revealed in the financial markets. In particular, we are linking investors' cognitive limitation, manifested in one aspect of their financial decisions, to their overall investment performance. In addition, the entire record of orders and trades with investor type enable us to draw implications for both individual and institutional investors. The cognitive limitation negatively affects the investment performance of individual investors, whereas the effect is less significant among institutional investors.

Our research contributes to the literature in the following two dimensions. First, we provide a new methodology that can be implemented in any data set with identified investor orders and trades data to study the association between cognitive limitation and investment performance. This is distinctive, as other existing cognitive ability measures, such as IQ, might not be available or might not directly reflect the financial acumen of investors. Second, we provide additional supportive evidence that past trading frequency helps improve financial cognitive ability. Thus, we also shed light on the debate playing out in the investor learning literature.

2. Related Literature and Hypotheses Development

2.1 Literature on Cognitive Limitation

Having originated primarily from psychology, the literature has shown that people often use cognitive shortcuts when processing information and making decisions (see Gilovich, Griffin, and Kahneman, 2002, for a review). One type of cognitive limitation identified by Rosch (1975) is that people rely on round numbers, such as multiples of 10, as cognitive reference points. Schindler and Kirby (1997) analyze the rightmost digits of selling prices in a sample of retail price advertisements and show that the overrepresentation of the digits 0 and 5 can be explained by their high cognitive accessibility. Lacetera, Pope, and Sydnor (2012), studying heuristic information processing in the used-car market, find that the tendency to focus on the left-most digit of a number affects customers' purchase decisions, which results in price discontinuity around the round numbers.

In the context of the financial market, extensive studies have shown that asset prices cluster at round numbers.[4] Aitken, Brown, Buckland, Izan, and Walter (1996) interpret the asset price clustering as investors having a natural "attraction" to round-number prices. Using trade records, Bhattacharya, Holden, and Jacobsen (2011) document an abnormal buy-sell imbalance when the stock price is one cent above or below round numbers. They argue that the phenomenon is due to a combination of limit order clustering and strategic limit order undercut by sophisticated investors.

2.2 Cognitive Limitation and Limit Order Clustering

Our first hypothesis stems from the tendency of some investors to use round numbers as cognitive shortcuts to save energy spent in extensive algorithmic processing, which leads to a disproportionately large volume of limit orders submitted at round-number prices.[5] However, due to data availability, few studies have directly studied investors' limit order submission

[4] See Neiderhoffer (1965, 1966); Ball, Torous, and Tschoegl (1985); Harris (1991); Goodhart and Curcio (1991); Christie and Schultz (1994); Christie, Harris, and Schultz (1994); Ley and Varian (1994); Gwilym, Clare, and Thomas (1998a, 1998b); Booth, Kallunki, Lin, and Martikainen (2000); Palmon, Smith, and Sopranzetti (2004); and Sonnemans (2005).

[5] This study also relates to the recent wave of research on investor inattention and trading (Barber and Odean, 2008; Hirshleifer, Lim, and Teoh, 2009; Yuan, 2012, among others). While Barber and Odean (2008) and Yuan (2012) study limited cognitive capability at the market level, we investigate whether there is heterogeneity in cognitive limitation at the investor level, and whether that is related to investment performance.

behavior. For instance, Osler (2003) analyzes the currency orders submitted to a specific dealer (NatWest Markets) between August 1,1999 and April 11, 2000 and finds that investors' price preference is in the order of integer, halves, and quarters.[6] With the complete records on the trades and quotes of both individual and institutional investors for a much longer period in Taiwan futures market, we propose and test the following hypothesis:

Hypothesis 1: Investors submit a disproportionately large volume of limit orders at round-number prices to save cognitive energy. The limit order clustering phenomenon is more evident when the price is a more cognitively accessible round number, and among individual investors.

Because limit orders are directly submitted by investors, the existing hypotheses on stock price clustering i.e., the negotiation hypothesis in Harris (1991) and the collusion hypothesis in Christie and Schultz (1994), cannot explain the limit order clustering. Both of the aforementioned hypotheses rely on the quote-driven trading mechanism in which market makers are responsible for providing quotes to maintain a liquid market whenever necessary, whereas TAIFEX operates under an order-driven trading mechanism in which there are no designated market makers. However, the documented limit order clustering might result from investors' need to hedge their index options positions, which have round-numbered strike prices. We address this potential explanation in two ways. First, we conduct a subsample analysis with investors that have no index options trading. Second, because the index options strike prices are only in multiples of 100, they cannot account for the limit order clustering at multiples of 50 and 10.

2.3 Cognitive Limitation and Investment Performance

If the limit order submission ratio at round-number prices reflects an investor's cognitive

[6] Ahn, Cai, and Cheung (2005); Bourghelle and Cellier (2007); and Chiao and Wang (2009) also find limit order clustering at round numbers in smaller samples from the Hong Kong Stock Exchange, Euronext Paris for CAC 40 shares, and the Taiwan Stock Exchange, respectively.

ability and financial acumen, the ratio may be associated with her investment performance. The poor investment performance of investors with lower cognitive abilities could result from a lower capability of acquiring and correctly interpreting information, or from more investment decisions that are affected by behavioral biases associated with the cognitive limitation. Several proxies for investors' cognitive abilities have been proposed in the literature to study how cognitive limitation is associated with investment performance. Chevalier and Ellison (1999) and Gottesman and Morey (2006) find that mutual fund performances can be predicted by the fund managers' average Scholastic Aptitude Test (SAT) scores and average Graduate Management Admission Test (GMAT) scores, respectively. Grinblatt, Keloharju, and Linnainmaa (2012) use the IQ scores of middle-aged male individual investors in Finland and find that high-IQ investors outperform low-IQ investors. Using the limit order submission ratio at round-number prices as a proxy of cognitive ability, our second hypothesis is as follows:

Hypothesis 2: Cognitive limitation, defined by the limit order submission ratio at round-number prices, is negatively associated with investors' subsequent investment performance.

We consider an additional testable hypothesis, which could also explain the negative association between the limit order submission ratio at round numbers and investment performance. If investors rationally pay for the cognitive energy they save by using round numbers as cognitive shortcuts, they essentially pay for the convenience they enjoy by submitting limit orders at round-number prices. Under this "pay-for-cognitive-shortcut" hypothesis, poor performance should only be exhibited for the round-numbered limit orders and not for the orders with other prices. However, if the submission ratio at round numbers represents investors' cognitive abilities, the inferior performance of investors with higher submission ratios should be found for the limit orders submitted at other prices, the market

orders, and the round-trip trades. Such poor performance may also be observed for the other assets they invest in, for example, the index options. The richness of our data set allows us to shed light on the different implications of these two alternative hypotheses.

It is important to note that instead of the mathematical, verbal, and logical abilities measured in the aforementioned tests, the submission ratio at round-number prices is a measure of cognitive limitation, which is revealed in investors' limit order submission behavior. The ratio can be calculated for any data set with identified investor trading data. This is innovative, as other existing cognitive ability measures might not be available on a large scale.

2.4 Cognitive Limitation and Investor Learning

The literature continues to debate whether investor learning improves investment decisions. Some studies argue that more trading experience could help investors to mitigate behavioral biases, know their investment capabilities, and enhance their performance. Feng and Seasholes (2005) and Dhar and Zhu (2006) both find that investors' trading experience, proxied by trading frequency, mitigates the reluctance to realize losses. This indicates that investor learning reduces the disposition effect. Seru, Shumway, and Stoffman (2010) show that some individual investors become better at trading with experience while others stop trading after learning of their poor ability. This implies that investor learning could result in better investment performance.

Other studies argue that reinforcement learning based on past investment returns might lead to naive optimistic behavior. Choi, Laibson, Madrian, and Metrick (2009) find that individual investors over-extrapolate from their personal experience when making savings decisions in their 401(K) accounts. Strahilevitz, Odean, and Barber (2011) show that investors repurchase stocks whose previous purchase resulted in positive emotions and avoid those that resulted in negative emotions. Chiang, Hirshleifer, Qian, and Sherman (2011) document that high returns in previous IPO auctions increase the likelihood of participating in future

auctions. However, both bidders' returns and their auction selection abilities deteriorate with experience. The two streams of literature use different measures for learning; the former uses past trading frequency and the latter uses past investment returns. We thus propose the following hypotheses:

Hypothesis 3a: Investors' limit order submission ratios at round numbers decrease with the number of limit orders they submitted in the previous year.

Hypothesis 3b: Investors' limit order submission ratios at round numbers increase with the returns of round-numbered limit orders they traded in the previous year.

If investors learn from submitting more limit orders in the past, they may become less affected by the round-number heuristics, which could lead to fewer limit orders submitted at round-number prices in the future. In other words, this learning-by-trading process alleviates the effect of cognitive limitation on investment decisions. However, if investors had high returns for their round-numbered limit orders in the previous year and learn through reinforcement, they may submit even more limit orders at round numbers in the current year. Hence, we expect to observe a positive relation between changes in limit order submission ratio at round numbers and the past investment returns for the round-numbered limit orders they submitted.

3. Data Description

We use complete records of the orders and trades in the Taiwan Futures Exchange with detailed investor type and identity information from January 2003 to September 2008. The orders data allow us to directly study investors' limit order submission behavior while the trades data allow us to evaluate the investor performance.

3.1 The Taiwan Futures Exchange

Investors are allowed to submit orders to the TAIFEX Electronic Trading System (ETS) from 8:30 a.m. to 1:45 p.m., Monday through Friday. Orders submitted before 8:45 a.m. or after 1:40 p.m. are matched by the open and close auctions, respectively. From 8:45 a.m. to 1:40 p.m., orders are matched immediately once they enter the 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 TAIFEX were the Taiwan Stock Exchange Index Futures (hereafter TXF), and the Mini-Taiwan Stock Exchange Index Futures (hereafter MXF). The TXF are based on all listed stocks on the Taiwan Stock Exchange and the MXF are a mini version of the TXF with roughly one-quarter of the margin and payoff. One index point increase in the transaction price yields a profit of 200 (50) TWD for one TXF (MXF) contract. Internet Appendix A provides more of the institutional details for TAIFEX.[7]

3.2 Submitted Limit Orders

In each submitted limit order, we observe its investor type (individual or institutional) and account number, along with other relevant information such as order price, quantity, submission time, etc. Panel A of Table 1 reports that in total, we have 108 million records of submitted limit orders during our sample period.[8] Among these orders, 61.87% are submitted by individual investors. Panel B shows that the total number of contracts submitted is 322 million, with 44.64% from individual investors. Individual investors in Taiwan seem to be more willing to trade index futures, compared with other developed markets. We discuss this phenomenon in Internet Appendix A.

When testing the investment performance and investor learning, we require that investors submit at least 10 limit orders in the two consecutive years to have a meaningful submission

[7] Institutional details for TAIFEX can also be found in Kuo and Lin (2013); Liu, Tsai, Wang, and Zhu (2010); and Li, Lin, Cheng, and Lai (2012).

[8] TAIFEX has a daily price limit of 7% in two ways, and the orders are valid only for one day. Therefore, we exclude limit orders that are submitted outside this range.

ratio at round numbers. In total, we have 156,171 investor-year observations.[9]

3.3 Executed Orders

Panel C of Table 1 reports the descriptive statistics for the number of executed contracts. There are 112 million contracts executed in total, with 68.80% from individual investors. The index level in TAIFEX ranges from 4,011 to 9,934. Therefore, we look at the last two digits of the order price to identify the round-number prices.

4. Limit Order Clustering at Round-number prices

Using detailed records of limit orders, in this section we address the following questions: Do investors submit a disproportionately large volume of limit orders at round-number prices? If yes, does the limit order clustering pattern differ between different investor types and products? Is the limit order clustering phenomenon persistent over time? What might the strategic order submission be, based on the limit order clustering phenomenon?

4.1 Limit Order Clustering at Round-number prices

To identify round-number prices, we focus on the last two digits of 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 100 different "XYs" (where X and Y are integers ranging from 0 to 9). We refer to round-number prices as XY = 00, 10, 20, …, 90 and calculate the submission ratio as:

$$SubRatio_{XY} = \frac{Number\ of\ limit\ orders\ submitted\ at\ "XY"}{Total\ Number\ of\ submitted\ limit\ orders} \quad (1)$$

The submission ratio measures the proportion of orders submitted with the last two digits

[9] Figure B1 of Internet Appendix B reports the cumulative distribution of the annual number of limit orders submitted by individual and institutional investors. In general, around 70% of individual investors trade more than 10 contracts per year.

of the order prices being "XY." Theoretically, if investors trade index futures fully based on their information, and are not cognitively constrained, their limit orders should be equally likely to be submitted at any given price. In contrast, if investors are affected by the round-number heuristics, they would submit disproportionately more limit orders at round-number prices.

The limit order submission ratio is plotted by the last two digits of the order prices in Panel A of Figure 1, which shows that limit order clustering is evident in TAIFEX.[10] The submission ratio is 3.1% at "00," which is 2.2% higher than that at "99" and "01." The most favored prices are those that end with "00," followed by those that end with "50," and then "20," "80," etc.[11] This indicates that when investors submit limit orders, they tend to choose a round-number order price, and the submission ratio at "XY" is increasing in its cognitive accessibility, i.e., the roundness of the numbers.[12]

One alternative explanation for the limit order clustering phenomenon is that investors hedge their positions in index options by index futures contracts, which only have round-numbered strike prices. However, the basic findings remain unchanged when we restrict our sample to investors that do not trade index options during our sample period. The results are reported in Figure B3 of Internet Appendix B. In addition, the strike prices of index options are only in multiples of 100, therefore, the hedging demand alone cannot account for the limit order clustering at multiples of 50 and 10. The pattern in Panel A of Figure 1 clearly indicates limit order clustering at round numbers other than multiples of 100, which is inconsistent with the hedging argument.

[10] The Kolmogorov-Smirnoff test rejects the null hypothesis that the last two digits of limit orders obey the uniform distribution.

[11] Figure 1 also shows a pattern of declining (increasing) order volumes as we move from "X2" to "X4" ("X6" to "X8") at every price level. One explanation is that the pronunciation of the number 4, irrespective of the order at which it appears, sounds like "death" or "die" in Mandarin, the official language in Taiwan. These numbers are thus considered inauspicious by some people. In contrast, the number 8 is considered auspicious in Chinese culture, as its pronunciation sounds like "good fortune." Brown, Chua, and Mitchell (2002) and Brown and Mitchell (2008) find some support for the influence of Chinese culture and superstition on traders' year-round number preferences. They also find an increased avoidance of the number 4 during the auspicious Chinese New Year, Dragon Boat, and Mid-Autumn festivals.

[12] In Figure B2 of Internet Appendix B, we show that if we only look the last single digit, the submission ratio is highest at "0," followed by "5."

4.2 Limit Order Clustering for Different Order Types

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

The takeaway from Panel B of Figure 1 is that the limit order clustering pattern is substantially more pronounced for individual investors. The submission ratio is 4.1% at "00," which almost five times those for "99" and "01." Limit orders cluster most at multiples of 100, then at multiples of 50, 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 cognitively accessible a number, the higher the likelihood that the number is chosen for the limit order price.

Panel C of Figure 1 shows that this pattern is similar for institutional investors, but the magnitude is not as large as that of individual investors. In particular, the submission ratio at "00" is 1.6%, which is only 0.6% higher than the uniform distribution benchmark. The results suggest that individual investors exhibit much more statistically significant and economically meaningful round-number heuristics when submitting limit orders. The institutional investors may exhibit some statistical significance in limit order clustering behavior, but the magnitude is dwarfed by that of the individual investors.

In Figure B4 of Internet Appendix B, we also plot the submission ratio separately for the TXF and MXF orders. There are 3.0% (3.3%) of limit orders submitted at "00" for TXF (MXF). The similar proportion of limit orders submitted at round-number prices for the two different index future products suggests that limit order clustering is a prevalent phenomenon.

4.3 Multivariate Regression Analysis

In this sub-section, we formally test the existence and prevalence of limit order clustering

through regressions on dummy variables indicating round-number prices and order types. For each limit order, we are able to recognize whether it is submitted by an 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 "XY," and perform the following regression:

$$
\begin{aligned}
SubRatio_{\mathrm{XY}} - 0.01 &= \alpha + \beta_1 D_{00} + \beta_2 D_{50} + \beta_3 D_{X0} + \beta_4 D_{00} \times D_{indv} + \beta_5 D_{50} \times D_{indv} + \beta_6 D_{X0} \\
&\times D_{indv} + \beta_7 D_{00} \times D_{MXF} + \beta_8 D_{50} \times D_{MXF} + \beta_9 D_{X0} \times D_{MXF} + \beta_{10} D_{00} \\
&\times D_{indv} \times D_{MXF} + \beta_{11} D_{50} \times D_{indv} \times D_{MXF} + \beta_{12} D_{X0} \\
&\times D_{indv} \times D_{MXF} + Distance_{XY} + \varepsilon_{XY} \qquad (2)
\end{aligned}
$$

where $SubRaio_{\mathrm{XY}}$ is the submission ratio at "XY" for a specific order type; D_{00}, D_{50}, and D_{X0} are dummy variables for price points "00," "50," and "X0;" X is an integer and X$\neq$0 or 5; D_{indv} and D_{MXF} are indicators for orders submitted by individual investors and MXF orders, respectively. $Distance_{XY}$ is the average distance of limit order price from the last trade price for limit orders submitted at "XY" price points.[13] 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_{12}, measure the marginal effect of a specific order type. For example, if β_4 is significantly larger than zero, 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 2 reports the parameter estimates for this regression and shows the F-tests for the differences between β_1, β_2, and β_3 in the last three rows.

Table 2 Model 2 shows that when the focus is exclusively on the round-number effect,

[13] For orders that are submitted far away from recent trade prices, we might expect more round number prices than that of more aggressive orders. Therefore, we include $Distance_{XY}$ as a control variable to address the effect of price distance. Specifically, for each limit order, the distance is calculated as the absolute difference between the limit order price and the last trade price scaled by the last trade price. The last trade price is defined as the first market transaction price in the previous second when the limit order is submitted. This definition of last trade price assumes that investors take the first market transaction in the previous second as the current trade price. The results are similar if we match the limit orders by the first transaction price in the previous minute.

the coefficients of D_{00}, D_{50}, and D_{X0} are all significantly positive with p-values smaller than 0.01. The limit order submission ratio at "00" is 1.7% higher than that of the non-round numbers, which is consistent with the pattern in Figure 1. Moreover, the parameter estimate is decreasing from D_{00}, to D_{50}, to D_{X0}, and the differences between them are not only statistically significant but also economically meaningful. For example, the submission ratio at "00" is 0.8% larger than that at "X0," whereas the submission ratio at "50" is 0.4% larger than that at "X0." The proportion of orders submitted at "XY" increases in its cognitive accessibility, which is consistent with the idea that investors use round numbers as cognitive shortcuts in their investment decisions. The high economic significance of the limit order clustering at round numbers also mitigates the concern that our result is only driven by the sheer number of observations.[14]

Model 3 shows that the limit order clustering at round-number prices is much more prominent among individual investors. The proportion of limit orders submitted by individual investors at "00" is 3.2% higher than non-round "XYs" ("XYs" that are not equal to "00," "10," "20,"…, "90"). The submission ratios at "50" and "X0" are also higher than the non-round "XYs" by 2.3% and 1.4%, respectively. Although with smaller magnitude, institutional investors also submit more orders at the round-number prices. Specifically, their submission ratio at "00" is 1% higher than the non-round "XYs", which is also significant with a p-value smaller than 0.01. This is in line with Locke and Mann (2005), who show that institutional investors also exhibit behavioral bias such as the disposition effect. In addition, Liu, Tsai, Wang, and Zhu (2010) document trading patterns consistent with the prospect theory for market makers and other types of institutional investors. Although institutional investors are generally well-educated and more specialized in trading, it is still possible for them to exhibit a certain level of cognitive limitation and the round-number heuristics when determining their order prices. The lower submission ratio at round numbers compared with that of individual investors suggests a higher level of cognitive ability among institutional

[14] Although we have 100 million limit orders, we only have 2,400 limit order submission ratios (observations) to conduct analysis for Table 2 (two investor types × two product types × six years data × 100 last two digits).

investors. Model 7 shows that when we incorporate the triple-interaction terms, the most influential factor is the individual investor dummy. The MXF orders cluster slightly more than the TXF orders.

To summarize, individual investors rely more on round-number heuristics, irrespective of submitting the MXF or TXF orders. The clustering phenomenon of limit orders increases with the cognitive accessibility of the numbers, i.e., from multiples of 10, to multiples of 50, and multiples of 100. Overall, these results are supportive of our first hypothesis.

4.4 Persistence of Limit Order Clustering for Individual Investors

To further confirm that the limit order clustering documented in the previous sub-section is not driven by price movements during a particular period, we look at the submission ratio at round-number prices in different years. To illustrate, we plot the proportion of orders submitted at "00" from 2003 to 2008. Figure B5 of Internet Appendix B shows that individual investors are consistently affected by the round-number heuristics when submitting limit orders. The submission ratio at "00" is above 3.5% throughout our sample period. For institutional investors, in contrast, the limit order clustering phenomenon seems to wane over time. For them, the submission ratio at "00" decreases from 2.6% to 1.5%. The result suggests that the limit order clustering phenomenon for individual investors is not driven by price movements and is persistent during our sample period.

