Tick Size, Round Numbers, and High Frequency Traders

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ABSTRACT

We analyze the behavior of investors around round numbers in a limit order market using high-quality data where we can track account-level trades. Using the buy-sell imbalance for each trader type, we find that non-HFTs exhibit round number bias while HFTs show opposite trading behavior. Our conditional analysis shows that cluster undercutting effect is the main driver of the bias and we do not find significant left-digit effect or threshold trigger effect. HFT buy (sell) trades around round numbers show positive (negative) returns. Stocks that are affected by the decrease in tick size experience less cluster undercutting behavior around round prices.

Keywords: Round numbers; cluster undercutting; retail investors; high-frequency traders; tick size

JEL codes: G14, G23, G41

1 Introduction

Investors trade assets at a price but trades differently depending on the numbers. Bhattacharya et al. (2012) show that investors focus on round numbers, like what some consumers would do when buying goods or services. People generally believe that financial market participants are rational, and that money is neutral. However, literature shows that certain investors are better off when it comes to investor performance. Specifically, retail traders are known to be worse off in stock and derivatives markets compared to institutional traders as shown in Odean (1999), Barber and Odean (2000), Barber et al. (2009), Kuo et al. (2015), among others.

In contrast, high-frequency traders are known to follow algorithms and should not show biases. Harris (2013) notes that HFTs do not allow emotion to cloud their judgment and quickly execute trades by observing vast amounts of information. Thus, if irrational traders lose due to round number biases, HFTs should be the counterparty of the irrational investors showing the opposite.

In this paper, we explore the high-quality dataset from the Korea Exchange (KRX) and analyze the different trading behaviors across different investor groups on the left-digit bias. Since we can track each account activity with investor classification for each group provided by the KRX, we analyze the differences in order imbalance around and at round numbers. Furthermore, we classify high-frequency traders (HFTs) based on the trading pattern and market share of each account.

Our unconditional analyses at each price points suggest that non-HFTs show round number biases in the KRX market. In the case where the price level is at xx400 or xx900 Korean Won, non-HFT traders are more likely to buy than sell. When the price level is at xx100 or xx600 Korean Won, these traders are more likely to sell than buy. We further classify the non-HFTs into domestic

retail investors, domestic institutions, and foreign investors. Our results show that domestic retail investors show significant biases around round numbers. However, we also find that domestic institutions and foreign investors that are non-HFTs also show round number biases although not as significant as domestic retail investors. However, we find that the HFTs trade executions are quite the opposite.

We also examine whether our unconditional results are driven by the left-digit effect, threshold trigger effect, or the cluster undercutting effect. Our results from the conditional analyses to distinguish these effects show that cluster undercutting effect is the dominant reason for the round number bias that we see in the KRX market.

Since we are interested in whether the round number bias trades have any consequences, we analyze the stock returns at each price point. Our findings show that the HFTs buy (sell) decisions at each price point around round numbers are significantly correlated with an increase (decrease) in stock price when compared with non-round number price points. We find opposite results for non-HFT traders overall. Our results confirm that the non-HFTs show bias trading activity around round numbers and HFTs are taking advantage of these biases.

While round number bias can come from psychological effects, the result may also come from the actual rounding effect as prices are not continuous. Thus, we extend the analysis if the bias persists when there is a change in the tick size. On January 25, 2023, the Korea Exchange changed the tick size so that the tick was reduced to stocks that are in certain price ranges, but it did not affect all the stocks traded in the market. During our sample period, 18 stocks in our sample were affected by this change and decreased their tick size from 50 Korean Won to 10 Korean Won. The affected stocks have a finer tick size and would be less effective by the rounding error. Our results show that round number biases decrease significantly after the tick size change.