4.5 Lower Execution Ratio and Longer Time-to-execution for Round-numbered Limit Orders

Is it possible that individual investors rationally submit limit orders at round numbers to enjoy better liquidity? Intuitively, limit buy orders are submitted at prices slightly below the current index level while limit sell orders are submitted at prices slightly above the current index level. Therefore, when limit buy orders cluster at a round number, it is unlikely that limit sell orders will cluster at the same round number simultaneously. Figures B6 and B7 of

Internet Appendix B show that limit orders submitted at round-number prices are less likely to be executed, and the duration from submission to execution is also longer for the executed limit orders. This pattern suggests that when limit orders cluster at the round numbers, the benefit of higher liquidity is likely to be enjoyed by the counterparties who submit market orders.

4.6 Strategic Limit Order Undercutting

Bhattacharya, Holden, and Jacobsen (2012) argue that sophisticated investors undercut limit orders one cent above round numbers when taking a long position and one point below when taking a short position. They find that the buy-sell order imbalance based on the Lee and Ready (1991) algorithm is highest (lowest) at a price ending with 99 (01) cents. To explore whether we do observe new buy (sell) limit orders undercutting one price point above (below) the round numbers, we also plot the buy-sell limit order submission ratio against the last two digits of index future prices. The result is in Figure B8 of Internet Appendix B, which indicates that the buy-sell limit order submission ratio is indeed highest at "01" and lowest at "99" (the last two digits of futures' prices). This is consistent with the undercutting argument in Bhattacharya et al. (2012).

Note that the buy-sell limit order submission ratio in Figure B8 is calculated based on the submitted limit orders while the buy-sell order imbalance in Bhattacharya et al. (2012) is calculated using Lee and Ready (1991) algorithm for executed orders. As most of the sell (buy) limit orders are picked up by market or aggressive limit buy (sell) orders and classified as the buyer-initiated (seller-initiated) orders, the highest point of the buy-sell limit order submission ratio in Figure B8 would be the lowest point of the buy-sell order imbalance in Bhattacharya et al. (2012), and vice versa.

5. Cognitive Limitation and Investor Performance

With the investor account identity, we are able to identify each investor and keep track of

her submission behavior and investment performance. In this section, our main objective is to test whether investors with lower cognitive abilities, manifested in a higher submission ratio at round-number prices in the previous year, will exhibit inferior investment performance in the current year. The basic thrust of our argument is that investors with lower cognitive abilities might have lower capabilities of accessing and interpreting information, or they are more susceptible to behavioral biases that have adverse impact on investment performance. The reasoning is in the same vein with Chevalier and Ellison (1999); Gottesman and Morey (2006); and Grinblatt, Keloharju, and Linnainmaa (2012).

5.1 The Measure of Cognitive Limitation

Our measure for the cognitive limitation of each investor in the current year is the previous year's submission ratio at the multiples of 10, i.e., the last two digits of index prices end with "X0" (X is an integer ranging from 0 to 9). To make sure that investors have a meaningful submission ratio at "X0" and investment performance, we require that investors submit at least 10 limit orders each year over the two consecutive years to be included in the sample.[15] After constructing the ratio, we then sort the investors into five groups according to the lagged ratio (submission ratio at year *t*-1) for our quintile analyses in the following sub-sections.

As Table 3 shows, both the lagged and current submission ratios at "X0" are quite spread out for the investors in different quintiles. For example, the submission ratio at "X0" of the quintile-1 individual investors is 9.2%, significantly lower than that (62.5%) of the quintile-5 individual investors. The quintile-5 individual investors rely more heavily than their quintile-1

[15] Our analysis on the association between cognitive limitation and investment performance might potentially suffer from the effects of investor attrition (survivorship bias) shown in Seru, Shumway, and Stoffman (2010). However, our argument is that investors with less cognitive abilities, represented by higher limit order submission ratios at round numbers, would perform worse. Because investors with least cognitive abilities are most likely to stop trading, the remaining investors in our empirical analyses after data filtering should have relatively better investment performance. Hence, the investor attrition should bias against us finding the negative relationship between cognitive limitation and investment performance in the quintile analysis. In addition, in Internet Appendix B, we also check whether our results hold up when we look at investment performance by submission ratio at 00 only (or at 00 and 50), and require investors to submit at least five (or fifteen) limit orders each year in the two consecutive years. The results remain that investors with lower cognitive abilities display inferior investment performance.

counterparts on the round-number heuristics when making investment decisions. This significant difference in the submission ratio at round-number prices implies a high heterogeneity in the degree of cognitive capability among investors. For the remainder of this paper, investors with higher (lower) submission ratios at round numbers are referred to as Q5 (Q1) investors. That is, Q5 (Q1) investors are viewed as those with lower (higher) cognitive abilities.

The limit order submission ratio at "X0" is quite persistent. Investors with higher submission ratios at round numbers in the previous year tend to have higher submission ratios at round numbers in the current year. For example, Q5 individual investors have limit order submission ratios of 0.625 and 0.55 for the previous year and the current year, respectively. The correlation of the submission ratio at round numbers for the two consecutive years at the investor level is 0.72 (0.59) for individual (institutional) investors.

Table 3 also shows that Q5 investors, both individual and institutional, have significant lower execution ratios for their submitted limit orders and longer time-to-execution for their executed limit orders than that of Q1 investors. These results are consistent with the order-level findings in Figures B6 and B7 of Internet Appendix B, that it is more difficult for investors to execute their round-numbered limit orders.

5.2 Cognitive Limitation and Performance of Limit Orders

The first aspect of investment performance we look at is the mark-to-market return of limit orders which initiate long or short positions.[16] Following Bhattacharya et al. (2012) and Linnainmaa (2010), we calculate the intraday return using the difference between the daily closing price and the initiating limit order's execution price, divided by the execution price. This calculation assumes that the initiating limit orders are covered (closed-out) at the closing price of the trading day. For each investor-year observation, we first calculate the average

[16] We only use initiating limit orders and market orders to evaluate the mark-to-market returns because the sum of mark-to-market returns for an initiating order and that for a closing order do not necessarily reflect the true performance of a round-trip trade. If the initiating and closing orders are executed on two different days, we are essentially using two different daily closing prices to calculate the returns. Hence, the sum of the two returns is an inaccurate calculation of the investor's performance.

intraday return, and then we average them with equal weights for all of the observations in each quintile. We also calculate 1-day and 5-day mark-to-market returns, which use closing prices of t+1 and t+5, respectively.

Figure 2 plots the mark-to-market returns against the quintile ranks of investors based on their limit order submission ratio at "X0". We find that intraday returns monotonically decrease with the submission ratio at "X0" for individual investors. Similar patterns also exist for 1-day and 5-day returns. This monotonic pattern provides convincing evidence that cognitive ability and investment performance are positively correlated for individual investors. For institutional investors, no clear pattern can be observed, except for the significant underperformance for Q5 institutional investors.

Table 4 presents the statistical tests between the investors with the top and the bottom quintiles of limit order submission ratios at round numbers. The Q5 individual investors underperform their Q1 counterparts by 3.9 basis points within a trading day. The inferior performance of the Q5 investors continues to deteriorate, and the gap widens to 14.3 basis points for the 5-day mark-to-market returns. For institutional investors, the difference in performance is also significant for intraday and 5-day returns and is mainly driven by the Q5 institutional investors.

Table 4 also indicates that individual investors in all quintiles experience negative mark-to-market returns in their limit orders, whereas only those institutional investors who submit substantially more limit orders at "X0" incur large losses. This is consistent with the findings in the literature that individual investors tend to lose money on their investments.

In addition to the univariate sorting, we perform the following cross-sectional regression:

$$Return_{i,t} = \alpha + \beta_1 SubRatio_{X0,i,t-1} + \beta_2 Ln(N_{i,t-1}) + \beta_3 Disposition_{i,t} + \varepsilon_{i,t} \quad (3)$$

where $Return_{i,t}$ is the average mark-to-market return for investor *i* in year *t*; $SubRatio_{X0,i,t-1}$ is investor *i*'s submission ratio at "X0" price points in year *t-1*; and

$Ln(N_{i,t-1})$ is the logged number of limit orders submitted by an investor in year *t-1*, which is a proxy for her trading experience. $Disposition_{i,t}$ measures the extent to which investor *i* is affected by the disposition effect in year *t*, and it is defined as the difference between the durations of losing and winning round-trip trades, scaled by the average of the two. Odean (1998) shows that the tendency to hold losing investments for too long and sell winning investments too soon leads to lower after-tax returns. Therefore, controlling for the disposition effect helps us to single out the effect of cognitive limitation on investment performance.[17] The coefficient of particular interest is β_1, as it measures how cognitive ability is associated with investment performance.

The first three columns of Table 9 show significantly negative coefficients of the submission ratio at "X0" for both individual and institutional investors. The estimated β_1 equals -0.05, implying that a one standard deviation increase in the submission ratio at "X0" (18.1%) leads to a 0.9 basis points decrease in the mark-to-market intraday return for individual investors, after controlling for trading experience and disposition effect. Similar results hold for the mark-to-market 1-day and 5-day returns. Notice that the coefficients for $Disposition_{i,t}$ are all significantly negative, suggesting that the more an investor is affected by the disposition effect, the lower are the returns of their investments. This is consistent with the findings in Odean (1998).

We also use a block-bootstrapping methodology to test the significance of the parameter estimates. This methodology mitigates the potential concern that investment performances across investors might be dependent for the panel regression analysis of Eq. (3). For each year *t*, we randomly select with replacement M_t observations, where M_t is the number of observations at year *t* in the original sample.[18] We then combine the selected observations from 2004 to 2008 to form a new panel and re-estimate the regression of Eq. (3). We repeat this procedure 1,000 times and report the results in Table 9, with the empirical p-values from

[17] Our findings remain qualitatively unchanged when we control for the distance of the limit order price to the last trade price at time of submission.

[18] We perform the block-bootstrapping at the annual level because the longest maturity for index futures contracts is one year.

the block-bootstrapping in brackets. The results confirm that investors' submission ratio at "X0" in the previous year is significantly negatively associated with limit order returns in the current year.

5.3 Cognitive Limitation Hypothesis vs. Pay-for-cognitive-shortcut Hypothesis

One may argue that the documented negative relation between the limit order submission ratio at round numbers and the investment performance may arise if investors rationally pay for the cognitive convenience. This "pay-for-cognitive-shortcut" hypothesis implies that the documented poor performance of limit orders among investors with low cognitive abilities is mainly driven by the round-numbered limit orders, as other limit orders are unlikely to be used as a way of saving cognitive energy. We thus examine the performance of the round-numbered limit orders, the non-round-numbered limit orders, the market orders, and the round-trip trades to substantiate our hypothesis. The analyses in the following three sub-sections help to rule out the "pay-for-cognitive-shortcut" argument.

5.3.1 Cognitive Limitation and Performance of Limit Orders with Round-numbered and Non-round-number Prices

In this sub-section, we calculate the mark-to-market limit order returns separately for limit orders submitted at "X0" prices and for those not submitted at "X0" prices. We again sort investors into quintiles according to their limit order submission ratio at "X0" in the previous year, and look at their limit order performance in the current year. Panel A of Table 5 shows that individual investors with lower cognitive abilities experience significantly lower intraday, 1-day, and 5-day returns, both for their limit orders submitted at round-number prices and for those submitted at non-round-number prices.

Furthermore, we take a closer look at the performance differences between the Q5 and Q1 investors regarding their limit orders submitted at each of the 100 last two digit prices, instead of a rougher dichotomized classification of round numbers and non-round numbers.

The idea is that if the inferior performance of the Q5 investors, compared with their Q1 counterparts, is concentrated on limit orders with those ten round-number prices ("X0"), then it would be consistent with the "pay-for-cognitive-shortcut" hypothesis. However, Table 6 shows that out of 100 different last two digits of the order prices, we find that at 98 price points the Q5 individual investors have lower intraday returns than their Q1 counterparts. Among them, at 86 price points, the underperformance is significant at the 1% significance level. For institutional investors, the underperformance is significant at 17 out of 100 price points. Similar results also hold for 1-day and 5-day returns.

The prevalent underperformance of individual investors with lower cognitive abilities exists for limit orders submitted at most price points. This corroborates our hypothesis that submitting a disproportionately large volume of limit orders at round-number prices is an indicator of investors' cognitive limitations, which are also associated with low limit order mark-to-market returns.

5.3.2 Cognitive Limitation and Performance of Market Orders

The mark-to-market intraday return of market orders is calculated in the same way that limit orders are calculated in the previous sub-section, i.e., assuming that the initiating market order is covered at the closing price of the trading day. For each investor-year observation, we first calculate the average intraday return in the current year, and then average them with equal weights among all of the observations in each quintile. Mark-to-market 1-day and 5-day returns are also calculated using the same logic.

Table 7 shows that individual investors with a higher submission ratio at "X0" in the previous year earn significantly lower intraday, 1-day, and 5-day mark-to-market returns for their market orders in the current year. The Q5 investors underperform the Q1 investors by 4.9 basis points in their market orders within a trading day. The magnitude is similar to that of the intraday limit order returns. The underperformance deteriorates to 7.9 (11.9) basis points one day (five days) after the transaction. The performance difference is, however, not significant between Q1 and Q5 institutional investors.

We find similar results based on multivariate regressions. The middle three columns of Table 9 show that the parameter estimates on the submission ratio at "X0" in year *t-1* are significantly negative for individual investors. Specifically, a one standard deviation increase in the submission ratio at "X0" (18.1%) leads to a 1.1 basis points decrease in the mark-to-market intraday return of market orders. The results are similar for the 1-day and 5-day returns. For institutional investors, we do not observe a significant relationship between market order returns and submission ratio at "X0." The results indicate that the underperformance of individual investors with low cognitive abilities is not restricted to their limit orders.

5.3.3 Cognitive Limitation and Performance of Round-Trip Trades

We follow Jordan and Diltz (2003) and Feng and Seasholes (2005) to calculate round-trip trade performance. A round-trip trade is identified as a newly initiated position, long or short, being covered. To adjust for the cross-sectional variation in round-trip duration, and to facilitate the comparison with the mark-to-market returns of executed orders, we focus on the round-trip daily profit and daily index returns for the investors.

The round-trip profit is calculated as the number of index points earned or lost times 200 (50) TWD for the TXF (MXF) contracts. The round-trip index return is calculated as the profit divided by the mean execution price of all buy orders within a round-trip trade.[19] We then calculate an investor's round-trip daily profit (index return) as the average round-trip profit (index return) divided by the average round-trip duration.[20] Similar to the mark-to-market returns, all items are first calculated for each investor and then averaged with equal weights for each quintile.

[19] A round-trip trade may contain several buys and sells before the position is back to zero.

[20] The outlier problem can be severe if we calculate the daily performance per round-trip. Many round-trip trades have a very short duration, leading to extremely large daily profits and daily index returns for those round-trip trades. Therefore, we first calculate the average round-trip duration and average profit for each investor, and then we calculate the investor's daily profit as average round-trip profit divided by average duration. Round-trip daily index returns are calculated in the same way. To exclude extreme outliers, we also truncate the sample by deleting the investors with round-trip daily profits out of the 0.5% to 99.5% range in our sample.

Panel A of Table 8 shows that the Q5 individual investors underperform Q1 individual investors by 997 TWD for daily profits. The realized underperformance in terms of round-trip daily index returns is about 10.2 basis points per trading day. To have a better picture of the economic losses, we estimate the total realized profit for each investor in each quintile per year (multiplying rows 1, 3, and 4 in Table 8). The Q5 individual investors lose 85,255 TWD (2,600 USD) more than their Q1 counterparts per year during our sample period. These incremental losses of Q5 individual investors are not driven by their excessive trading, as Barber and Odean (2000) suggest. In fact, Q5 investors trade less than their counterparts. This is in line with our hypothesis that the inferior performance of Q5 individual investors is mainly driven by their cognitive limitations. The pattern is similar for institutional investors, with a lower statistical significance due to a smaller sample size.

Table 8 also shows that investors tend to have a shorter duration for the winning round-trip trades and a longer duration for the losing ones, which indicates that investors are affected by the disposition effect when making their investments, as shown in Odean (1998). Therefore, we control for the disposition effect to single out the effect of cognitive limitations on investment performance when we conduct the multivariate regression analysis.

The last two columns of Table 9 present the results of multivariate regressions for the round-trip trades. The coefficients of the submission ratio at “X0” are significantly negative for individual investors. A one standard deviation increase in the submission ratio at “X0” (18.1%) leads to a lower (269 TWD) round-trip daily profit and a lower (2.93 basis points) daily index return. We do not find similar results for institutional investors after controlling for the number of orders submitted in the previous year and the disposition effect.

In summary, the inferior performance of Q5 individual investors (those with lower cognitive abilities) due to their round-numbered limit orders, non-round-numbered limit orders, market orders, and round-trip trades corroborate our Hypothesis 2 that individual investors with lower cognitive capabilities perform worse than those with higher cognitive

abilities. These results also help to rule out the alternative "pay-for-cognitive-shortcut" hypothesis.[21]

5.4 Cognitive Limitation and Investors' Market Timing Ability

In this sub-section, we adopt the transaction-based calendar-time (TBCT) portfolio approach from Seasholes and Zhu (2010) as an alternative methodology to test investment performance in the dimension of market timing ability. This methodology allows us to address the concern of cross-sectional correlation in the investor-year panel, on top of the block-bootstrapping used in the panel regressions.

For each day, we sort the investors who trade a specific product into deciles according to their limit order submission ratios at "X0" in the previous year. We then examine whether investors with lower cognitive abilities have lower market timing abilities; that is, whether they take more long positions when the market is up and more short positions when the market is down. Specifically, we perform the following panel regression:

$$BuyRatio_{s,t,i,RankSubRatio} = \alpha + \beta_1 Return_{s,t,i} + \beta_2\, Rank\_SubRatio_{X0,s,t-1,i} + \beta_3 (Return_{s,t,i} \times Rank\_SubRatio_{X0,s,t-1,i}) + \varepsilon_{s,t,i,RankSubRatio} \quad (4)$$

$BuyRatio_{s,t,i,Rank\_SubRatio}$ is calculated in two different ways. In Model 1, we calculate it as the number of buy contracts scaled by the total number of contracts executed. In Model 2, we calculate it as the difference between the numbers of buy and sell contracts, divided by the average of the two. $Return_{s,t,i}$ is the market return of product *i* at day *s* of year *t*. Both limit and market orders are included in this analysis. $Rank\_SubRatio_{X0,s,t-1,i}$ is the decile rank of investors trading product *i* at day *s*, classified by their limit order submission ratio at "X0"

[21] One may be concerned that the negative correlation between the submission ratio at "X0" and investment performance is driven by the skewness of the performance. Boyer, Mitton, and Vorkink (2010) show that expected idiosyncratic skewness and returns are negatively correlated. If skewness is also positively correlated with investors' propensity to submit limit orders at round-number prices, it would also be consistent with our findings. However, we find that the skewness of investment performance is significantly negatively correlated with the submission ratio at "X0." This rules out the concern that our result is driven by the interaction of skewness preference and order submission behavior.

at year *t-1*, with decile 10 representing the highest round-numbered submission ratio For each year *t*, each day *s*, and each product *i*, we sort investors trading that product into deciles based on their submission ratio at "X0" in the previous year *t-1*. Product *i* could be the MXF or TXF orders that expire in one month, two months, three months, six months, nine months, or one year. To ensure a reasonable submission ratio at "X0", we require that investors submit at least 10 limit orders in two consecutive years. The parameter of interest is β_3, which captures the relative market-timing capabilities of investors with higher submission ratios at "X0."

Table 10 reports a significantly negative β_3 for both the limit and market order trades of individual investors. In other words, individual investors with lower cognitive abilities take fewer long positions when the market return is positive, compared with those exhibiting higher cognitive abilities. This implies lower market timing skills among investors with lower cognitive abilities. A similar pattern can be found for institutional investors.

Collectively, the analyses on the investment returns and the market timing ability are supportive of our argument that investors with lower cognitive abilities, defined by higher submission ratios at round numbers, have inferior investment performance.

6. Trading Experience Mitigates Cognitive Limitation

In this section, we examine how trading experience, in terms of both past trading frequency and past trading returns, affect investors' cognitive limitations. We perform the following regression:

$$SubRatio_{X0,i,t} - SubRatio_{X0,i,t-1} = \alpha + \beta_1 Ln(N_{i,t-1}) + \beta_2\, Return_{X0,i,t-1} + \beta_3\, SubRatio_{X0,i,t-1} + \beta_4\, Disposition_{i,t} + \varepsilon_{i,t} \quad (5)$$

where $SubRatio_{X0,i,t}$ and $SubRatio_{X0,i,t-1}$ are investor *i*'s submission ratio at "X0" price point in the current and previous year (X is an integer ranging from 0 to 9). The differences in the submission ratios over the two consecutive years measure the extent to which investors

become less affected by the round-number heuristics through learning. $Ln(N_{i,t-1})$ is the logged number of limit orders submitted in the previous year, which is a proxy for learning from the past trading frequency, similar to that used in Feng and Seasholes (2005) and Dhar and Zhu (2006). If investors become more sophisticated after learning from their past trading, they are less likely to rely on the round-number heuristics when submitting their limit orders. The coefficient β_1 is thus expected to be negative. $Return_{X0,i,t-1}$ is the mark-to-market intraday limit order return, which is a proxy for the reinforcement learning in the same spirit as that found in Strahilevitz, Odean, and Barber (2011) and Chiang, Hirshleifer, Qian, and Sherman (2011). If investors learn through reinforcement, positive past round-numbered limit order returns should result in more subsequent round-numbered limit order submissions. The coefficient β_2 is thus expected to be positive. $Disposition_{i,t}$ is the difference between the durations of losing and winning round-trips, divided by the average of the two. To ensure a reasonable submission ratio at "X0", we require investors to submit at least 10 limit orders in two consecutive years.

Panel A of Table 11 shows that the change in the submission ratio at round numbers is negatively related to the number of limit orders submitted in the previous year for individual investors. The coefficients for $Ln(N_{i,t-1})$ are significantly negative at the 1% significance level for both Models 1 and 3. Specifically, according to the estimated coefficient in Model 3, a one standard deviation increase in the number of limit orders submitted in the previous year (51) will reduce the submission ratio at round numbers by 2% in the subsequent year. This indicates that individual investors learn from their past trading frequency and become less reliant on the round-number heuristics in their subsequent limit order submissions, which is consistent with our Hypothesis 3a.

However, the coefficient β_2 for $Return_{X0,i,t-1}$ is less robust and becomes insignificant after incorporating the past trading frequency into the regression. The round-numbered limit order submission ratio of individual investors does not seem to be materially affected by their previous round-numbered limit order performance, which is not

supportive of our Hypothesis 3b on reinforcement learning.

Panel B of Table 11 shows that for institutional investors, both past trading frequency and past trading returns help to reduce their limit order submission at the round numbers. The results are again supportive of our Hypothesis 3a but not of our Hypothesis 3b.

7. Cross-Market Analysis, Longer-term Investment Performance, and Robustness Check

7.1 Cross-Market Analysis

To further validate the association between cognitive limitation and investment performance, we examine the two following questions: First, do investors with a higher limit order submission ratio at round numbers in the futures market also submit more round-numbered limit orders in their options trading? Second, and more importantly, is cognitive limitation, revealed in the futures market, also associated with options investment performance?

In TAIFEX, one investor account can be used to trade both futures and options. With the account identification, we construct a subset of investors who trade in both the futures and options markets during our sample period. We perform two separate regressions to investigate the limit order clustering phenomenon and investor performance in the options market:

$$SubRatio_{X0,i,t,options} \ or \ Return_{i,t,options} = \alpha + \beta_1 SubRatio_{X0,i,t,futures} + \beta_2 Ln(N_{i,t-1,options}) + \beta_3 \ Disposition_{i,t,options} + \varepsilon_{i,t} \quad (6)$$

where $SubRatio_{X0,i,t,options}$ is investor *i*'s options limit order submission ratio at round numbers in year *t-1*. The options tick size in TAIFEX depends on the transaction prices, and we therefore define "options round-number prices" as the options prices that are multiples of the tick sizes times 10. A detailed description of the tick sizes is displayed in Table B5 of Internet Appendix B. $Return_{i,t,options}$ is investor *i*'s mark-to-market returns or round-trip

performance in the options market at year *t*. $SubRatio_{X0,i,t,futures}$ is investor *i*'s futures limit order submission ratio at "X0" price point in year *t-1* (X is an integer ranging from 0 to 9). $Ln(N_{i,t-1,options})$ is the logged number of options limit orders submitted in year *t-1*. $Disposition_{i,t,options}$ is the disposition effect in the options market, which is calculated as the difference between the durations of losing and winning round-trips, divided by the average of the two. To be included in the regression, an investor must submit at least 10 futures limit orders and 10 options limit orders for both of the two consecutive years. This sub-set of investors submits about 63 million options limit orders, which accounts for about 26% of the total options limit orders in TAIFEX.

The results are reported in Table B6 of Internet Appendix B. Individual investors with higher round-numbered limit order submission ratios in the futures market also have higher round-numbered limit order submission ratios in the options market. Likewise, they have lower investment performance in their options limit orders, market orders, and round-trip trades. This sub-sample analysis indicates that cognitively constrained investors behave and perform similarly across markets. Collectively, the cognitive limitation we identify from the limit order submission at round numbers in the index futures market is most likely to be an investor's trait, which is related to her investment performance and can be carried over to various markets.

7.2 Cognitive Limitation and Longer-term Investment Performance

In this subsection, we perform regression analysis for longer-term mark-to-market returns and average monthly profit. The longer-term mark-to-market returns for limit and market orders are calculated in three different variations: a) from the submission to 22 trading days afterwards, b) from the submission to the end of the calendar month, and c) from the submission to the expiration day (the third Wednesday of the expiration month). The average monthly profit is the average profit per contract from a series of transactions conducted over

the course of a month, where the unclosed position is assumed to be closed out at the closing price by the end of the month.

Table B7 of Internet Appendix B shows that, for individual investors, submission ratio at "X0" is negatively associated with longer-term mark-to-market returns and average monthly profit. The parameter estimates for limit and market orders are comparable to each other.

Table B8 of Internet Appendix B reports the results on mark-to-market returns of limit orders submitted at "X0" and non-"X0" prices. It shows that the negative association of cognitive limitation and longer-term investment performance exists for both round-numbered and non-round-numbered limit orders.

7.3 Robustness Check

In the previous analysis, we exclude investors who submit fewer than 10 limit orders in two consecutive years and construct the limit order submission ratio based on the proportion of limit orders submitted at multiples of 10. To make sure that our results are not driven by the filtering criteria and how we define the limit order submission ratio at round numbers, we check whether our results remain when we require investors to submit more than five (or fifteen) limit orders in two consecutive years, and when we construct the limit order submission ratio at multiples of 100 or at multiples of 50.

Table B9 of Internet Appendix B shows that when we require investors to submit more than five or fifteen limit orders in two years, individual investors with high submission ratios at round numbers still significantly underperform their counterparts in their round-numbered limit orders, non-round-numbered limit orders, market orders, and round-trip trades. The underperformance remains significant irrespective of using multiples of 100, 50, or 10 as the round numbers. This indicates that the main results from previous sections are robust to the different sample filtering criteria and the various definitions of round numbers.

8. Conclusion

This paper investigates whether cognitive limitation is associated with investors' limit order submission behavior and performance. We document a strong and persistent limit order clustering pattern in the Taiwan Futures Exchange among individual investors. The limit order clustering at multiples of 100 is the strongest, followed by those at multiples of 50 and 10. Individual investors rely more on round-number heuristics; they submit 4.1% of their orders at prices that are multiples of 100. For institutional investors, the limit order clustering phenomenon is less significant, with only 1.6% of limit orders submitted at prices that are multiples of 100. The result also shows a large cross-sectional heterogeneity in the submission ratios at round-number prices.

We find a negative relationship between cognitive limitation and investor performance. Individual investors with lower cognitive abilities, defined by a higher submission ratio at round numbers, experience significantly lower intraday, 1-day, and 5-day returns. The underperformance appears for limit orders submitted at both round-numbered and non-round-number prices, for market orders, and for realized round-trips. Investors behave in a similar fashion in the options market. Investors with lower cognitive abilities also exhibit inferior longer-term investment performance.

Our findings suggest that for individual investors who are cognitively constrained, trading on their own could result in poor investment performance. One way that individual investors can self-check whether they are cognitively constrained is by looking at their submission ratio at round-number prices. That being said, we also find that the number of limit orders submitted in the previous year helps to reduce individual investors' propensity to submit limit orders with round-number prices. Learning by trading more frequently mitigates individual investors' reliance on the round-number heuristics and improves their future investment decisions.

References

Ahn, H., J. Cai, and Y. Cheung. 2005. Price Clustering on the limit-order book: Evidence from the Stock Exchange of Hong Kong. *Journal of Financial Markets* 8: 421–451.

Aitken, M., P. Brown, C. Buckland, H. Izan, and T. Walter. 1996. Price clustering on the Australian Stock Exchange. *Pacific-Basin Finance Journal* 4: 297–413.

Ball, C., W. Torous, and A. Tschoegl. 1985. The degree of price resolution: The case of the gold market. *Journal of Futures Markets* 5: 29–43.

Barder, B. M., and T. Odean. 2000. Trading is hazardous to your wealth: The common stock investment performance of individual investors. *Journal of Finance* 55: 773–806

Barber, B. M., and T. Odean. 2008. All that glitters: The effect of attention and news on the buying behavior of individual institutional investors. *Review of Financial Studies* 21: 785–818.

Barber, B. M., Y. Lee, Y. Liu, and T. Odean. 2009. Just how much do individual investors lose by trading? *Review of Financial Studies* 22: 609–632.

Bhattacharya, U., C. W. Holden, and S. Jacobsen. 2012. Penny wise, dollar foolish: Buy-sell imbalances on and around round numbers. *Management Science* 58: 413–431.

Booth, G., J. Kallunki, J. Lin, and T. Martikainen. 2000. Internalization and stock price clustering: Finish evidence. *Journal of International Money and Finance* 19: 737–751.

Bourghelle, D. and A. Cellier. 2009. Limit order clustering and price barriers on financial markets: Empirical evidence from Euronext. Working paper, University of Lille.

Boyer, B., T. Mitton, and K. Vorkink. 2010. Expected idiosyncratic skewness. *Review of Financial Studies* 23: 169–202.

Brown, P., A. Chua, and J. Mitchell. 2002. The influence of cultural factors on price clustering: Evidence from Asia-Pacific stock markets. *Pacific-Basin Finance Journal* 10: 307–332.

Brown, P. and J. Mitchell. 2008. Culture and stock price clustering: Evidence from The Peoples' Republic of China. *Pacific-Basin Finance Journal* 16: 95–120.

Chevalier, J., and G. Ellison. 1999. Are some mutual fund managers better than others? Cross-sectional patterns in behavior and performance. *Journal of Finance* 54: 875–899.

Chiang, Y., D. Hirshleifer, Y. Qian, and A. E. Sherman. 2011. Do investors learn from experience? Evidence from frequent IPO investors. *Review of Financial Studies* 24: 1560–1589.

Chiao, C. and Z. Wang. 2009. Price clustering: Evidence using comprehensive limit-order data. *The Financial Review* 44: 1–29.

Choi, J. J., D. Laibson, B. C. Madrian, and A. Metrick. 2009. Reinforcement Learning and Savings Behavior. *Journal of Finance* 64: 2515–2534.

Christie, W., and P. Schultz. 1994. Why do NASDAQ market makers avoid odd-eighth quotes? *Journal of Finance* 49: 1813–1840.

Christie, W., J. Harris, and P. Schultz. 1994. Why did NASDAQ market makers stop avoiding odd-eighth quotes? *Journal of Finance* 49: 1841–1860.

Dhar, R., and N. Zhu. 2006. Up close and personal: Investor sophistication and the disposition effect. *Management Science* 52: 726–740.

Feng, L., and M. Seasholes. 2005. Do investor sophistication and trading experience eliminate behavioral biases in financial markets? *Review of Finance* 9: 305–351.

Goodhart, C. and R. Curcio. 1991. The clustering of bid/ask prices and the spread in the foreign exchange market. FMG Discussion Paper 110, Financial Markets Group, London.

Gilovich, T., D. Griffin, and D. Kahneman, editors. 2002. Heuristics and biases: The Psychology of Intuitive Judgement. New York, Cambridge University Press.

Gottesman, A., and M. Morey. 2006. Manager education and mutual fund performance. *Journal of Empirical Finance* 13: 145–182.

Grinblatt, M., M. Keloharju, and J. Linnainmaa. 2012. IQ, trading behavior, and performance. *Journal of Financial Economics* 104: 339–362.

Gwilym O., A. Clare, and S. Thomas. 1998a. Price clustering and bid-ask spreads in international bond futures. *Journal of international financial markets institutions and money* 8: 379–394.

Gwilym O., A. Clare, and S. Thomas. 1998b. Extreme price clustering in the London equity index futures and options markets. *Journal of Banking and Finance* 22(9): 1193–1206.

Harris, L. 1991. Stock price clustering and discreteness. *Review of Financial Studies* 4: 389–415.

Hendershott, T., C. Jones, and A. Menkveld. 2010. Does algorithmic trading improve liquidity? *Journal of Finance* 66: 1–33.

Hirshleifer, D., S. S. Lim, and S. H. Teoh. 2009. Driven to distraction: Extraneous events and underreaction to earnings news. *Journal of Finance* 64: 2289–2325

Jordan, D., and D. Diltz. 2003. The profitability of day traders. *Financial Analysts Journal* 59: 85–95.

Kuo, W. and T. Lin. 2013. Overconfident Individual Day Traders: Evidence from Taiwan Futures Market. *Journal of Banking and Finance* 37: 3548–3561.

Lacetera, N., D. G. Pope, and J. R. Sydnor. 2012. Heuristic thinking and limited attention in the car market. *American Economic Review* 102: 2206–2236.

Lee, C. and M. Ready. 1991. Inferring trade direction from intraday data. *Journal of Finance* 46: 733–746.

Ley, E., H. R. Varian. 1994. Are there psychological barriers in the Dow-Jones Index? *Applied Financial Economics* 4: 217–114.

Li, H. C., C. H. Lin, T. Y. Cheng, and S. Lai. 2012. How different types of traders behave in the Taiwan Futures Market? *Journal of Futures Markets* 33: 1097–1117.

Linnainmaa, J. T. 2010. Do limit orders alter inferences about investor performance and behavior? *Journal of Finance* 65: 1473–1506.

Liu, Y., C. Tsai, M. Wang, and N. Zhu. 2010. Prior consequences and subsequent risk taking: New field evidence from the Taiwan Futures Exchange. *Management Science* 56: 606–620.

Locke, P. R., and S. C. Mann. 2005. Professional trader discipline and trade disposition. *Journal of Financial Economics* 76: 401–44.

Neiderhoffer, V. 1965. Clustering of stock prices. *Operations Research* 13: 258–265.

Neiderhoffer, V. 1966. A new look at clustering of stock prices. *Journal of Business* 39: 390–413.

Odean, T. 1998. Are investors reluctant to realize their losses? *Journal of Finance* 53: 1775–1798.

Osler, C. L. 2003. Currency orders and exchange rate dynamics: An explanation for the predictive success of technical analysis. *Journal of Finance* 58: 1791–1818.

Palmon, O., B. Smith, and B. Sopranzetti. 2004. Clustering in real estate prices: Determinants and consequences. *Journal of Real Estate Research* 26: 115–136.

Simon, H. A. 1955. A behavioral model of rational choice. *Quarterly Journal of Economics* 69: 99–118.

Rosch, E. 1975. Cognitive reference point. *Cognitive Psychology* 7: 532–547.

Schindler, R. and P. Kirby. 1997. Patterns of rightmost digits used in advertised prices: Implications for nine-ending effects. *Journal of Consumer Research* 24: 192–201.

Seasholes, M. and N. Zhu. 2010. Individual investors and local bias. *Journal of Finance* 65: 1987–2010.

Seru, A., T. Shumway, and N. Stoffman. 2010. Learning by trading. *Review of Financial Studies* 23: 705–739.

Sonnemans, J. 2005. Price clustering and natural resistance points in the Dutch stock market: A nature experiment. *European Economic Review* 50: 1937–1950.

Sopranzetti, B. and V. Datar. 2002. Price clustering in foreign exchange spot markets. *Journal of Financial Markets* 5: 411–417.

Strahilevitz, M. A., T. Odean, and B. M. Barber. 2011. Once burned, twice shy: How naïve learning, counterfactuals, and regret affect the repurchase of stocks previously sold. *Journal of Marketing Research* 68. 102–120.

Subrahmanyam, A. 1991. A theory of trading in stock index futures. *Review of Financial Studies* 4: 17–51.

Yuan, Y. 2012. Market-Wide Attention, Trading, and Stock Returns. Working paper, Shanghai Advanced Institute of Finance and University of Pennsylvania.

Table 1. Descriptive Statistics of Limit Order Quotes and Trades

Panel A: Number of Limit Orders Submitted

Year	Total	Investor type		Product type	
		Individual	Institutional	MXF	TXF
2003	8,391,970	7,874,288	517,682	2,460,478	5,931,492
2004	11,756,902	10,436,137	1,320,765	3,821,759	7,935,143
2005	9,336,187	7,171,025	2,165,162	2,482,810	6,853,377
2006	16,080,187	10,088,540	5,991,647	4,943,571	11,136,616
2007	26,218,095	13,297,493	12,920,602	10,489,454	15,728,641
2008	36,699,943	18,251,513	18,448,430	14,855,950	21,843,993
Total	108,483,284	67,118,996	41,364,288	39,054,022	69,429,262
Ratio	100.00%	61.87%	38.13%	36.00%	64.00%

Panel B: Number of Limit Order Contracts Submitted

Year	Total	Investor type		Product type	
		Individual	Institutional	MXF	TXF
2003	19,945,949	16,859,030	3,086,919	3,411,265	16,534,684
2004	30,930,065	22,720,915	8,209,150	6,600,858	24,329,207
2005	28,661,053	18,980,375	9,680,678	4,953,050	23,708,003
2006	50,802,391	25,136,643	25,665,748	14,261,405	36,540,986
2007	88,136,766	27,900,386	60,236,380	38,522,631	49,614,135
2008	103,837,651	32,290,826	71,546,825	46,157,645	57,680,006
Total	322,313,875	143,888,175	178,425,700	113,906,854	208,407,021
Ratio	100.00%	44.64%	55.36%	35.34%	64.66%

Panel C: Number of Limit Order Contracts Executed

Year	Total	Investor type		Product type	
		Individual	Institutional	MXF	TXF
2003	11,873,156	9,783,808	2,089,348	1,886,517	9,986,639
2004	16,906,816	12,754,376	4,152,440	2,875,775	14,031,041
2005	13,243,799	8,893,996	4,349,803	1,656,836	11,586,963
2006	18,869,565	12,509,174	6,360,391	2,588,846	16,280,719
2007	23,168,312	14,571,645	8,596,667	4,311,353	18,856,959
2008	27,763,746	18,418,047	9,345,699	8,095,657	19,668,089
Total	111,825,394	76,931,046	34,894,348	21,414,984	90,410,410
Ratio	100.00%	68.80%	31.20%	19.15%	80.85%

This table reports the summary statistics of the limit orders quotes and trades for two major Taiwan index futures in the Taiwan Futures Exchange from January 2003 to September 2008. In 2008, we only have orders and trades data from January to September. The number of limit orders submitted, the number of limit order contracts submitted, and the number of limit order contracts executed is reported in Panel A, B, and C, respectively. The number of limit orders (contracts) is reported separately for individual investors and institutional investors, and for Taiwan Stock Exchange Futures (TXF) and Mini-Taiwan Stock Exchange Futures (MXF).

Table 2. Limit Order Clustering at Round Number Prices

Independent Variables	Parameter Estimates						
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Intercept	-0.001***	-0.002***	-0.001***	-0.002***	-0.001***	-0.001***	-0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
D_{00}	0.021***	0.017***	0.010***	0.013***	0.010***	0.019***	0.011***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
D_{50}	0.014***	0.013***	0.005***	0.011***	0.005***	0.013***	0.006***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
D_{X0}	0.009***	0.009***	0.004***	0.008***	0.004***	0.008***	0.004***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$D_{00}\times D_{indv}$			0.022***		0.020***		0.019***
			(0.000)		(0.000)		(0.000)
$D_{50}\times D_{indv}$			0.018***		0.015***		0.015***
			(0.000)		(0.000)		(0.000)
$D_{X0}\times D_{indv}$			0.010***		0.008***		0.008***
			(0.000)		(0.000)		(0.000)
$D_{00}\times D_{MXF}$				0.006		-0.011**	-0.003
				(0.212)		(0.022)	(0.510)
$D_{50}\times D_{MXF}$				0.004		-0.007**	-0.000
				(0.315)		(0.020)	(0.992)
$D_{X0}\times D_{MXF}$				0.002***		-0.004***	0.000
				(0.004)		(0.000)	(0.623)
$D_{00}\times D_{indv}\times D_{MXF}$					0.005**	0.025***	0.007
					(0.034)	(0.000)	(0.117)
$D_{50}\times D_{indv}\times D_{MXF}$					0.006***	0.020***	0.006**
					(0.001)	(0.000)	(0.043)
$D_{X0}\times D_{indv}\times D_{MXF}$					0.003***	0.011***	0.003***
					(0.000)	(0.000)	(0.000)
$Distance_{XY}$		0.962**	-0.100	1.248***	-0.014	0.210	-0.096
		(0.012)	(0.458)	(0.000)	(0.917)	(0.435)	(0.483)
Number of obs.	2,400	2,400	2,400	2,400	2,400	2,400	2,400
Adjusted R^2	0.553	0.564	0.741	0.572	0.750	0.684	0.750
D_{00}-D_{X0}	0.012***	0.008***	0.06**	0.005**	0.006**	0.009***	0.007***
	(0.000)	(0.004)	(0.013)	(0.011)	(0.019)	(0.000)	(0.000)
D_{50}-D_{X0}	0.005***	0.004**	0.001**	0.003*	0.003	0.005**	0.002**
	(0.009)	(0.020)	(0.223)	(0.099)	(0.239)	(0.048)	(0.013)
D_{00}-D_{50}	0.007**	0.004	0.005**	0.004	0.002	0.006**	0.005***
	(0.047)	(0.277)	(0.082)	(0.691)	(0.102)	(0.079)	(0.003)

This table reports the parameter estimates of the following regression:

$$SubRatio_{XY} - 0.01 = \alpha + \beta_1 D_{00} + \beta_2 D_{50} + \beta_3 D_{X0} + \beta_4 D_{00} \times D_{indv} + \beta_5 D_{50} \times D_{indv} + \beta_6 D_{X0} \times D_{indv} + \beta_7 D_{00} \times D_{MXF} + \beta_8 D_{50} \times D_{MXF} + \beta_9 D_{X0} \times D_{MXF} + \beta_{10} D_{00} \times D_{indv} \times D_{MXF} + \beta_{11} D_{50} \times D_{indv} \times D_{MXF} + \beta_{12} D_{X0} \times D_{indv} \times D_{MXF} + Distance_{XY} + \varepsilon_{XY}$$

The dependent variable is the deviation of the actual submission ratio at "XY" price point from its theoretical value assuming uniform distribution of the limit order prices (X and Y are integer numbers ranging from 0 to 9). Each Year, submission ratios are calculated separately for individual and institutional investors and for MXF and TXF orders. D_{00}, D_{50}, and D_{X0} are dummy variables for price points "00," "50", and "X0" (X≠0 , 5). D_{indv} and D_{MXF} are indicators for orders submitted by individual investors and for Mini-Taiwan Stock Exchange Futures orders, respectively. $Distance_{XY}$ is the average distance of limit order price from the last trade price for limit orders submitted at "XY" price points. For each limit order, the distance is calculated as the absolute difference between the limit order price and the last trade price scaled by the last trade price. In the last three rows we report results for the F-tests for $\beta_1 = \beta_2 = \beta_3$. *, **, and *** indicate significance levels of 0.1, 0.05, and 0.01, respectively.