Although previous studies thoroughly investigate the existence of—and the mechanism underlying—round number bias in individual investors' trading, the research on institutional participants is relatively scant. Gao, Meng, et al. (2018) find that institutional investors also tend to choose round numbers when bidding in primary, initial public offering auctions. However, the underlying causes of these biases remain unclear. Using data from global markets, Chen (2018) suggests that informed stealth trading may take advantage of clustering orders by uninformed traders. Although the study thoroughly reviews investors' trading activities at certain prices, it does not specifically probe investors' reactions to price changes and neglects the heterogeneity across different investor groups.

Our paper is closely related to Lee (2023). Lee (2023) shows that HFTs and non-HFTs show different trading patterns around round numbers and HFTs make larger profits around round number prices. However, the paper relies on an old NASDAQ HFT dataset and depends on the HFT classification provided by NASDAQ that acknowledges that not all non-HFTs in the database may be misclassified. Our HFT classification relies not only on the speed of the signal by observing the quote and trade data timed at milliseconds, but also on the market size using relative trading volume as well as the end-of-day inventory. Also, our work uses up-to-date data and account-level information provided by the KRX. Yu et al. (2023) examines the left-digit bias using account-level futures data at KRX.

Our study contributes to the literature by illustrating the differences between individual and institutional trading behaviors based on cognitive biases. While the left-digit biases of individual or retail investors have been frequently investigated, those of institutional investors have seldom been discussed. Our findings highlight the linkage between such market inefficiency and the type of market participants. Additionally, as encouraged by Bhattacharya et al. (2012), we

provide an extended view of the literature regarding the left-digit bias by investigating an emerging market.

Our paper also contributes to the tick size literature by analyzing the tick size effect on behavioral bias. Most of the tick size literature has focused on the market liquidity and price discovery effects (Harris, 1994; Ahn et al., 1998; Bessembinder, 2000; Goldstein and Kavajecz, 2000; Chung and Chuwonganant, 2004; Chung et al., 2004; Griffith and Roseman, 2019; Chung et al., 2020; Chakrabarty et al., 2022). Gao et al. (2022) show that tick size increase deters institutional trading using the 2016 SEC Tick Size Pilot Program.

In the following section we describe the data used. We analyze our results in Section 3 and conclude in Section 4.

2 Data

2.2 Korea Exchange Stock Market and Market Data

The Korean stock market has several unique characteristics that are important for detailed analysis. First, the Korea Stock Exchange runs two exchanges, namely KOSPI and KOSDAQ. While both markets are highly liquid owing to the abundant trades of both institutional and individual investors, we focus on the largest stocks in KRX so that our results are not driven by firm-specific events that may drive the price movements. The high liquidity lowers transaction costs and reduces market friction, implying that analyses of the KRX market can mitigate market biases. Second, individual investors actively participate in the KRX market. Trades by individual investors account for more than 70% of all trades, and trades by institutions and foreign investors represent a relatively small fraction of total transactions.

We utilize that data from KRX that has a masked identification number for each account recorded in KRX.[1] We work with both quote and trade data. For each trade or quote, we have the information of each trade or submitted quote with a timestamp (at millisecond level), price, order type (market order, limit order, stop order, etc.), investor group (retail, institution), county of origin (domestic/foreign), best 5 bid and ask price and depth, among others. Since we have timestamps for both buy and sell orders when a trade is executed, we do not need to infer if a trade is buy- or sell-initiated.

Our sample comprises common stocks in the KOSPI market from October 4, 2022, to March 15, 2023. Further, we choose stocks from the KOSPI200 index to minimize the noise in price fluctuations that may drive our results. We select the stocks in the KOSPI200 index continuously throughout our sample period. We also exclude stocks that do not experience stock splits or reverse stock splits during our sample period, and exclude stocks that show low liquidity where market makers were involved during the period.[2] We further limit our sample so that the stock price is within the 10,000 Korean Won to 100,000 Korea Won range at least once during our sample period to simply our analyses as the tick size varies with price level. After all these filters, we are left with 128 stocks for our analyses.