Table 3. Submission Ratio at "X0" and Investors' Descriptive Statistics in Two Consecutive Years

Panel A: Individual Investors

Quintile Ranks	Q1	Q2	Q3	Q4	Q5	Diff (Q5-Q1)	p-value
Number of investor-year obs.	30,675	30,872	30,820	30,660	30,803		
Statistics in the previous year							
Number of limit orders submitted	417	252	175	139	110		
Number of limit order contracts submitted	1,074	693	351	243	212		
Number of limit order contracts executed	509	391	195	138	101		
Limit order submission ratio at "X0"	0.092	0.193	0.286	0.403	0.625		
Execution ratio	0.861	0.893	0.875	0.844	0.762		
Time-to-execute (s)	400	318	389	522	863		
Statistics in the current year							
Number of limit orders submitted	462	293	196	158	131		
Number of limit order contracts submitted	1,193	790	385	266	240		
Number of limit contracts executed	545	442	225	155	122		
Limit order submission ratio at "X0"	0.145	0.229	0.301	0.389	0.550	0.405***	0.000
Execution ratio	0.870	0.896	0.882	0.855	0.793	-0.077***	0.000
Time-to-execute (s)	375	314	379	482	747	372***	0.000

Panel B: Institutional Investors

Quintile Ranks	Q1	Q2	Q3	Q4	Q5	Diff (Q5-Q1)	p-value
Number of investor-year obs.	466	470	467	474	464		
Statistics in the previous year							
Number of limit orders submitted	29,788	15,332	974	320	346		
Number of limit order contracts submitted	137,889	71,065	6,107	1,763	1,144		
Number of limit order contracts executed	22,414	22,309	4,307	1,174	820		
Limit order submission ratio at "X0"	0.083	0.146	0.201	0.298	0.524		
Execution ratio	0.899	0.930	0.916	0.900	0.842		
Time-to-execute (s)	266	190	219	282	484		
Statistics in the current year							
Number of limit orders submitted	42,376	36,093	973	2,272	526		
Number of limit order contracts submitted	164,611	176,016	5,576	7,560	1,983		
Number of limit contracts executed	24,724	30,536	4,142	1,209	1,364		
Limit order submission ratio at "X0"	0.143	0.181	0.224	0.287	0.403	0.260***	0.000
Execution ratio	0.916	0.941	0.922	0.912	0.869	-0.047***	0.000
Time-to-execute (s)	240	170	207	223	402	162***	0.001

In this table we sort investors into quintiles by their limit order submission ratio at “X0” in the previous year, and report the descriptive statistics for the investor-year pair with two consecutive years limit order submission history (X is an integer ranging from 0 to 9). Quintile-5 (Q5) investors have the highest submission ratio. Execution ratio is the proportion of contracts executed for undeleted limit orders. Time-to-execute is the interval between the order submission time and the execution time for all executed limit order contracts. All items are first calculated for each investor-year observation and then averaged up in each quintile. Results for individual and institutional investors are reported separately. To ensure reasonable submission ratio at “X0”, we require that investors must submit at least 10 limit orders in each of the two consecutive years. The Satterthwaite p-value assumes unequal variances of investor performance in quintiles 1 and 5. *, **, and *** indicate significance levels of 0.1, 0.05, and 0.01, respectively.

Table 4. Submission Ratio at "X0" and Mark-to-market Return of Limit Orders

Panel A: Individual Investors

Quintile Ranks	Q1	Q2	Q3	Q4	Q5	Diff (Q5-Q1)	p-value
Intraday return (%)	-0.068	-0.077	-0.085	-0.097	-0.107	-0.039***	0.000
1-day return (%)	-0.095	-0.110	-0.124	-0.144	-0.167	-0.072***	0.000
5-day return (%)	-0.147	-0.188	-0.222	-0.250	-0.290	-0.143***	0.000

Panel B: Institutional Investors

Quintile Ranks	Q1	Q2	Q3	Q4	Q5	Diff (Q5-Q1)	p-value
Intraday return (%)	0.019	0.020	0.016	-0.014	-0.062	-0.081***	0.000
1-day return (%)	-0.036	0.048	0.047	-0.055	-0.090	-0.054	0.230
5-day return (%)	-0.006	0.023	0.106	-0.022	-0.284	-0.278***	0.004

In this table we sort investors into quintiles by their limit order submission ratio at "X0" in the previous year, and report the descriptive statistics for the investor-year pair with two consecutive years limit order submission history (X is an integer ranging from 0 to 9). Quintile-5 (Q5) investors have the highest submission ratio. Execution ratio is the proportion of contracts executed for undeleted limit orders. Time-to-execute is the interval between the order submission time and the execution time for all executed limit order contracts. All items are first calculated for each investor-year observation and then averaged up in each quintile. Results for individual and institutional investors are reported separately. To ensure reasonable submission ratio at "X0", we require that investors must submit at least 10 limit orders in each of the two consecutive years. The Satterthwaite p-value assumes unequal variances of investor performance in quintiles 1 and 5. *, **, and *** indicate significance levels of 0.1, 0.05, and 0.01, respectively.

Table 5. Submission Ratio at "X0" and Mark-to-market Return of Limit Orders Submitted at "X0" Prices and Non-"X0" Prices

Panel A: Individual Investors

Quintile Ranks	Q1	Q2	Q3	Q4	Q5	Diff (Q5-Q1)	p-value
Performance of limit orders submitted at "X0" prices							
Intraday return (%)	-0.052	-0.078	-0.085	-0.097	-0.114	-0.062***	0.000
1-day return (%)	-0.068	-0.108	-0.122	-0.139	-0.173	-0.105***	0.000
5-day return (%)	-0.101	-0.167	-0.201	-0.250	-0.308	-0.207***	0.000
Performance of limit orders submitted at non-"X0" prices							
Intraday return (%)	-0.069	-0.075	-0.084	-0.095	-0.095	-0.026***	0.000
1-day return (%)	-0.097	-0.111	-0.123	-0.143	-0.158	-0.061***	0.000
5-day return (%)	-0.151	-0.196	-0.218	-0.236	-0.259	-0.108***	0.000

Panel B: Institutional Investors

Quintile Ranks	Q1	Q2	Q3	Q4	Q5	Diff (Q5-Q1)	p-value
Performance of limit orders submitted at "X0" prices							
Intraday return (%)	0.019	0.064	0.018	0.032	-0.058	-0.077**	0.014
1-day return (%)	-0.049	0.079	0.096	0.108	0.004	0.054	0.406
5-day return (%)	-0.011	0.025	-0.017	0.082	-0.200	-0.190	0.163
Performance of limit orders submitted at non-"X0" prices							
Intraday return (%)	0.022	0.011	0.019	-0.028	-0.044	-0.066**	0.017
1-day return (%)	-0.033	0.029	0.014	-0.105	-0.112	-0.080	0.125
5-day return (%)	-0.008	0.027	0.097	-0.045	-0.345	-0.337***	0.002

In this table we sort investors into quintiles by their limit order submission ratio at "X0" in the previous year, and report the current year's performance of limit orders separately for those submitted at "X0" prices and non-"X0" prices (X is an integer ranging from 0 to 9). Quintile-5 (Q5) investors have the highest submission ratio. Mark-to-market intraday returns of limit orders are 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. Only initiating limit orders are included into this calculation. All items are first calculated for each investor-year pair and then averaged up in each quintile. Results for individual and institutional investors are reported separately. To ensure reasonable submission ratio at "X0", we require that investors must submit at least 10 limit orders in each of the two consecutive years. The Satterthwaite p-value assumes unequal variances of investor performance in quintiles 1 and 5. *, **, and *** indicate significance levels of 0.1, 0.05, and 0.01, respectively.

Table 6. Number of "XY"s Where Investors with Least Cognitive Abilities Underperform

Panel A: Individual Investors

Significance Level	Number of price points where Quintile-5 investors underperform Quintile-1 investors		
	Intraday return	1-day return	5-day return
p≤1	98	99	98
p<0.1	91	94	86
p<0.05	89	88	79
p<0.01	86	83	69

Panel B: Institutional Investors

Significance Level	Number of price points where Quintile-5 investors underperform Quintile-1 investors		
	Intraday return	1-day return	5-day return
p≤1	44	33	80
p<0.1	27	17	65
p<0.05	22	17	60
p<0.01	17	14	52

In this table, we sort investors into quintiles based on their limit order submission ratio at "X0" in the previous year, and report the number of "XY"s where Quintile-5 investors (significantly) underperform Quintile-1 investors in the current year (X and Y are integers ranging from 0 to 9). The underperformance is determined by looking at the intraday, 1-day, as well as 5-day mark-to-market return of limit orders. The intraday mark-to-market 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. Only initiating limit orders are included into this calculation. The significance level is indicated by Satterthwaite p-value, which assumes unequal variances of investor performance in quintile 1 and 5. To ensure reasonable submission ratio at "X0", we require that investors must submit at least 10 limit orders in each of the two consecutive years.

Table 7. Submission Ratio at "X0" and Mark-to-market Return of Market Orders

Panel A: Individual Investors

Quintile Ranks	Q1	Q2	Q3	Q4	Q5	Diff (Q5-Q1)	p-value
Intraday return (%)	-0.022	-0.047	-0.053	-0.053	-0.071	-0.049***	0.000
1-day return (%)	-0.052	-0.080	-0.095	-0.104	-0.131	-0.079***	0.000
5-day return (%)	-0.105	-0.173	-0.204	-0.212	-0.223	-0.119***	0.000

Panel B: Institutional Investors

Quintile Ranks	Q1	Q2	Q3	Q4	Q5	Diff (Q5-Q1)	p-value
Intraday return (%)	-0.055	0.033	0.010	-0.041	-0.074	-0.019	0.692
1-day return (%)	-0.122	-0.141	-0.020	-0.053	-0.067	0.055	0.616
5-day return (%)	-0.151	-0.243	0.037	0.236	-0.132	0.019	0.930

In this table we sort investors into quintiles by their limit order submission ratio at "X0" in the previous year, and report the mark-to-market intraday, 1-day and 5-day returns of market orders in the current year (X is an integer ranging from 0 to 9). Quintile-5 (Q5) investors have the highest submission ratio. Mark-to-market intraday returns of market orders are 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. Only initiating market orders are included into this calculation. All items are first calculated for each investor-year pair and then averaged up in each quintile. Results for individual and institutional investors are reported separately. To ensure reasonable submission ratio at "X0", we require that investors must submit at least 10 limit orders in each of the two consecutive years. The Satterthwaite p-value assumes unequal variances of investor performance in quintiles 1 and 5. *, **, and *** indicate significance levels of 0.1, 0.05, and 0.01, respectively.

Table 8. Submission Ratio at "X0" and the Performance of Round-trip Trades

Panel A: Individual Investors

Quintile Ranks	Q1	Q2	Q3	Q4	Q5	Diff (Q5-Q1)	p-value
Daily profit (TWD)	-1,045	-1,930	-2,148	-2,301	-2,042	-997***	0.000
Daily index return (%)	-0.078	-0.164	-0.189	-0.209	-0.180	-0.102***	0.000
Number of round-trips	73	63	53	44	37	-36***	0.000
Round-trip duration (day)	2.128	2.115	2.335	2.578	3.277	1.149***	0.000
Duration of winning round-trips (day)	1.739	1.750	1.977	2.137	2.670	0.932***	0.000
Duration of losing round-trips (day)	2.925	2.882	3.103	3.460	4.429	1.504***	0.000

Panel B: Institutional Investors

Quintile Ranks	Q1	Q2	Q3	Q4	Q5	Diff (Q5-Q1)	p-value
Daily profit (TWD)	71,481	60,816	62,337	15,420	20,592	-50,888**	0.046
Daily index return (%)	5.786	4.993	4.402	1.738	1.742	-4.044**	0.032
Number of round-trips	95	69	44	48	29	-66***	0.003
Round-trip duration (day)	5.087	6.146	5.432	4.510	5.002	-0.085	0.866
Duration of winning round-trips (day)	4.816	5.783	5.221	4.372	4.927	0.112	0.835
Duration of losing round-trips (day)	5.116	6.282	5.391	4.830	4.732	-0.384	0.427

In this table we sort investors into quintiles by their limit order submission ratio at "X0" in the previous year, and report the round-trip performance in the current year (X is an integer ranging from 0 to 9). Quintile-5 (Q5) investors have the highest 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 as the average round-trip profit or index return divided by the average round-trip duration. All items are first calculated for each investor-year pair and then averaged up in each quintile. Results for individual and institutional investors are reported separately. To ensure reasonable submission ratio at "X0", we require that investors must submit at least 10 limit orders in each of the two consecutive years. And we truncate the investors at 0.5% level on both sides by their round-trip daily profit to exclude outliers. The Satterthwaite p-value assumes unequal variances of investor performance in quintiles 1 and 5. *, **, and *** indicate significance levels of 0.1, 0.05, and 0.01, respectively.

Table 9. Panel Regression Analysis for Submission Ratio at "X0" and Investment Performance

Panel A: Individual Investors

Independent Variables	Mark-to-market return of limit orders (%)			Mark-to-market return of market orders (%)			Performance of round-trip trades	
	Intraday return	1-day return	5-day return	Intraday return	1-day return	5-day return	Daily profit (TWD)	Daily index return (%)
$SubRatio_{X0,i,t-1}$	-0.051***	-0.101***	-0.208***	-0.062***	-0.117***	-0.169***	-1,486.976**	-0.162***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.019)	(0.001)
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.038]	[0.003]
$Ln(N_{i,t-1})$	0.011***	0.016***	0.020***	0.012***	0.016***	0.015**	1,176.185***	0.107***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.014)	(0.000)	(0.000)
	[0.002]	[0.002]	[0.002]	[0.002]	[0.002]	[0.013]	[0.006]	[0.002]
$Disposition_{i,t}$	-0.020***	-0.050***	-0.157***	-0.015***	-0.041***	-0.123***	-4,770.539***	-0.413***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Intercept	-0.117***	-0.156***	-0.276***	-0.065***	-0.100***	-0.156***	-6,285.092***	-0.533***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.001]	[0.000]
Year Fixed-effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of obs.	146,151	146,140	145,897	83,953	83,804	81,903	146,619	146,619
Adjusted R^2	0.018	0.011	0.019	0.004	0.003	0.003	0.003	0.004

Panel B: Institutional Investors

Independent Variables	Mark-to-market return of limit orders (%)			Mark-to-market return of market orders (%)			Performance of round-trip trades	
	Intraday return	1-day return	5-day return	Intraday return	1-day return	5-day return	Daily profit (TWD)	Daily index return (%)
$SubRatio_{X0,i,t-1}$	-0.204***	-0.217**	-0.583***	-0.055	0.183	0.364	14,061.936	2.218
	(0.000)	(0.014)	(0.003)	(0.596)	(0.395)	(0.389)	(0.820)	(0.615)
	[0.000]	[0.097]	[0.004]	[0.182]	[0.438]	[0.103]	[0.413]	[0.423]
$Ln(N_{i,t-1})$	-0.003	-0.003	0.002	0.014*	-0.001	0.057	37,971.693**	3.543***
	(0.459)	(0.651)	(0.922)	(0.053)	(0.939)	(0.147)	(0.037)	(0.009)
	[0.164]	[0.048]	[0.048]	[0.024]	[0.438]	[0.050]	[0.138]	[0.055]
$Disposition_{i,t}$	-0.044***	-0.101***	-0.213***	-0.006	-0.011	-0.188**	-156,989.673***	-11.664***
	(0.000)	(0.000)	(0.000)	(0.755)	(0.810)	(0.040)	(0.000)	(0.000)
	[0.000]	[0.000]	[0.000]	[0.440]	[0.082]	[0.015]	[0.000]	[0.000]
Intercept	0.068	0.028	0.045	0.010	0.015	0.083	1,783.356	-1.789
	(0.108)	(0.689)	(0.763)	(0.882)	(0.921)	(0.799)	(0.982)	(0.759)
	[0.116]	[0.740]	[0.643]	[0.044]	[0.812]	[0.919]	[0.582]	[0.253]
Year Fixed-effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of obs.	2,013	2,013	2,009	1,114	1,108	1,073	2,022	2,022
Adjusted R^2	0.032	0.025	0.022	0.011	0.010	0.008	0.054	0.061

In this table we report the parameter estimates for the following panel regression: $Return_{i,t} = \alpha + \beta_1 SubRatio_{X0,i,t-1} + \beta_2 Ln(N_{i,t-1}) + \beta_3 Disposition_{i,t} + \varepsilon_{i,t}$ where $Return_{i,t}$ is the average mark-to-market returns or round-trip performance for investor *i* at year *t*. $SubRatio_{X0,i,t-1}$ is investor *i*'s submission ratio at "X0" price points in the previous year (X is an integer ranging from 0 to 9). $Ln(N_{i,t-1})$ is the log of number of limit orders submitted in the previous year. $Disposition_{i,t}$ is the difference between the current year's duration of losing and winning round-trips, divided by the average of the two. Mark-to-market 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. Results for individual and institutional investors are reported separately. Standard errors are adjusted for heteroskedasticity. We also employ block-bootstrapping strategy to test the significance of the parameter estimates. For each year *t*, we select with replacement M_t observations, where M_t is the number of observations at year t in the original sample. We then combine the selected observations from 2004 to 2008 to form a new sample, perform the panel regression, and obtain the parameter estimates. We repeat this procedure 1,000 times, and report the empirical p-value from the block-bootstrapping strategy in brackets below the p-value from the original regression. To ensure reasonable submission ratio at "X0", we require that investors must submit at least 10 limit orders in each of the two consecutive years. *, **, and *** indicate significance levels of 0.1, 0.05, and 0.01, respectively.