2.2 HFT Classification

We designate account IDs as high-frequency traders (HFTs) based on the following criteria during the sample period:

(i) make up more than 0.01% of trading volume;

[1] The data with the masked identification number is not for sale. This is only available through working with the researchers at KRX.
[2] For stocks that exhibit low liquidity, KRX contracted with securities companies to act as market makers. In other cases, KRX does not have appointed market makers.

(ii) have an end-of-day inventory of less than 40% of their trading volume; and

(iii) exhibit a median stock-day order-to-cancel time below 250 milliseconds.

The first two criteria are similar to those used by Brogaard et al. (2019), who classified traders as HFTs using data-driven criteria focusing on trading volumes and end-of-day inventory characteristics. These criteria reflect the characteristics of HFTs as relatively larger short-term speculators. However, potential classification challenges, as noted in Brogaard et al. (2019), must be acknowledged. For instance, small HFTs or those with larger positions may be misclassified as non-HFTs. Moreover, strategies such as arbitraging between cash and futures markets, where offsetting positions are often held overnight, could be erroneously categorized as non-HFTs. Additionally, HFT firms may have multiple IDs, leading to potential misidentification if HFT firms distribute their trading across the multiple IDs. Such misclassification would diminish the distinction between HFTs and non-HFTs.

We apply additional criteria (iii), which is related to the order execution speed of each account as HFTs are more likely to pick off orders quickly that deviate from the fundamental value, or in our case, show behavioral biases. As KRX allows amendments to existing orders, we calculate the order-cancellation or order-amendments pair and check if a median time for the day falls within 250 milliseconds at least once during our sample period.

[Insert Table 1 about here]

Table 1 shows summary statistics of trader type for our sample period. Within our sample, we find 5,586,147 accounts active. By applying all filters (i)—(iii), we have 56 accounts classified as HFTs. All other accounts are classified as non-HFTs, where we further classifiy them into

domestic retail, domestic institution, and foreign investor. Each HFT account averages about 5,400 shares traded with 274 million Korean Won (approximately $200,000) per day. These numbers are relatively large when compared to domestic retail or domestic institutions. Foreign investors show similar trade sizes but carry large inventories overnight compared to our definition of HFTs. We also find that more than 99 percent of accounts active during our sample period are domestic retail investors. KRX is known to have a large number of retail investors in the market. Thus, we have an ideal setting of investigating investors' behavioral biases.

2.3 Tick Size Change

On January 25, 2023, KRX changed the tick size to match the tick size for both KOSPI and KOSDAQ markets, but also to provide finer granularity for some price levels. KRX has different tick sizes for different price levels. Tick sizes before and after the change can be found in Figure 1.

[Insert Figure 1 about here]

As we choose our sample to be within 10,000 and 99,000 Korean Won, our samples will have tick sizes of 10, 50, or 100 Korean Won depending on their price level and date. Interestingly, stocks that are in 10,000 to 20,000 Korean Won in our sample will experience different tick sizes before and after the tick size change. We will explore these samples separately to identify the effect of tick size on round number biases.

3 Empirical Analyses

3.1 Unconditional Buy-Sell Imbalance

For each price point, we aggregate buys and sells for each stock. Then, the buy/sell ratio (BSR) is computed for each firm. We use three different buy/sell ratios, i) number of buys/number of sells, ii) shares bought/share sold, and ii) dollar (Korean Won) volume bought/dollar (Korean Won) volume sold. We subtract one from all ratios so that the positive (negative) BSR is associated with more buy (sell) imbalance, with a value of 0 indicating no imbalance (perfect balance). We define price point as the last two or three digits of transaction prices in Korean Won.

To briefly check the overview of our sample, we first observe stocks that are within the 50,000 to 99,000 Korean Won where we have a unified tick size of 100 Korean Won. We present the median buy-sell imbalances of these sub-samples for each tick focusing on the last four digits of price in Figure 1.