Table 10. Submission Ratio at "X0", Market Return, and the Buy Ratio

Panel A: Individual Investors

Independent Variables	Limit order contracts		Market order contracts	
	Model 1	Model 2	Model 1	Model 2
$Return_{s,t,i}$	-4.937***	-1.234***	15.360***	3.840***
	(0.000)	(0.000)	(0.000)	(0.000)
$Rank\_SubRatio_{X0,s,t-1,i}$	0.027***	0.007***	0.034***	0.009***
	(0.000)	(0.000)	(0.000)	(0.000)
$Return_{s,t,i} \times Rank\_SubRatio_{X0,s,t-1,i}$	-1.774***	-0.444***	-1.368***	-0.342***
	(0.000)	(0.000)	(0.000)	(0.000)
Intercept	0.433***	0.608***	0.179***	0.545***
	(0.000)	(0.000)	(0.000)	(0.000)
Number of Obs.	68,770	68,770	39,624	39,624
Adjusted R^2	0.041	0.041	0.033	0.033

Panel B: Institutional Investors

Independent Variables	Limit order contracts		Market order contracts	
	Model 1	Model 2	Model 1	Model 2
$Return_{s,t,i}$	14.393***	3.598***	20.602***	5.150***
	(0.000)	(0.000)	(0.000)	(0.000)
$Rank\_SubRatio_{X0,s,t-1,i}$	0.021***	0.005***	0.025***	0.006***
	(0.000)	(0.000)	(0.000)	(0.000)
$Return_{s,t,i} \times Rank\_SubRatio_{X0,s,t-1,i}$	-2.090***	-0.522***	-0.870***	-0.218***
	(0.000)	(0.000)	(0.004)	(0.004)
Intercept	-0.231***	0.442***	-0.108***	0.473***
	(0.000)	(0.000)	(0.000)	(0.000)
Number of Obs.	32,261	32,261	14,344	14,344
Adjusted R^2	0.009	0.009	0.030	0.030

In this table, we report the parameter estimates for the following panel regression:
$BuyRatio_{s,t,i,RankSubRatio} = \alpha + \beta_1 Return_{s,t,i} + \beta_2\ Rank\_SubRatio_{X0,s,t-1,i} + \beta_3(Return_{s,t,i} \times Rank\_SubRatio_{X0,s,t-1,i}) + \varepsilon_{s,t,i,RankSubRatio}$
For each year *t*, each day *s*, and each product *i*, we sort market participants trading that product into deciles based on their submission ratio at "X0" in the previous year *t-1* (X is an integer ranging from 0 to 9). We employ two specifications for the calculation of $BuyRatio_{s,t,i,Rank\_SubRatio}$. In Model 1, we calculate it as the number of buy contracts (taking long positions) scaled by total number of contracts executed. In Model 2, we calculate it as the difference between the numbers of buy and sell contracts, divided by the average of the two. Product *i* could be MXF or TXF orders that expire in 1 month, two months, three months, six months, nine months, or one year. $Return_{s,t,i}$ is the return of product *i* at day *s* of year *t*. $Rank\_SubRatio_{X0,s,t-1,i}$ is the decile rank of investors trading product *i* at day *s*, classified by their limit order submission ratio at "X0" at year *t-1*. Both limit and market orders are included into this analysis. Results for individual and institutional investors are reported separately. To ensure reasonable submission ratio at "X0", we require that investors must submit at least 10 limit orders in each of the two consecutive years. Standard errors are adjusted for heteroskedasticity. *, **, and *** indicate significance levels of 0.1, 0.05, and 0.01, respectively.

Table 11. Trading Experience and the Change in Submission Ratio at "X0"

Panel A: Individual Investors

Independent Variables	Model 1	Model 2	Model 3
$Ln(N_{i,t-1})$	-0.007***		-0.005***
	(0.000)		(0.000)
$Return_{X0,i,t-1}$		-0.158*	-0.111
		(0.084)	(0.222)
$SubRatio_{X0,i,t-1}$	-0.262***	-0.238***	-0.246***
	(0.000)	(0.000)	(0.000)
$Disposition_{i,t}$	-0.001***	-0.002***	-0.001**
	(0.005)	(0.002)	(0.022)
Intercept	0.132***	0.093***	0.117***
	(0.000)	(0.000)	(0.000)
Year fixed-effect	Yes	Yes	Yes
Number of obs.	146,619	137,239	137,239
Adjusted R^2	0.153	0.139	0.141

Panel B: Institutional Investors

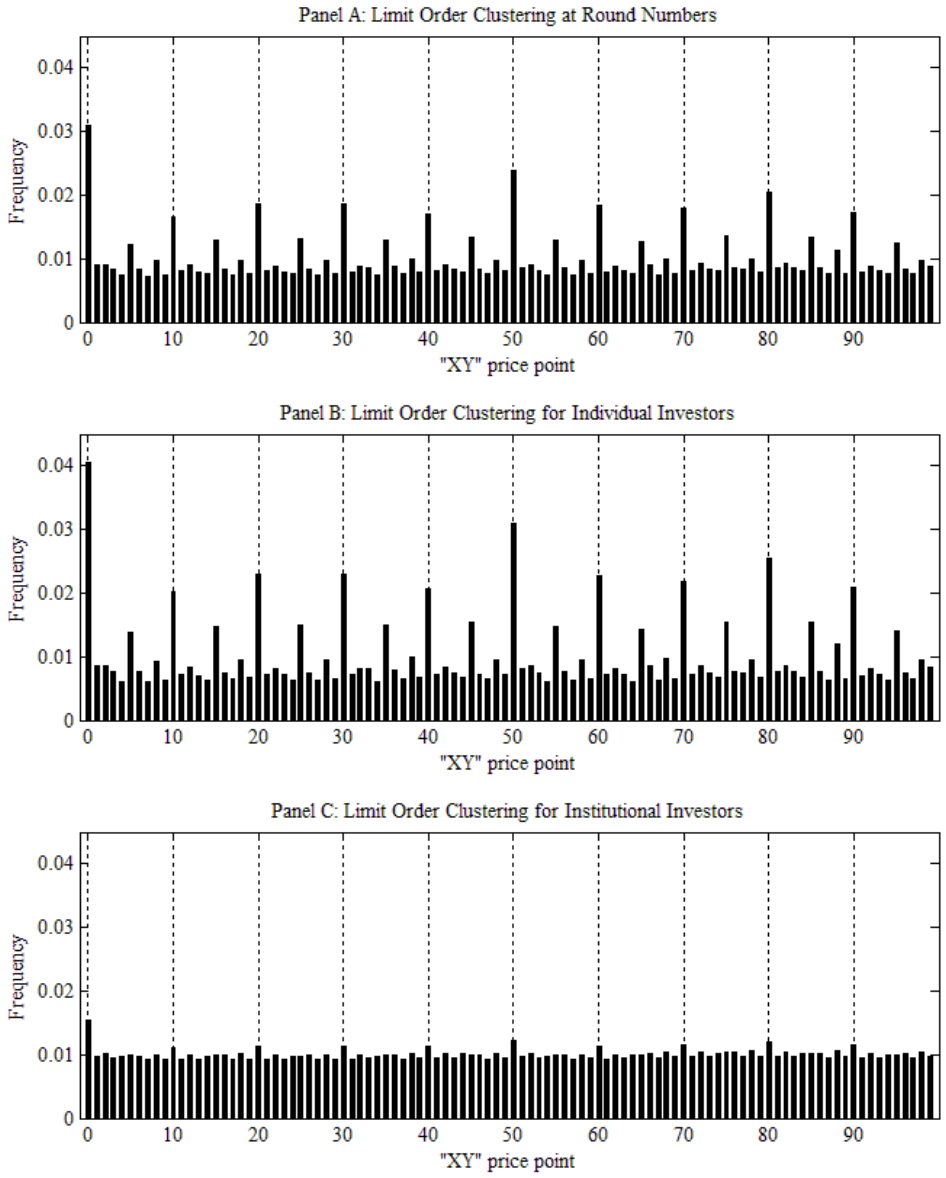
Independent Variables	Model 1	Model 2	Model 3
$Ln(N_{i,t-1})$	-0.004***		-0.003*
	(0.007)		(0.060)
$Return_{X0,i,t-1}$		-2.605***	-2.603***
		(0.000)	(0.000)
$SubRatio_{X0,i,t-1}$	-0.449***	-0.416***	-0.427***
	(0.000)	(0.000)	(0.000)
$Disposition_{i,t}$	0.012***	0.014***	0.014***
	(0.002)	(0.000)	(0.000)
Intercept	0.142***	0.108***	0.126***
	(0.000)	(0.000)	(0.000)
Year fixed-effect	Yes	Yes	Yes
Number of obs.	2,022	1,894	1,894
Adjusted R^2	0.286	0.273	0.274

In this table we report the parameter estimates for the following panel regression:

$$SubRatio_{X0,i,t} - SubRatio_{X0,i,t-1} = \alpha + \beta_1 Ln(N_{i,t-1}) + \beta_2\ SubRatio_{X0,i,t-1} + \beta_3\ Disposition_{i,t} + \beta_4\ Return_{X0,i,t-1} + \varepsilon_{i,t}$$

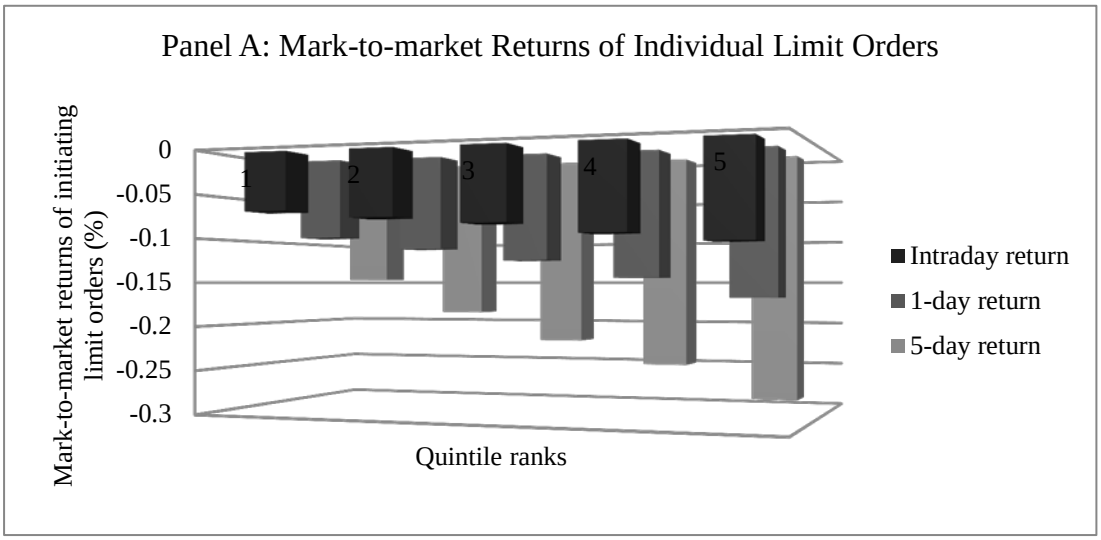
where $SubRatio_{X0,i,t}$ and $SubRatio_{X0,i,t-1}$ are the investor *i*'s submission ratio at "X0" price point in the current and previous year (X is an integer ranging from 0 to 9). $Ln(N_{i,t-1})$ is natural log of the number of limit orders submitted in the previous year. $Disposition_{i,t}$ is the difference between duration of losing and winning round-trips, divided by the average of the two. $Return_{X0,i,t-1}$ is the mark-to-market intraday return for limit orders submitted at "X0." To ensure reasonable submission ratio at "X0", we require that investors must submit at least 10 limit orders in each of the two consecutive years. Standard errors are adjusted for heteroskedasticity. *, **, and *** indicate significance levels of 0.1, 0.05, and 0.01, respectively.

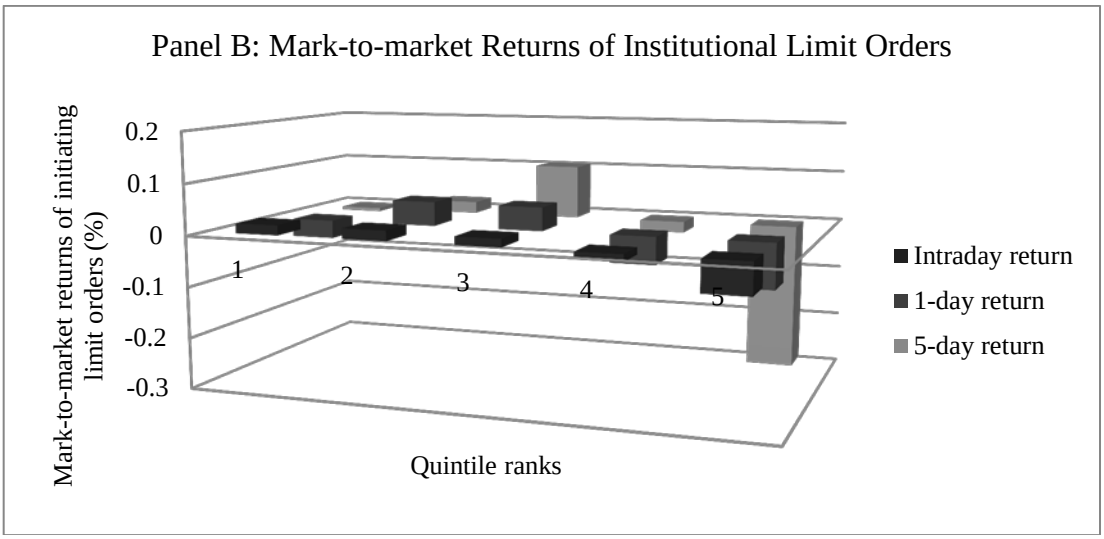
Figure 1. Limit Order Clustering at Round Number Prices



In this figure, we report the frequency of limit orders submitted at "XY" price points (X and Y are integers ranging from 0 to 9). The frequency is the submission ratio at “XY” price points, calculated as the number of limit orders submitted at "XY" divided by the total number of limit orders submitted at all different “XY”s. We first report the figure for limit orders submitted by all investors, and then for limit orders submitted by individual or institutional investors separately.

Figure 2. Submission Ratio at "X0" and Mark-to-market Return for Limit Orders





In this figure, we sort investors into quintiles by their limit order submission ratio at "X0" in the previous year, and plot the mark-to-market intraday, 1-day and 5-day returns of limit orders in the current year (X is an integer ranging from 0 to 9). The returns for individual and institutional limit orders are plotted in upper and lower panels, respectively. Quintile-5 (Q5) investors have highest submission ratio. Mark-to-market intraday returns of limit orders are 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. Only initiating limit orders are included into this calculation. All items are first calculated for each investor-year pair and then averaged up in each quintile. Results for individual and institutional investors are reported separately. To ensure reasonable submission ratio at "X0", we require that investors must submit at least 10 limit orders in each of the two consecutive years.

Internet Appendix A: Institutional Details of Taiwan Futures Exchange

1. Background and Trading Rules
2. Margin Rules
3. Why Do Individual Investors Actively Participate in TAIFEX?
4. Details of Index Futures Contracts and Index Options Contracts

A1: Background and Trading Rules

The Taiwan Futures Exchange (TAIFEX) introduced its first product, the futures contracts on the Taiwan Stock Exchange Capitalization Weighted Stock Index (hereafter TXF), on July 21st of 1998.[1] The trading of the mini version of TXF (hereafter MXF) with one-quarter of the margins and payoffs of TXF began on April 9th of 2001. The trading of index options contracts began on December 24th of 2001.

The transactions on TAIFEX were originally matched by an automated-batch call auction system during the trading period from 9:00 A.M. to 12:15 P.M. The trading period was extended on January 1, 2001 to the hours of 8:45 A.M. to 1:45 P.M. The call auction trading mechanism aggregates all orders submitted to the central limit order book for 15 minutes prior to the market opening at 8:45 A.M., and the opening price is determined by matching the largest number of submitted buy and sell orders. From the opening to 1:40 P.M., buy and sell orders submitted during a specified time interval are batched and executed at a single clearing price at which all buy (sell) orders with higher (lower) limit prices than the clearing price are executed. When the TXF was offered to trade on TAIFEX, an electronic periodic call auction trading mechanism was used during regular trading hours with a 30-second delay between call auctions. The time delay was reduced to 20 seconds on December 4th of 1998; decreased further to 10 seconds on December 6th of 1999, and finally eliminated on July 29th of 2002. Therefore, TAIFEX operates as a continuous auction market with the market opening and closing call auctions from July 30th of 2002 onwards.[2] During the last 5-minutes interval from 1:40 P.M to 1:45 P.M., orders are accumulated and are matched in a competitive call auction to establish the closing price at 1:45 P.M. As such, TAIFEX operates as an order-driven call market on a real-time basis according to price and time priority without the intermediation of designated market makers.

Investors are allowed to submit both market orders and limit orders to the Electronic Trading System (ETS). Market orders have higher price priority in trading than other marketable limit orders. An investor placing a market order to buy or sell more contracts than the amount currently outstanding at the best bid and ask prices would have to "walk up or down the book." Orders on TAIFEX are valid only for the current trading day and would not be included in the limit order book on future trading days even if they are not successfully executed. The information about the order submissions and transactions is disseminated to the public on a "real-time" basis through electronic screens, with information on the last traded

[1] During our sample period, the numbers of constituent company of the Taiwan Stock Exchange Capitalization Weighted Stock Index are 669, 697, 691, 688, 698, and 718 in the end of 2003, 2004, 2005, 2006, 2007, and 2008, respectively.

[2] Note that the 5-minute call auction that was used to determine the market closing price was terminated on October 8th of 2007. Since then, index futures and options contracts on TAIFEX are traded on a continuous auction basis after the market opening.

price, transaction volume, the best five bid and ask prices, and the outstanding contract numbers waiting to be executed at these prices.

A2: Margin Rules

TAIFEX adopts a pre-margin system in which an investor is required to deposit cash as the initial margin in her margin account before she is able to place orders. The initial margin is set to cover 99 per cent of a single-day price volatility risk based on stock price movements within certain periods of time. The maintenance margin is normally set at around the level of 75 per cent of initial margin. Note that the accrued interest of the deposited cash in the margin account does not belong to the investor. It belongs to the futures commission merchants and accounts for a visible portion of their operation profits.

As shown in Figure A1, the initial margin has experienced significant fluctuation during our sample period spanning from January 2003 to September 2008. In January 2003, it was 90,000 New Taiwan dollars (TWD) for a contract of TXF futures, decreased to 75,000 TWD in May 2003, and then fluctuated between 90,000 TWD and 120,000 TWD until February 2007. The initial margin reached its peak 195,000 on August 22nd of 2007 to contain the increasing market volatility induced by the subprime financial crisis. The initial margin then decreased afterwards to 87,000 TWD to the end of our sample period. The initial margin for the MXF futures contract was set at a quarter of that for the TXF futures contract during our sample period.

A3: Why Do Individual Investors Actively Trade in TAIFEX?

Unlike index futures and options markets in the US and the Europe, individual investors actively trade the index futures in TAIFEX. Table I of the revised draft shows that individual investors account for 61.9% (68.8%) of limit orders submitted (executed). It is surprising that individual investors in Taiwan have such high participation in trading these derivatives. In this subsection, we first look into the details of both their index futures and index options trading to understand the main motivation for trading index futures. We then propose some explanations based on the existing studies and stylized facts.

In general, the primary motivations of trading derivatives include speculation, hedging, and arbitrage. As investors are not required to specify the purpose of each transaction, it might be difficult for econometricians to accurately document how many investors are speculating, hedging, and arbitraging. Therefore, we try to infer investors' trading motivations from their transaction records. Essentially, for example, if an investor takes a long (short) position in index futures and sells (buys) an index call option with the same expiration date, we argue that the reason for this investor to trade index futures is more likely to be arbitraging or

hedging. On the contrary, if an investor just takes a long or short position in index futures without corresponding trades in the index options in the opposite direction, this investor might be just speculating for this trade.

We thus first identify index futures trades that can be matched to the index options trades with the same expiration dates and in the opposite trading directions from the same investor. We then calculate the ratio of these trades over total trades for individual and institutional investors separately. In the aggregate, the ratio is 35% for the individual investors and 86% for the institutional investors. In other words, there are 65% (14%) of individual (institutional) trades tend to be speculating as these trades do not have corresponding index options trades in the opposite directions. The result suggests that the speculation need seems to be the most important reason for individual investors to trade actively in TAIFEX.

Note that investors can also hedge or arbitrage by simultaneously trading the component stocks of the index and the index futures (index arbitrage strategies). Unfortunately, we do not have the detailed stock trading record data at the account level for our index futures investors. Even if the account level data from the Taiwan Stock Exchange is available to us, the two exchanges do not use the same account identifier, which makes the matching of the accounts in two exchanges impossible.

Nevertheless, index arbitrage strategies involve complicated calculation of theoretical prices and delicate implementation procedure to take advantage of significant deviations between the theoretical prices and actual prices of the index futures, the index options contracts, and the component stocks. This might be a difficult task for an average individual investor who lacks of professional knowledge of pricing derivatives contracts, sufficient capital to influence price movement of value stocks, and computer programs to facilitate the trading strategies. Although we are not able to completely rule out the possibility that some individual investors employ such index arbitrage or hedging strategies, we believe that such individual investors are relatively rare in TAIFEX.

Next, the natural question to ask is why do individual investors speculate so much in TAIFEX? We propose the following reasons according to the existing literature. First, the index futures contracts have a quite simple payoff structure, i.e., one index point change representing 200 TWD gain or loss (50 TWD for mini index futures). This straightforward payoff structure might attract some individual investors who treat trading as a fun and exciting gambling activity. As Barber, Lee, Liu, and Odean (2009) and Gao and Lin (2013) find some individual investors in Taiwan gambling in the stock market, some investors in TAIFEX might also gamble in the index futures contracts. Moreover, the high and cheap leverage of the futures contracts might also magnify the thrill and excitement, which makes these contracts attractive gambles.

Second, Kuo and Lin (2013) find that individual day traders in TAIFEX, identified ex

ante by initiating day-trade orders, are in general losing money. They conclude that individual day traders in TAIFEX are overconfident and have biased information. Their result is consistent with Barber, Lee, Liu, and Odean (2009) who find individual investors in the Taiwan stock market suffer large losses. The overconfidence, therefore, might also partially contribute to the high individual participation and trading in TAIFEX.

Finally, according to Gao and Lin (2013), individual investors account for around 70% of total trading volume in the Taiwan stock market during 2002 to 2009. The number is similar to what we find in the index futures market. Individual investors in Taiwan seem to prefer managing their investments on their own, compared with other developed markets.

In summary, the stylized facts that individual investors hold under-diversified portfolios consisting mainly small-cap stocks together with the above-mentioned analyses suggest that portfolio hedging or arbitraging is unlikely to be the major motivation for individual investors to trade actively in TAIFEX. Therefore, the speculation is the most probable trading motivation for these individual investors.[3] And this speculation tendency might be driven by the gambling need, the investor overconfidence, and the preference of managing investment by themselves.

[3] Our private conversation with a high-rank officer in TAIFEX is consistent with the view that speculation seems to be the major motivation for individual investors to actively trade index futures.

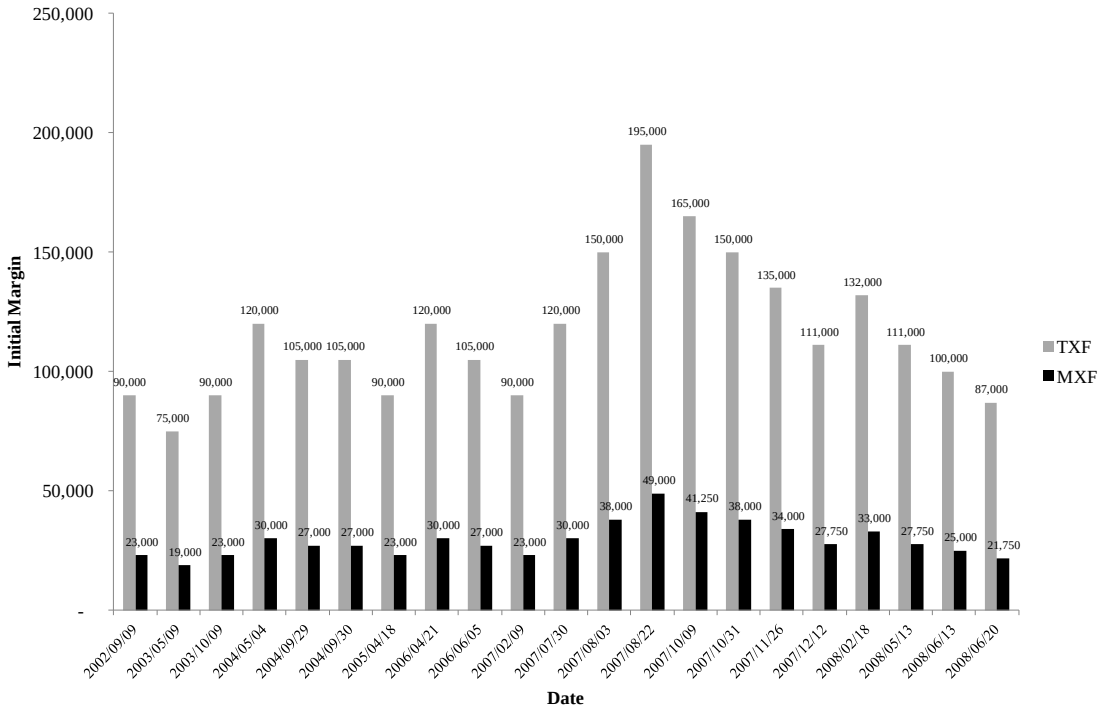
A4: Details of Index Futures Contracts and Index Options Contracts

This subsection provides the main features of index futures, mini-index futures, and the index options contracts traded in TAIFEX.[4]

Description	TAIEX Futures (TXF)	Mini-Index Futures (MXF)	TAIEX Options (TXO)
Location	Taiwan	Taiwan	Taiwan
Underlying asset	Taiwan capitalization weighted index (TAIEX)	Taiwan capitalization weighted index (TAIEX)	Taiwan capitalization weighted index (TAIEX)
Contract size	NT$200 × per index point	NT$50 × per index point	NT$50 (per index point)
Contract month	Spot month, the next calendar month, and the next three quarterly months	Spot month, the next calendar month, and the next three quarterly months	Spot month, the next two calendar months, and the next two quarterly months
Trading hours	• 08:45AM-1:45PM Taiwan time Monday through Friday of the regular business days of the Taiwan Stock Exchange • 08:45AM-1:30PM on the last trading day for the delivery month contract	• 08:45AM-1:45PM Taiwan time Monday through Friday of the regular business days of the Taiwan Stock Exchange • 08:45AM-1:30PM on the last trading day for the delivery month contract	• 08:45AM - 1:45 PM Taiwan time Monday through Friday of the regular Taiwan Stock Exchange business days • 08:45AM-1:30PM on the last trading day for the expired contract
Method of trading	• Prior to Market Open (Orders accepted from 8:30 to 8:45): Call auction at 8:45 • During Trading Hours (From 8:45 to 13:45): Continuous Matching	• Prior to Market Open (Orders accepted from 8:30 to 8:45): Call auction at 8:45 • During Trading Hours (From 8:45 to 13:45): Continuous Matching	• Prior to Market Open (Orders accepted from 8:30 to 8:45): Call auction at 8:45 • During Trading Hours (From 8:45 to 13:45): Continuous Matching
Tick size	One index point (NT$ 200)	One index point (NT$ 50)	• < 10 points: 0.1 point (NT$5) • >=10 points,<50 points: 0.5 point (NT$25) • >=50 points, <500 points: 1 point (NT$50) • >=500 points, <1,000 points: 5 point (NT$250) • >=1,000 points: 10 point (NT$500)
Average daily volume	98,570	63,922	433,832
Price limit	7% of the previous settlement price	7% of the previous settlement price	7% of the previous closing price of the underlying index

[4] The data source is the TAIFEX website, and more details can be found in the following URL: http://www.taifex.com.tw/eng/eng2/TX.asp

Figure A1. The Variation in Initial Margin during January 2003 to September 2008.



Internet Appendix B: Descriptive Statistics by Year and Additional Analyses, and Robustness Checks

Appendix B provides the descriptive statistics of the data by year, the results of additional tests, and the robustness checks in complement to the results in the main text. Specifically, the Appendix B contains:

1. Descriptive Statistics of the Data in Taiwan Futures Exchange by Year:
    a. Number of market orders and contracts submitted and traded.
    b. Number of investors submitting limit orders in TAIFEX.
    c. Number of limit order contracts matched with the two investor types.
    d. Round-trip duration for the two index futures products.
    e. Cumulative distribution of investors on numbers of limit orders submitted.

2. Additional Analyses:
    a. Definition of round number prices for options limit orders.
    b. Limit orders submission at round numbers and investment performance in the options markets.
    c. Submission ratio at “X0” and long-term investment performance.
    d. Submission ratio at “X0” and long-term investment performance for limit orders submitted at “X0” and non-“X0” prices.
    e. Limit order clustering at the last digit prices.
    f. Limit order clustering for investors without options trading.
    g. Limit order clustering for the two index futures products.
    h. Limit order clustering over time.
    i. Limit orders execution ratio and time-to-execution at “XY” price points.
    j. Limit orders buy-sell ratio at “XY” price points.

3. Robustness Checks:
    Different sample filters and various definitions of round-numbered index futures prices.

Table B1. Market Orders and Trades in Taiwan Futures Exchange

Panel A: Number of Market Orders Submitted

Year	Total	Investor type		Product type	
		Individual	Institutional	MXF	TXF
2003	2,015,574	1,962,682	52,892	545,908	1,469,666
2004	2,458,067	2,363,627	94,440	738,767	1,719,300
2005	1,447,864	1,400,140	47,724	374,960	1,072,904
2006	2,292,074	2,190,809	101,265	638,951	1,653,123
2007	3,172,267	3,086,196	86,071	1,105,158	2,067,109
2008	4,608,112	4,504,201	103,911	2,096,429	2,511,683
Total	15,993,958	15,507,655	486,303	5,500,173	10,493,785
Ratio	100.00%	96.96%	3.04%	34.39%	65.61%

Panel B: Number of Market Order Contracts Submitted

Year	Total	Investor type		Product type	
		Individual	Institutional	MXF	TXF
2003	3,800,784	3,597,579	203,205	747,890	3,052,894
2004	4,744,810	4,349,674	395,136	1,013,877	3,730,933
2005	2,790,302	2,622,773	167,529	521,832	2,268,470
2006	4,505,184	4,201,853	303,331	935,302	3,569,882
2007	5,893,247	5,593,744	299,503	1,543,108	4,350,139
2008	7,798,193	7,503,351	294,842	2,787,625	5,010,568
Total	29,532,520	27,868,974	1,663,546	7,549,634	21,982,886
Ratio	100.00%	94.37%	5.63%	25.56%	74.44%

Panel C: Number of Market Order Contracts Executed

Year	Total	Investor type		Product type	
		Individual	Institutional	MXF	TXF
2003	3,785,510	3,584,397	201,113	745,025	3,040,485
2004	4,698,900	4,310,249	388,651	1,008,056	3,690,844
2005	2,767,582	2,601,056	166,526	519,669	2,247,913
2006	4,480,856	4,180,985	299,871	931,392	3,549,464
2007	5,829,434	5,534,144	295,290	1,525,718	4,303,716
2008	7,588,976	7,303,578	285,398	2,711,596	4,877,380
Total	29,151,258	27,514,409	1,636,849	7,441,456	21,709,802
Ratio	100.00%	94.38%	5.62%	25.53%	74.47%

This table reports the summary statistics of the number of market orders and contracts submitted and executed for two major Taiwan index futures in the Taiwan Futures Exchange from January 2003 to September 2008. In 2008, we only have orders data from January to September. The numbers of market orders and market-order contracts submitted are reported in Panels A and B, while numbers of market order contracts executed are reported in Panels C. The numbers of market orders (contracts) are reported separately for individual investors and institutional investors, and for Taiwan Stock Exchange Futures (TXF) and Mini-Taiwan Stock Exchange Futures (MXF).

Table B2. Number of Investors in Taiwan Futures Exchange

Year	Total Number of Investors Submitting Limit Orders		
	All Investors	Individual Investors	Institutional Investors
2003	104,153	103,075	1,078
2004	119,124	117,066	2,058
2005	86,923	85,273	1,650
2006	77,273	75,328	1,945
2007	79,317	77,759	1,558
2008	89,221	87,344	1,877
Total	556,011	545,845	10,166
Ratio	100.00%	98.17%	1.83%

This table reports the summary statistics of the number of investors submitting two major Taiwan index futures in Taiwan Futures Exchange from January 2003 to September 2008. In 2008, we only have trades data from January to September. The numbers of individual investors and institutional investors are reported separately.

Table B3. Average Round-trip Duration in Taiwan Futures Exchange

Year	Round-trip duration (day)			
	Individual investors		Institutional investors	
	MXF	TXF	MXF	TXF
2003	1.821	1.551	1.557	1.925
2004	1.424	1.226	1.103	1.543
2005	2.336	1.949	2.068	2.629
2006	1.285	1.004	1.001	1.771
2007	0.884	0.755	0.555	1.532
2008	0.631	0.532	0.439	1.247

This table reports the average round-trip duration in Taiwan Futures Exchange from January 2003 to September 2008. In 2008, we only include trades from January to September. Round-trip duration is the number of trading days between the initiating and closing position of a round-trip. The round-trip duration is reported separately for individual investors and institutional investors, and for Taiwan Stock Exchange Futures (TXF) and Mini-Taiwan Stock Exchange Futures (MXF).

Table B4. Contract Execution Matched by Different Investor Types

Panel A: Number of All Contracts

	Hit by individual	Hit by institutional	Total	Percentage
Institutional investors	25,459,532	10,515,730	35,975,262	26%
Individual investors	77,116,804	25,459,532	102,576,336	74%
Total	102,576,336	35,975,262	138,551,598	
Percentage	74%	26%		100%

Panel B: Number of Initiating Contracts

	Hit by individual	Hit by institutional	Total	Percentage
Institutional investors	13,971,795	5,605,958	19,577,753	27%
Individual investors	40,860,447	13,373,484	54,233,931	73%
Total	54,832,242	18,979,442	73,811,684	
Percentage	74%	26%		100%

In this table we report the number of contracts executed when the transactions are matched with individual or institutional investors. For illustration, we report the number of all executed contracts and also separately for initiating contracts only. Initiating contracts are those to initiate new positions.

Table B5: Definition of Round Number Prices for Options Limit Orders

Options price (TWD)	Tick size (TWD)	Examples of round number prices for the options limit orders (TWD)
0~10	0.1	1, 2, 3, 4, …
10~50	0.5	5, 10, 15, 20, …
50~500	1	10, 20, 30, 40, …
500~1000	5	50, 100, 150, 200, …
>1000	10	100, 200, 300, 400, …

This table presents the definitions of round-numbered prices for the index options limit orders. Options limit orders are considered as submitted at round numbers if the order prices are multiples of tenfold of the tick size.

Table B6. Limit Orders Clustering at Round Numbers and Investment Performance for Index Options

Panel A: Individual Investors

Independent Variables	$SubRatio_{round,i,t,options}$	Mark-to-market return of options limit orders			Mark-to-market return of options market orders			Performance of Round-trip trades	
		Intraday (%)	1-day (%)	5-day (%)	Intraday (%)	1-day (%)	5-day (%)	Daily profit (TWD)	Daily index return (%)
$SubRatio_{X0,i,t,futures}$	0.354***	-0.822***	-2.153***	-4.202***	-0.900	-1.591	-1.985	-4,707.234***	-236.311***
	(0.000)	(0.002)	(0.000)	(0.000)	(0.605)	(0.564)	(0.581)	(0.000)	(0.000)
$Ln(N_{i,t-1,options})$	-0.006***	0.159***	0.321***	0.556***	-0.189	-0.387	-0.125	812.861***	123.432***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.335)	(0.101)	(0.716)	(0.000)	(0.000)
$Disposition_{i,t,options}$	-0.004***	-0.289***	-0.281	-3.484***	-1.251**	-0.658	-2.398**	5,274.790***	35.018*
	(0.000)	(0.000)	(0.108)	(0.000)	(0.019)	(0.285)	(0.019)	(0.000)	(0.092)
Intercept	0.183***	-1.072***	-3.265***	-8.309***	0.124	2.994*	2.009	-1,652.278***	-349.572***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.927)	(0.097)	(0.429)	(0.000)	(0.000)
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of obs.	50,310	43,702	43,689	43,557	19,555	19,213	17,848	49,845	49,845
Adjusted R^2	0.217	0.002	0.002	0.010	0.000	0.001	0.000	0.052	0.010

Panel B: Institutional Investors

Independent Variables	$SubRatio_{round,i,t,options}$	Mark-to-market return of options limit orders			Mark-to-market return of options market orders			Performance of Round-trip trades	
		Intraday (%)	1-day (%)	5-day (%)	Intraday (%)	1-day (%)	5-day (%)	Daily profit (TWD)	Daily index return (%)
$SubRatio_{X0,i,t,futures}$	0.276***	-3.504	-1.553	-0.264	-7.050	-22.798	24.437	-6,637.397	868.189
	(0.000)	(0.134)	(0.651)	(0.966)	(0.382)	(0.113)	(0.368)	(0.722)	(0.146)
$Ln(N_{i,t-1,options})$	-0.005**	0.206*	0.346	0.182	-0.213	1.473*	1.945	5,832.481***	478.961***
	(0.010)	(0.078)	(0.181)	(0.704)	(0.597)	(0.073)	(0.343)	(0.003)	(0.000)
$Disposition_{i,t,options}$	0.008	-0.412	1.183	-1.596	-1.384	-1.630	3.392	19,868.213***	442.490***
	(0.232)	(0.394)	(0.291)	(0.441)	(0.445)	(0.756)	(0.584)	(0.000)	(0.002)
Intercept	0.198***	-1.773	-3.662*	-10.204**	2.374	-0.238	-35.747*	-34,345.988***	-2,480.962***
	(0.000)	(0.188)	(0.072)	(0.023)	(0.554)	(0.985)	(0.052)	(0.008)	(0.000)
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of obs.	971	846	846	846	374	369	348	966	966
Adjusted R^2	0.145	0.009	0.001	0.004	-0.011	-0.001	-0.002	0.032	0.081

In this table we report the parameter estimates for the following panel regression:

$SubRatio_{round,i,t,options}$ *or* $Return_{i,t,options} = \alpha + \beta_1 SubRatio_{X0,i,t,futures} + \beta_2 Ln(N_{i,t-1,options}) + \beta_3\, Disposition_{i,t,options} + \varepsilon_{i,t}$

where $SubRatio_{X0,i,t,options}$ is the investor *i*'s options limit order submission ratio at round numbers in year *t-1*. Since options tick size in TAIFEX depends on the transaction prices, we define "options round number prices" as the options prices that are multiples of tenfold of the tick size as shown in Table B5. $Return_{i,t,options}$ is investor *i*'s mark-to-market returns or round-trip performance in the options market at year *t*. $SubRatio_{X0,i,t,futures}$ is investor i's futures limit order submission ratio at "X0" price point in year *t-1* (X is an integer ranging from 0 to 9). $Ln(N_{i,t-1,options})$ is the natural log of number of options limit orders submitted in year *t-1*. $Disposition_{i,t,options}$ is the disposition effect in the options market, which is calculated as the difference between duration of losing and winning round-trips, divided by the average of the two. Results for individual investors and institutional investors are reported separately. To ensure reasonable submission ratio at "X0", we require that investors must submit at least 10 futures limit orders in two consecutive years. Standard errors are adjusted for heteroskedasticity. *, **, and *** indicate significance levels of 0.1, 0.05, and 0.01, respectively.

Table B7. Submission Ratio at "X0" and Investor Longer-term Performance

Panel A: Individual Investors

Independent Variables	Marked-to-market return of limit orders (%)			Marked-to-market return of market orders (%)			Average monthly profit (TWD)
	22-day return	Month-end return	Return till expiration	22-day return	Month-end return	Return till expiration	
$SubRatio_{X0,i,t-1}$	-0.537***	-0.230***	-0.298***	-0.335***	-0.193***	-0.289***	-1,522.869***
	(0.000)	(0.000)	(0.000)	(0.007)	(0.000)	(0.000)	(0.000)
$Ln(N_{i,t-1})$	0.068***	0.031***	0.066***	0.018	0.021***	0.049***	152.876***
	(0.000)	(0.000)	(0.000)	(0.378)	(0.001)	(0.000)	(0.000)
$Disposition_{i,t}$	-0.603***	-0.191***	-0.351***	-0.462***	-0.136***	-0.268***	-1,143.579***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Intercept	-0.342***	-0.314***	-0.303***	-0.229**	-0.186***	-0.165***	-2,465.125***
	(0.000)	(0.000)	(0.000)	(0.034)	(0.000)	(0.001)	(0.000)
Year Fixed-effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of obs.	108,623	145,787	145,787	41,213	83,850	83,850	146,254
Adjusted R^2	0.029	0.050	0.048	0.013	0.012	0.012	0.048

Panel B: Institutional Investors

Independent Variables	Marked-to-market return of limit orders (%)			Marked-to-market return of market orders (%)			Average monthly profit (TWD)
	22-day return	Month-end return	Return till expiration	22-day return	Month-end return	Return till expiration	
$SubRatio_{X0,i,t-1}$	-1.006	-0.708***	-1.159***	-1.482	0.222	-0.294	-2,334.086**
	(0.193)	(0.001)	(0.000)	(0.300)	(0.590)	(0.646)	(0.035)
$Ln(N_{i,t-1})$	0.122**	0.006	0.074**	0.063	0.016	0.004	-122.521
	(0.043)	(0.727)	(0.019)	(0.577)	(0.659)	(0.935)	(0.212)
$Disposition_{i,t}$	-0.210	-0.240***	-0.491***	-0.774**	0.017	-0.136	-1,211.594***
	(0.185)	(0.000)	(0.000)	(0.012)	(0.850)	(0.327)	(0.000)
Intercept	-0.286	0.206	-0.009	0.252	0.082	0.403	315.205
	(0.513)	(0.162)	(0.968)	(0.754)	(0.790)	(0.336)	(0.677)
Year Fixed-effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of obs.	1,463	1,982	1,982	520	1,106	1,106	1,991
Adjusted R^2	0.027	0.030	0.044	0.027	0.000	0.012	0.020

In this table we report the parameter estimates for the following panel regression: $Return_{i,t} = \alpha + \beta_1 SubRatio_{X0,i,t-1} + \beta_2 Ln(N_{i,t-1}) + \beta_3 Disposition_{i,t} + \varepsilon_{i,t}$
where $Return_{i,t}$ is the longer-term average mark-to-market returns or average monthly profit per contract for investor *i* at year *t*. The longer-term Mark-to-market returns of limit orders are calculated in three different variations: a) from the submission to 22 trading days afterwards, b) from the submission to the end of the calendar month, and c) from the submission to the expiration day (the third Wednesday of the expiration month). The average monthly profit is the average profit of transactions conducted within a month. The profit of unclosed positions is calculated assuming that they are closed out by the end of the month. $SubRatio_{X0,i,t-1}$ is investor *i*'s submission ratio at "X0" price points in the previous year (X is an integer ranging from 0 to 9). $Ln(N_{i,t-1})$ is the log of number of limit orders submitted in the previous year. $Disposition_{i,t}$ is the difference between the current year's duration of losing and winning round-trips, divided by the average of the two. Results for individual and institutional investors are reported separately. Standard errors are adjusted for heteroskedasticity. To ensure reasonable submission ratio at "X0", we require that investors must submit at least 10 limit orders in each of the two consecutive years. *, **, and *** indicate significance levels of 0.1, 0.05, and 0.01, respectively.