[Insert Figure 2 about here]

In Panel A of Figure 2, we plot the buy-sell imbalances for non-HFTs. We find that in most price points below the threshold (xx400, xx900), that is one tick below the 500 and 1,000 level, non-HFTs tend to buy. In cases of price points above the threshold (xx100, xx600), that is one tick above the 500 and 1,000 level, non-HFTs are more likely to sell in 15 of 20 price points. This is consistent with the behavioral bias. If we look at all 100 price levels (focusing on the last four digits), we do not find a significant asymmetry of buy or sell imbalance.

In Panel B, we work on the same exercise focusing on the HFTs. In the case of price points below the threshold, only 12 price levels show more buys out of 20. More interestingly, when the price is above the threshold, HFTs are more likely to buy than sell as shown in 17 of 20 possible price levels.

Our observation in Figure 2 calls for our analyses to split the sample into HFTs and non-HFTs. Furthermore, we analyze the non-HFTs into domestic retail, domestic institutions, and foreign investors to observe for any differences by trader types.

We estimate regression models for different investor types (HFTs, domestic retail, domestic institutions, and foreign investors) to see whether investors show different trading behavior around threshold price points. We use the dependent variable BSR_i for firm i and the independent variables are dummy variables of each price point of our interest. Our regression is as follows:

$$BSR_i = \beta_1 Below10K_i + \beta_2 Above10K_i + \beta_3 Below5K_i + \beta_4 Above5K_i + \beta_5 Below1K_i + \beta_6 Above1K_i + \beta_7 Below500_i + \beta_8 Above500_i + \varepsilon_i \quad (1)$$

where we include eight range of price points of interest. *Below10K*, *Above10K*, *Below5K*, *Above5K*, *Below1K*, *Above1K*, *Below500*, *Above500* are all dummy variables if the price is one tick above or below the reference point. However, as can be seen in Figure 1, the tick size depends on the price level. For example, when the price starts with digits 1 through 4 (10,000 to 49,900 Korean Won), a tick is 50 Korean Won, while a tick is 100 Korean Won when the first digit of a stock price starts with 5 through 9 (50,000 to 99,000 Korean Won). Thus, we define the above dummies as follows:

- For prices below 50,000 Korean Won:
    - *Below10K* dummy is 1 if the price is *x*0950, and 0 otherwise.
    - *Above10K* dummy is 1 if the price is *x*0050, and 0 otherwise.
    - *Below5K* dummy is 1 if the price is *x*4950, and 0 otherwise.
    - *Above5K* dummy is 1 if the price is *x*5050, and 0 otherwise.

- *Below1K* dummy is 1 if the price is *xy*950 where $y \notin \{4,9\}$, and 0 otherwise.
- *Above1K* dummy is 1 if the price is *xy*050 where $y \notin \{0,5\}$, and 0 otherwise.
- *Below500* dummy is 1 if the price is *xx*450 and 0 otherwise.
- *Above500* dummy is 1 if the price is *xy*550, and 0 otherwise.

- In cases where the prices are above 50,000 Korean Won:
  - *Below10K* dummy is 1 if the price is *x*0900, and 0 otherwise.
  - *Above10K* dummy is 1 if the price is *x*0100, and 0 otherwise.
  - *Below5K* dummy is 1 if the price is *x*4900, and 0 otherwise.
  - *Above5K* dummy is 1 if the price is *x*5100, and 0 otherwise.
  - *Below1K* dummy is 1 if the price is *xy*900 where $y \notin \{4,9\}$, and 0 otherwise.
  - *Above1K* dummy is 1 if the price is *xy*100 where $y \notin \{0,5\}$, and 0 otherwise.
  - *Below500* dummy is 1 if the price is *xx*400 and 0 otherwise.
  - *Above500* dummy is 1 if the price is *xy*600, and 0 otherwise.

In Table 2, we show the coefficient of each price point of our interest using regression equation (1). We use number of buys and sells (Panel A), shares bought and sold (Panel B), and dollar volume measure of bought and sold (Panel C) for the dependent variable BSR_i.