Table B8. Submission Ratio at "X0" and Longer-term Mark-to-market Return of Limit Orders Submitted at "X0" and Non-"X0" Prices

Panel A: Individual Investors

Independent Variables	Marked-to-market return of limit orders submitted at "X0" (%)			Marked-to-market return of limit orders submitted at non-"X0" (%)		
	22-day return	Month-end return	Return till expiration	22-day return	Month-end return	Return till expiration
$SubRatio_{X0,i,t-1}$	-0.537***	-0.230***	-0.298***	-0.335***	-0.193***	-0.289***
	(0.000)	(0.000)	(0.000)	(0.007)	(0.000)	(0.000)
$Ln(N_{i,t-1})$	0.068***	0.031***	0.066***	0.018	0.021***	0.049***
	(0.000)	(0.000)	(0.000)	(0.378)	(0.001)	(0.000)
$Disposition_{i,t}$	-0.603***	-0.191***	-0.351***	-0.462***	-0.136***	-0.268***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Intercept	-0.342***	-0.314***	-0.303***	-0.229**	-0.186***	-0.165***
	(0.000)	(0.000)	(0.000)	(0.034)	(0.000)	(0.001)
Year Fixed-effect	Yes	Yes	Yes	Yes	Yes	Yes
Number of obs.	108,623	145,787	145,787	41,213	83,850	83,850
Adjusted R^2	0.029	0.050	0.048	0.013	0.012	0.012

Panel B: Institutional Investors

Independent Variables	Marked-to-market return of limit orders submitted at "X0" (%)			Marked-to-market return of limit orders submitted at non-"X0" (%)		
	22-day return	Month-end return	Return till expiration	22-day return	Month-end return	Return till expiration
$SubRatio_{X0,i,t-1}$	-1.006	-0.708***	-1.159***	-1.482	0.222	-0.294
	(0.193)	(0.001)	(0.000)	(0.300)	(0.590)	(0.646)
$Ln(N_{i,t-1})$	0.122**	0.006	0.074**	0.063	0.016	0.004
	(0.043)	(0.727)	(0.019)	(0.577)	(0.659)	(0.935)
$Disposition_{i,t}$	-0.210	-0.240***	-0.491***	-0.774**	0.017	-0.136
	(0.185)	(0.000)	(0.000)	(0.012)	(0.850)	(0.327)
Intercept	-0.286	0.206	-0.009	0.252	0.082	0.403
	(0.513)	(0.162)	(0.968)	(0.754)	(0.790)	(0.336)
Year Fixed-effect	Yes	Yes	Yes	Yes	Yes	Yes
Number of obs.	1,463	1,982	1,982	520	1,106	1,106
Adjusted R^2	0.027	0.030	0.044	0.027	0.000	0.012

In this table we report the parameter estimates for the following panel regression: $Return_{i,t} = \alpha + \beta_1 SubRatio_{X0,i,t-1} + \beta_2 Ln(N_{i,t-1}) + \beta_3 Disposition_{i,t} + \varepsilon_{i,t}$ where $Return_{i,t}$ is the average longer-term mark-to-market returns of limit orders submitted at "X0" or non-"X0" prices for investor *i* at year *t*. The longer-term Mark-to-market returns of limit orders are calculated in three different variations: a) from the submission to 22 trading days afterwards, b) from the submission to the end of the calendar month, and c) from the submission to the expiration day (the third Wednesday of the expiration month). $SubRatio_{X0,i,t-1}$ is investor *i*'s submission ratio at "X0" price points in the previous year (X is an integer ranging from 0 to 9). $Ln(N_{i,t-1})$ is the log of number of limit orders submitted in the previous year. $Disposition_{i,t}$ is the difference between the current year's duration of losing and winning round-trips, divided by the average of the two. Results for individual and institutional investors are reported separately. Standard errors are adjusted for heteroskedasticity. To ensure reasonable submission ratio at "X0", we require that investors must submit at least 10 limit orders in each of the two consecutive years. *, **, and *** indicate significance levels of 0.1, 0.05, and 0.01, respectively.

Table B9. Robustness Test for Submission Ratio at Round Numbers and Investment Performance

Panel A: Individual Investors

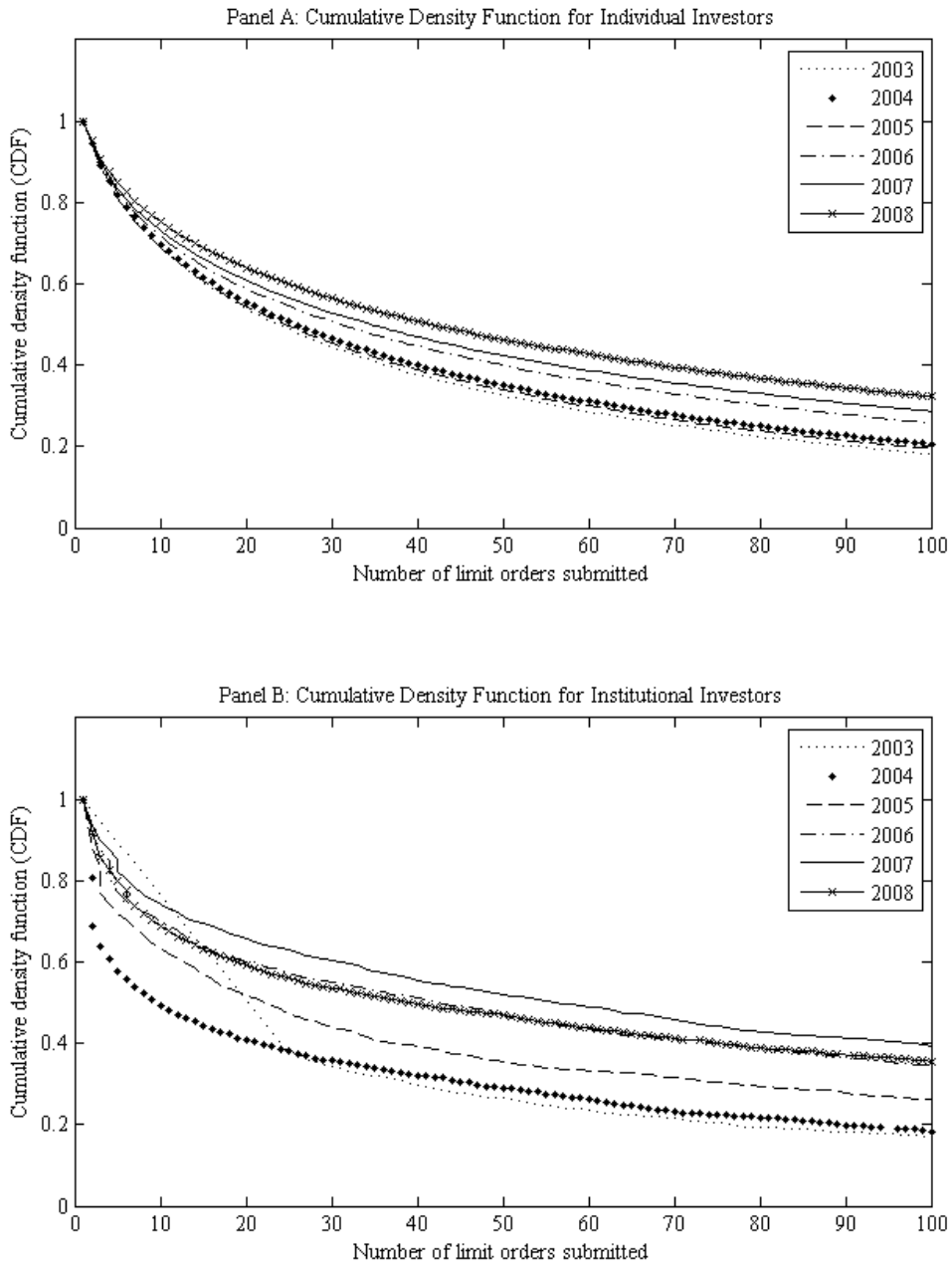
Investment Performance	Diff (Q5-Q1)					
	More than 5 limit orders in two years			More than 15 limit orders in two years		
	$SubRatio_{00}$	$SubRatio_{0050}$	$SubRatio_{X0}$	$SubRatio_{00}$	$SubRatio_{0050}$	$SubRatio_{X0}$
Mark-to-market returns of all initiating limit orders						
Intraday return (%)	-0.009***	-0.025***	-0.038***	-0.015***	-0.032***	-0.039***
	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
1-day return (%)	-0.036***	-0.061***	-0.079***	-0.036***	-0.058***	-0.067***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
5-day return (%)	-0.101***	-0.128***	-0.166***	-0.071***	-0.099***	-0.133***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Mark-to-market returns of initiating limit orders submitted at "X0" prices						
Intraday return (%)	-0.059***	-0.034***	-0.062***	-0.017*	-0.036***	-0.059***
	(0.000)	(0.000)	(0.000)	(0.056)	(0.000)	(0.000)
1-day return (%)	-0.094***	-0.053***	-0.110***	-0.037**	-0.051***	-0.094***
	(0.000)	(0.000)	(0.000)	(0.039)	(0.000)	(0.000)
5-day return (%)	-0.188***	-0.149***	-0.232***	-0.076**	-0.144***	-0.188***
	(0.000)	(0.000)	(0.000)	(0.028)	(0.000)	(0.000)
Mark-to-market returns of initiating limit orders submitted at non-"X0" prices						
Intraday return (%)	-0.008***	-0.025***	-0.025***	-0.015***	-0.031***	-0.029***
	(0.005)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
1-day return (%)	-0.034***	-0.064***	-0.065***	-0.036***	-0.063***	-0.061***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
5-day return (%)	-0.077***	-0.121***	-0.119***	-0.065***	-0.096***	-0.106***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Mark-to-market return of all imitating market orders						
Intraday return (%)	-0.010**	-0.029***	-0.044***	-0.019***	-0.039***	-0.049***
	(0.037)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)
1-day return (%)	-0.032***	-0.053***	-0.084***	-0.051***	-0.066***	-0.082***
	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
5-day return (%)	-0.047**	-0.073***	-0.125***	-0.079***	-0.075***	-0.121***
	(0.019)	(0.000)	(0.000)	(0.001)	(0.002)	(0.000)
Performance of round-trip trades						
Daily profit (TWD)	-221.26***	-346.03***	-872.46***	-475.42***	-667.92***	-1136.8***
	(0.008)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Daily index return (%)	-0.038***	-0.043***	-0.099***	-0.059***	-0.076***	-0.119***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Panel B: Institutional Investors

Investment	Diff (Q5-Q1)					
Performance	More than 5 limit orders in two years			More than 15 limit orders in two years		
	$SubRatio_{00}$	$SubRatio_{0050}$	$SubRatio_{X0}$	$SubRatio_{00}$	$SubRatio_{0050}$	$SubRatio_{X0}$
Mark-to-market returns of all initiating limit orders						
Intraday return (%)	-0.011	-0.056**	-0.081***	-0.027	-0.034*	-0.060***
	(0.626)	(0.024)	(0.001)	(0.172)	(0.082)	(0.002)
1-day return (%)	0.008	-0.042	-0.065	-0.021	-0.093**	-0.067*
	(0.884)	(0.438)	(0.173)	(0.613)	(0.028)	(0.098)
5-day return (%)	0.047	-0.012	-0.218**	-0.030	-0.187**	-0.155*
	(0.641)	(0.912)	(0.028)	(0.751)	(0.046)	(0.093)
Mark-to-market returns of initiating limit orders submitted at "X0" prices						
Intraday return (%)	0.018	-0.099	-0.090***	-0.058	-0.017	-0.050
	(0.812)	(0.105)	(0.005)	(0.419)	(0.769)	(0.106)
1-day return (%)	0.197	0.153	0.010	0.105	0.115	0.014
	(0.147)	(0.190)	(0.889)	(0.453)	(0.283)	(0.820)
5-day return (%)	0.104	0.055	-0.200	0.007	-0.096	-0.088
	(0.670)	(0.800)	(0.140)	(0.977)	(0.648)	(0.487)
Mark-to-market returns of initiating limit orders submitted at non-"X0" prices						
Intraday return (%)	0.004	-0.042*	-0.058**	-0.020	-0.025	-0.067***
	(0.863)	(0.089)	(0.040)	(0.303)	(0.212)	(0.010)
1-day return (%)	0.015	-0.060	-0.069	-0.018	-0.094**	-0.089*
	(0.763)	(0.265)	(0.188)	(0.676)	(0.026)	(0.063)
5-day return (%)	0.040	-0.022	-0.270**	-0.042	-0.192**	-0.213**
	(0.692)	(0.835)	(0.015)	(0.663)	(0.045)	(0.037)
Mark-to-market return of all initiating market orders						
Intraday return (%)	-0.032	-0.003	0.000	-0.028	-0.020	0.013
	(0.450)	(0.944)	(0.999)	(0.537)	(0.673)	(0.792)
1-day return (%)	-0.037	-0.072	0.020	-0.026	-0.055	0.114
	(0.686)	(0.474)	(0.841)	(0.818)	(0.652)	(0.346)
5-day return (%)	0.065	-0.021	0.035	0.195	0.023	0.142
	(0.763)	(0.921)	(0.868)	(0.425)	(0.931)	(0.561)
Performance of round-trip trades						
Daily profit (TWD)	-14,508	-64,686***	-49,772**	-39,304	-84,118***	-56,748*
	(0.264)	(0.001)	(0.029)	(0.117)	(0.001)	(0.059)
Daily index return (%)	-1.032	-5.056***	-3.916**	-2.760	-6.514***	-4.421**
	(0.268)	(0.000)	(0.020)	(0.120)	(0.000)	(0.043)

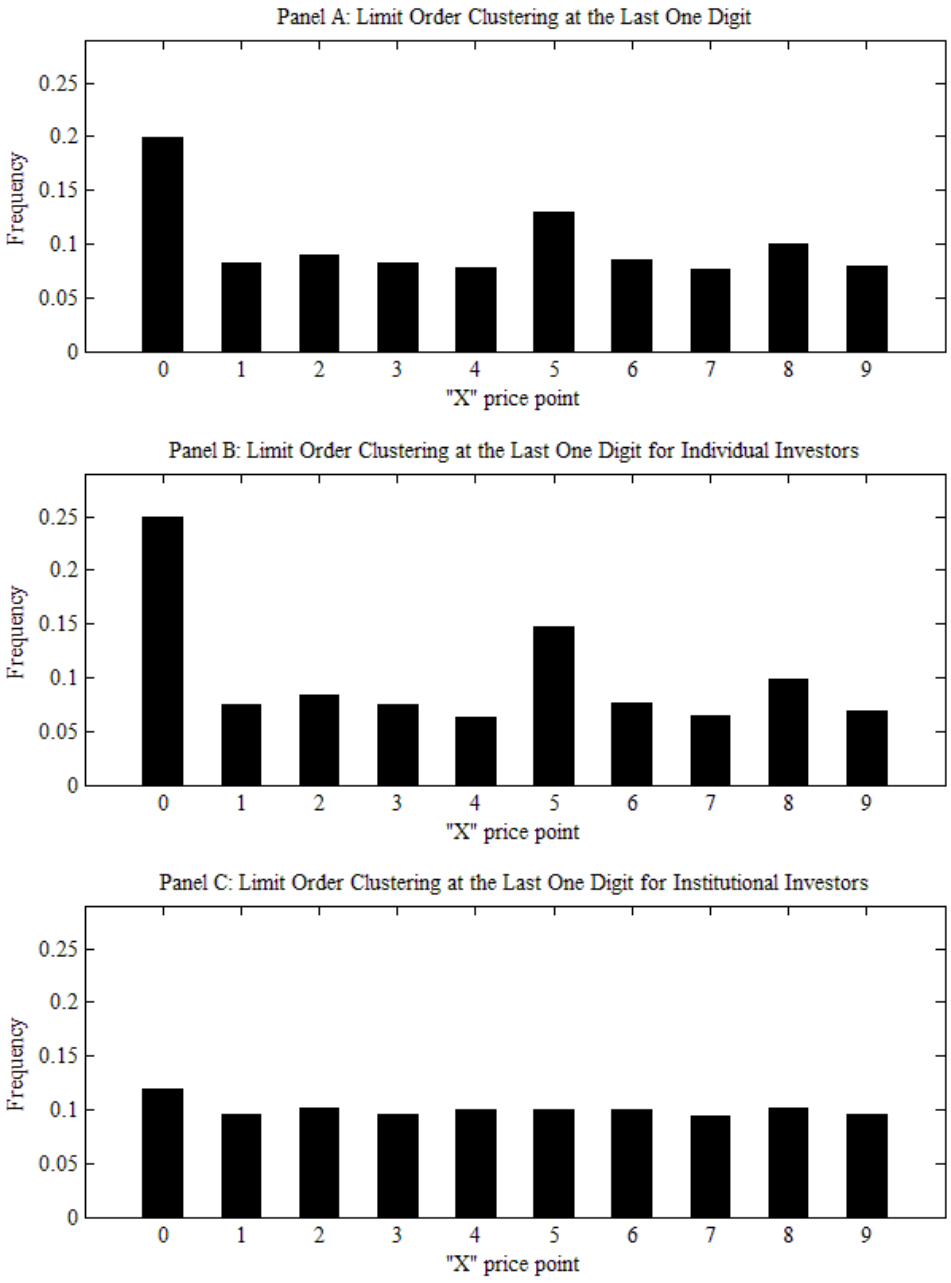
In this table we sort investors into quintiles by their limit order submission ratio at round numbers in the previous year, and report the difference in the current year's performance of quintile-5 (Q5) investors and quintile-1 (Q1) investors where the Q5 investors have highest submission ratio. We employ three specifications to identify round number prices: prices ending with "00", prices ending with "00" and "50", and prices ending with "X0" (X is an integer ranging from 0 to 9). For investment performance, we look at the mark-to-market intraday, 1-day and 5-day returns of all initiating limit orders, initiating limit orders submitted at "X0" prices, initiating limit orders submitted at non-"X0" prices, all initiating market orders, as well as the performance of round-trip trades. Mark-to-market intraday return is 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. All items are first calculated for each investor-year pair and then averaged up in each quintile. Results for individual and institutional investors are reported separately. The Satterthwaite p-value assumes unequal variances of investor performance in quintiles 1 and 5. To ensure reasonable submission ratio at round numbers, we require that investors must submit at least 5 or 15 limit orders in two consecutive years. *, **, and *** indicate significance levels of 0.1, 0.05, and 0.01, respectively.

Figure B1. Cumulative Density Functions of Investors in Taiwan Futures Exchange



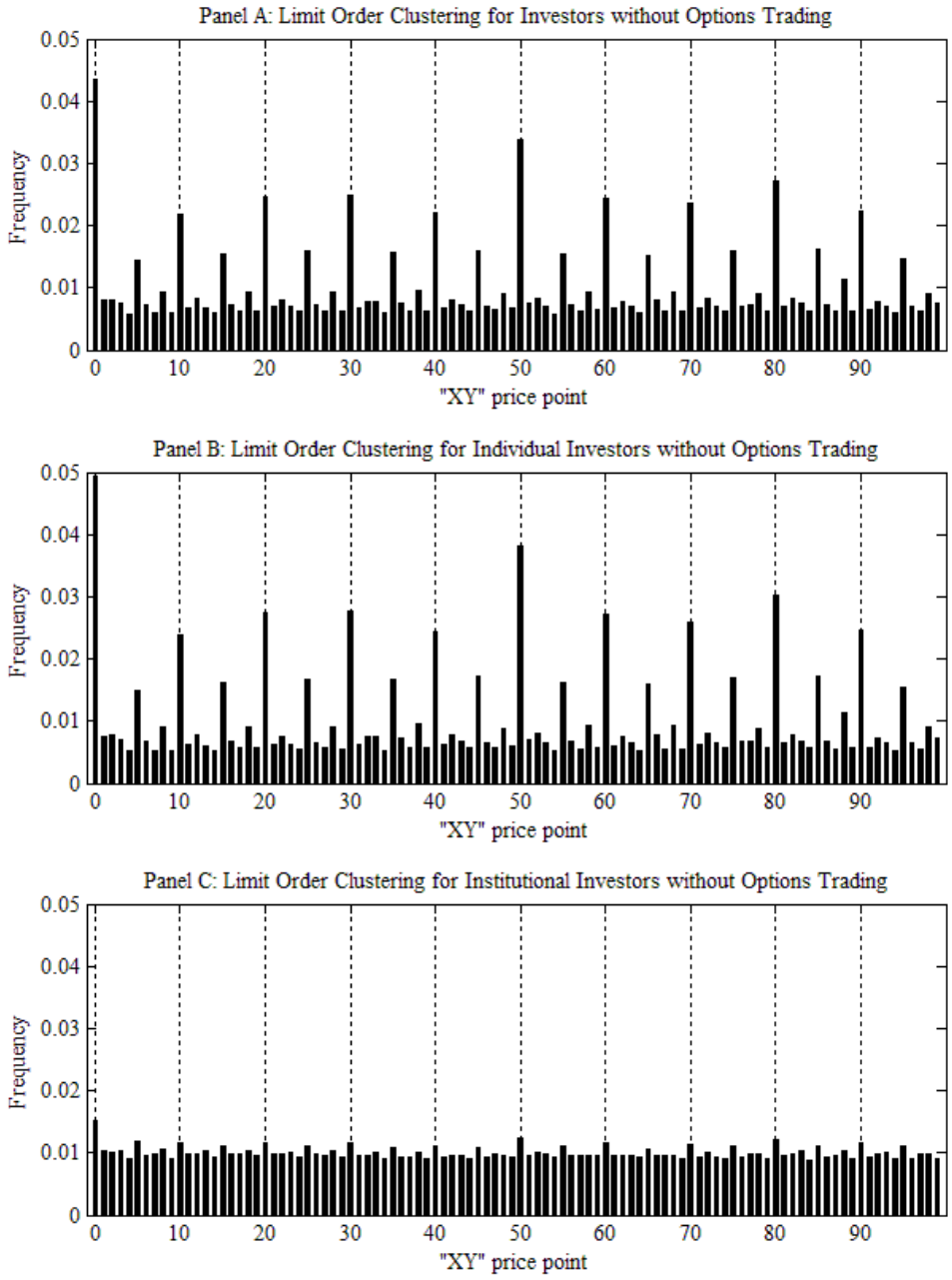
The two figures report the cumulative distribution of the investors submitting limit orders in Taiwan Futures Exchange from January 2003 to September 2008. In 2008, we only include investors from January to September. The cumulative distribution of investors is calculated as the number of investors with fewer or equal to *N* limit orders submitted divided by total number of investors, while N ranges from 1 to 100. Individual investors and institutional investors are reported in the top and bottom figures, respectively.

Figure B2. Limit Order Clustering at the Last One Digit



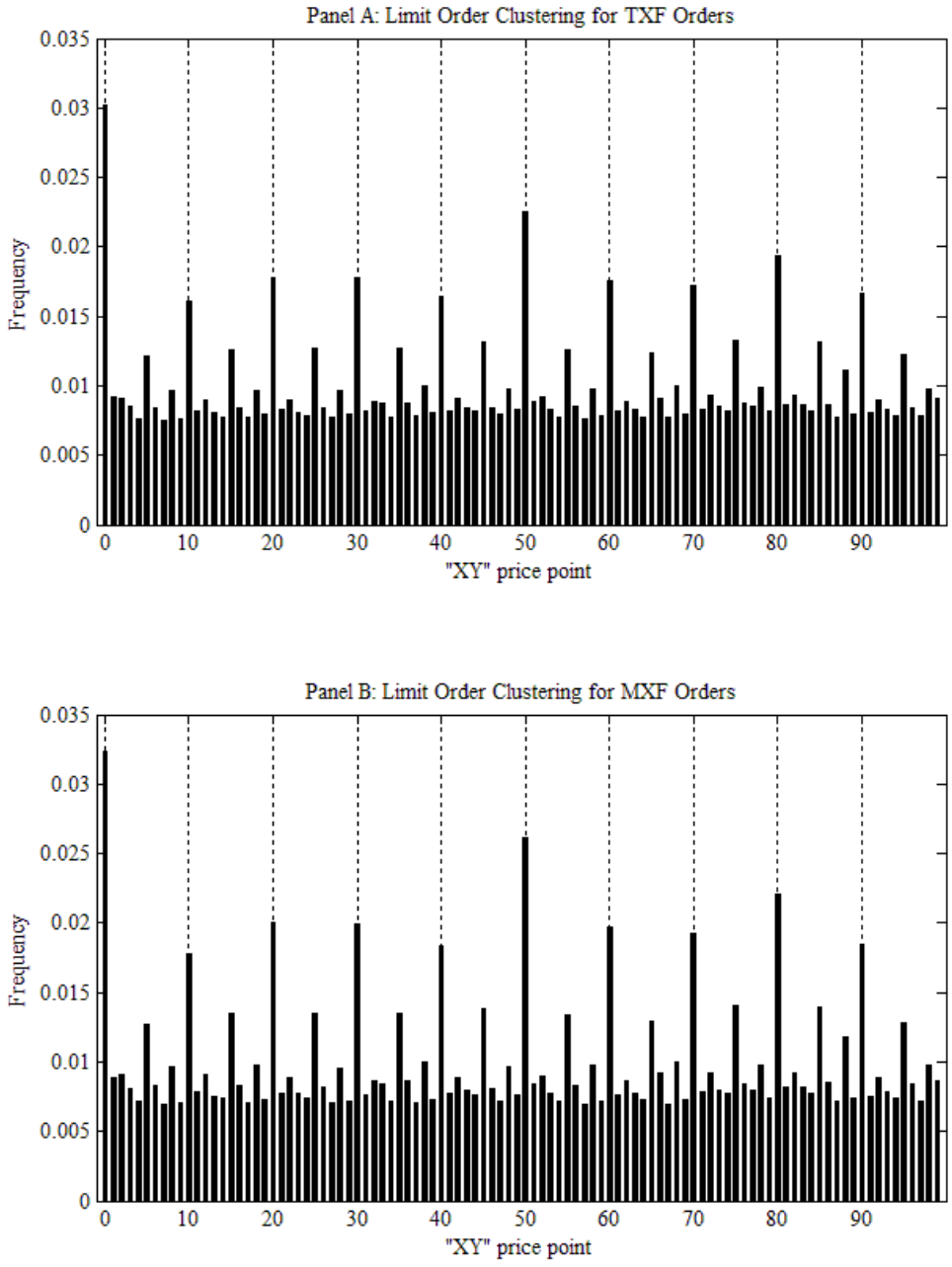
In this figure, we plot the frequency of limit orders submitted at "X" price points. The frequency at "X" price point is defined as the number of limit orders submitted at "X" divided by total number of limit orders submitted at all different "X"s (X is an integer ranging from 0 to 9).

Figure B3. Limit Order Clustering for Investors without Options Trading



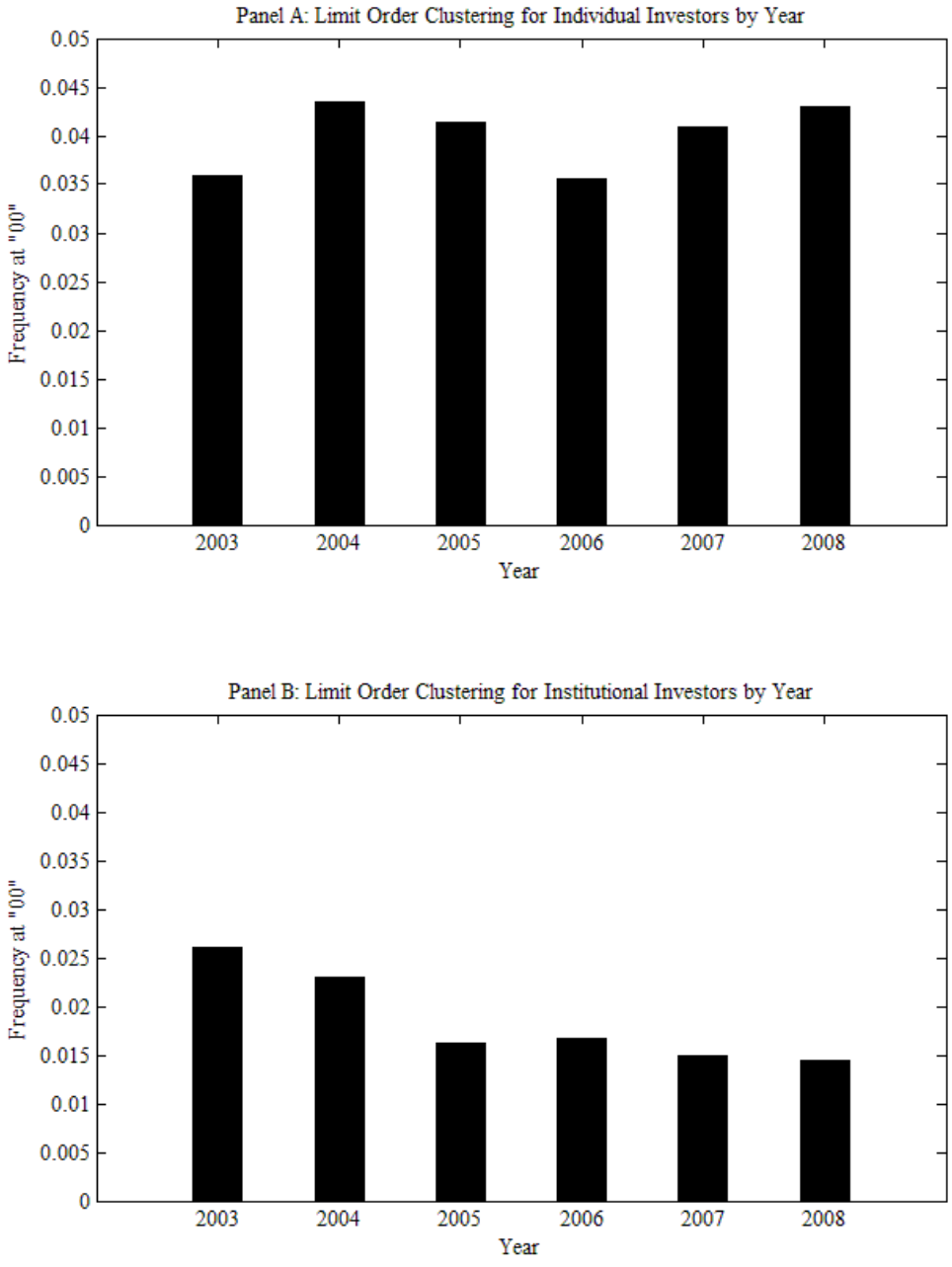
In this figure, we plot the frequency of limit orders submitted at "XY" price points for a subset of investors without options trading. The frequency at "XY" is defined as the number of limit orders submitted at "XY" divided by total number of limit orders submitted at all different "XY"s (X and Y are integers ranging from 0 to 9).

Figure B4. Limit Order Clustering for Different Products



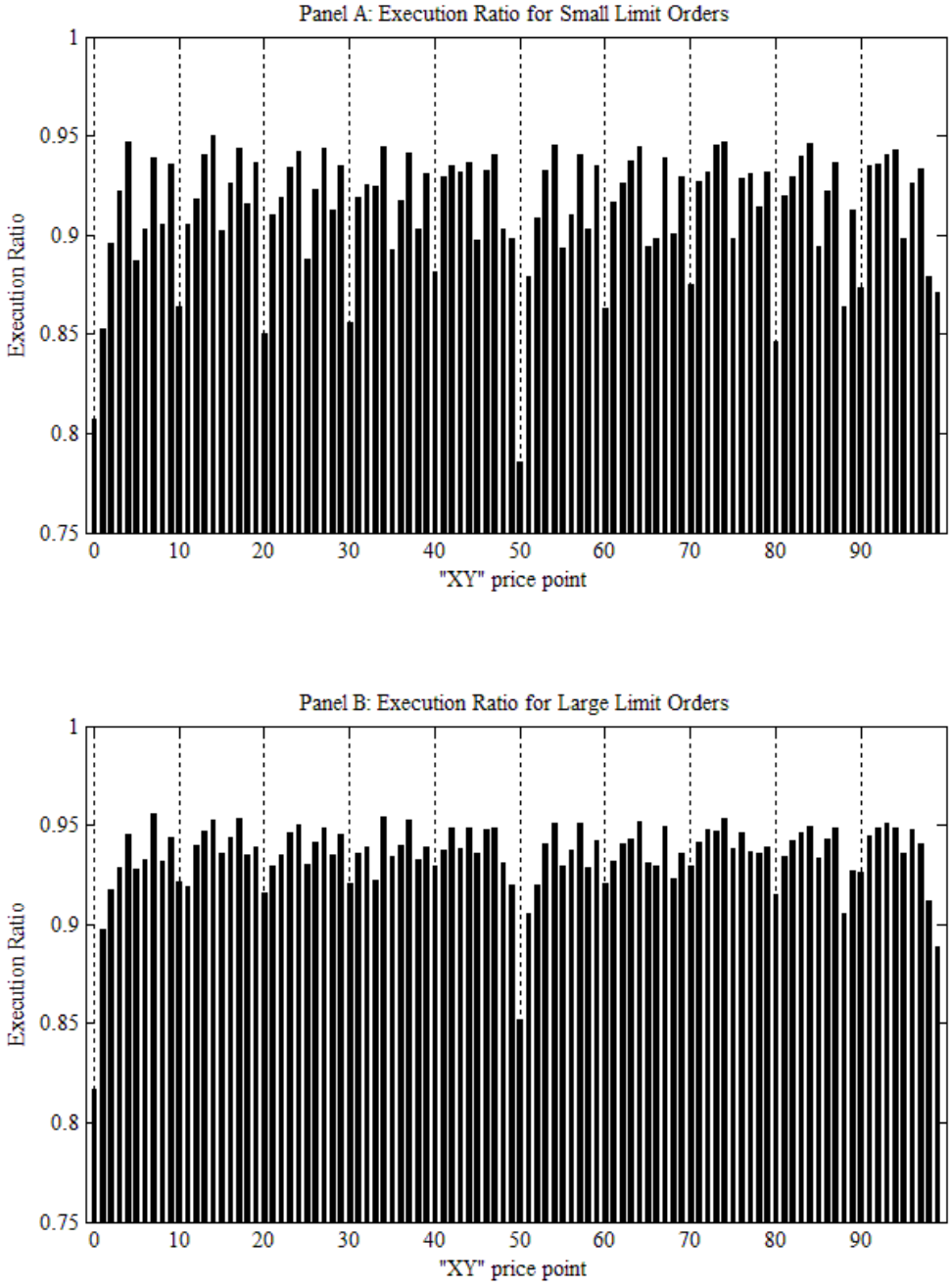
In this figure, we plot the frequency of limit orders submitted at "XY" price points separately for Taiwan Stock Exchange Index Futures (TXF) and Mini-Taiwan Stock Exchange Index Futures (MXF). The frequency at "XY" is defined as the number of TXF (MXF) limit orders submitted at "XY" divided by total number of TXF (MXF) limit orders submitted at all "XY"s (X and Y are integers ranging from 0 to 9).

Figure B5. Limit Order Clustering Over Time



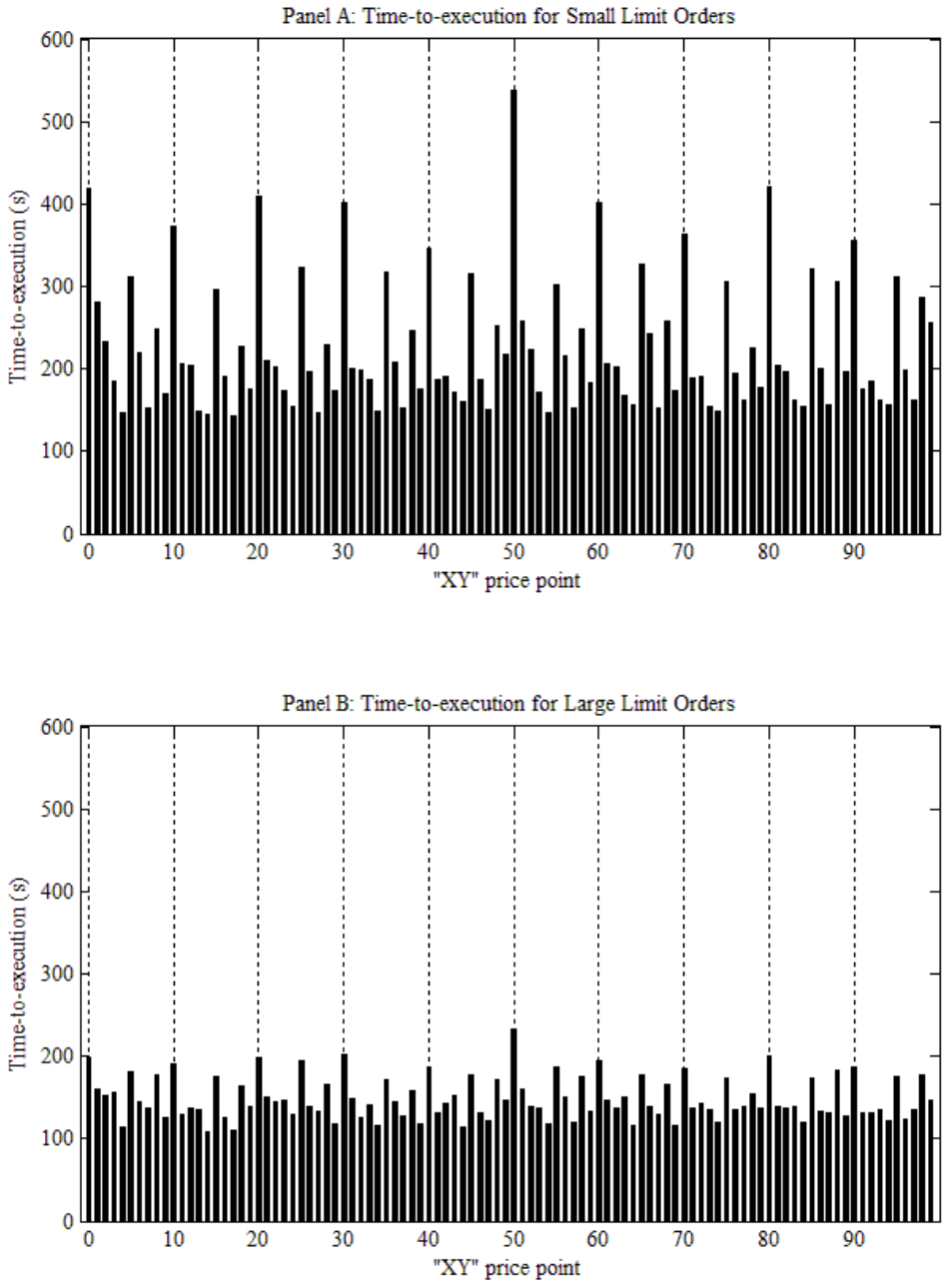
In this figure, we plot the frequency of limit orders submitted at multiples of a hundred from 2003 to 2008. In 2008, we have access to data from January to September only. The frequencies are calculated for individual investors and institutional investors separately.

Figure B6. Execution Ratio at "XY" price point



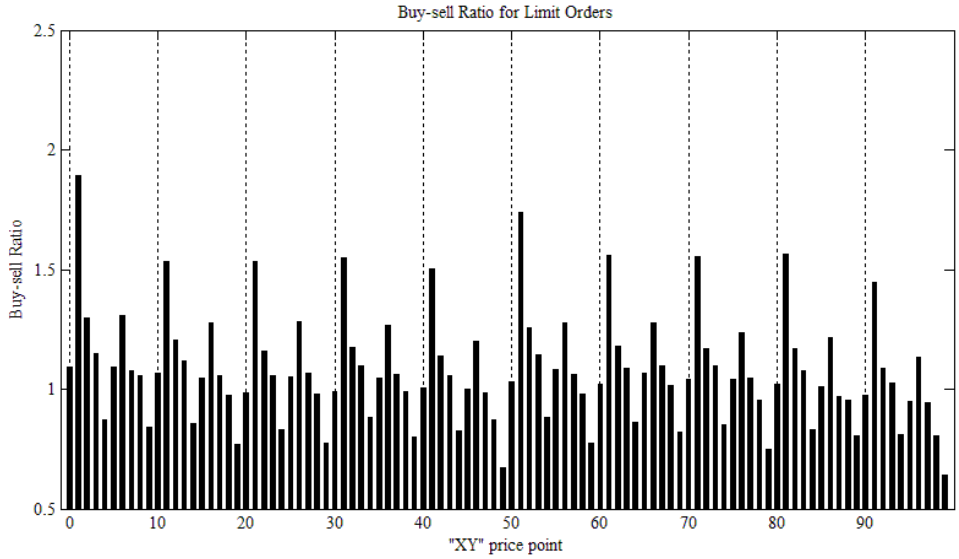
In this figure, we plot the execution ratio for the non-cancelled limit orders against the last two digits of the order price, separately for small and large limit orders. We classify small orders as those with only one contract, and large orders as those with more than five contracts. Execution ratio at "XY" price points is defined as the number of limit orders executed when they are submitted at "XY"s divided by the total number of non-cancelled limit orders submitted at "XY" price points (X and Y are integers ranging from 0 to 9).

Figure B7. Time-to-execution at "XY" price point



In this figure, we plot the time-to-execution for the executed limit orders against the last two digits of the limit order price, separately for small and large limit orders. Time-to-execution at "XY" price points is defined as the interval between the limit order's submission time and the execution time when they are submitted at "XY" price points (X and Y are integers ranging from 0 to 9). We classify small orders as those with only one contract, and large orders as those with more than five contracts.

Figure B8. Buy-Sell Ratio at "XY" price point



In this figure, we plot the buy-sell ratio against the last two digits of the limit order prices. Buy-sell ratio at "XY" price points is defined as the number of limit buy orders submitted at "XY"s divided by total number limit sell orders submitted at "XY"s (X and Y are integers ranging from 0 to 9).

References

Barber, B.M., Y. Lee, Y. Liu, and T. Odean. 2009. Just how much do individual investors lose by trading? *Review of Financial Studies* 22: 609–632.

Kuo, W. Y., and T. C. Lin. 2013. Overconfident individual day traders: evidence from the Taiwan Futures market. *Journal of Banking and Finance* 37: 3548–3561.

Gao, X. and T. C. Lin. 2013. Do individual investors treat trading as a fun and exciting gambling activity? Evidence from repeated natural experiments. Working Paper, the University of Hong Kong.