[Insert Table 2 about here]

When we look at coefficients of *Below10K*, *Below1K*, and *Below500* for HFTs, we find them to be negative, and in most cases significant. On the other hand, non-HFTs overall show positive and significant coefficients. Specifically, we find the coefficients to be positive and significant for domestic retail investors for all three coefficients across all panels. Domestic

institutions and foreign investors show positive and significant coefficients for *Below1K*, and *Below500* across all panels, but we do not find these results for *Below10K*. Interestingly, we find coefficients on *Below5K* to be positive across all investor types. Our results show that there seems to be a round number bias below the threshold level by non-HFTs, while HFTs show the opposite.

Next, we look at the trading behavior at prices one tick above, coefficients of *Above10K*, *Above5K*, *Above1K*, and *Above500.* For HFTs, we find positive and significant results for *Above1K* and *Above500*. However, we do not find significant results for *Above10K* and *Above5K*. Also, we find negative and significant results for domestic retail investors on *Above1K* coefficients only among all different investor types and different thresholds for non-HFTs. Thus, we do not seem to observe consistent round number bias on one tick above the threshold level.

One possible reason that we find the asymmetry is that on ticks above the threshold level, one needs to hold on the asset in order to sell when one believes that the price is high. While short selling is possible during our sample period, it is very limited and only allows covered shorts. Furthermore, short selling is more restrictive to retail investors. Thus, it is less likely to show lower BSR measure.

3.3 Conditional Buy-Sell Imbalance

The results in Table 2 are an unconditional test as it does not check if the price reached to the specific price after a increase or decrease in price level. As Bhattacharya et al. (2012) mentions, this can be caused by left-digit effect, threshold trigger effect, or cluster undercutting. To distinguish the effects, we run the conditional regression as follows:

$$Dep_j = \Sigma_k[\beta_{k1} AskFallsBelow10K_j \times I_k + \beta_{k2} AskFallsBelow500_j \times I_k$$
$$+\beta_{k3} AskFallto10K_j \times I_k + \beta_{k4} AskFallsto500_j \times I_k$$

$$+\beta_{k5} BidRisesto10K_j \times I_k + \beta_{k6} BidRisesto500_j \times I_k$$

$$+\beta_{k7} BidRisesAbove10K_j \times I_k + \beta_{k8} BidRisesAbove500_j \times I_k + I_k]$$

$$+Controls + \varepsilon_j \quad (2)$$

Where the dependent variable is + shares bought (or + Korean Won bought) for a buy and – shares sold (or – Korean Won sold) for each trade *j*. Subscript *k* is investor type that can be an element from the set {HFT,non-HFT} or {HFT,domestic retail, domestic institution, foreign} and I_k is a dummy variable for each investor type *k*. We define the price dummy variables used in the above equation (2) as follows:

- *AskFallsBelow10K* is a 1 for all trades after the best ask price falls from [x0000,x0500) to below x0000 until the best ask leaves (z9500,x0000) where z=x-1, and 0 otherwise.
- *AskFallsBelow500* is 1 for all trades after the best ask price falls from [xx500,xy000) to to below xx500 until the best ask leaves (xx000,xx500) where y=x+1, and 0 otherwise.
- *AskFallsto10K* is 1 for all trades after the best ask falls from (x0000,x0500) to x0000 until the best ask leaves x0000, and 0 otherwise.
- *AskFallsto500* is 1 for all trades after the best ask falls from (xx500,xy000) to xx500 until the best ask leaves xx500 where y=x+1, and 0 otherwise.
- *BidRisesto10K* is 1 for all trades after the best bid rises from (x9500,y0000) to y0000 where y=x+1 until the best bid leaves y0000, and 0 otherwise.
- *BidRisesto500* is 1 1 for all trades after the best bid rises from (xx000,xx500) to xx500 until the best bid leaves xx500, and 0 otherwise.
- *BidRisesAbove10K* is 1 for all trades after the best bid rises from (x9500,y0000) to above y0000 until the best bid leaves (y0000,y0500) where y=x+1, and 0 otherwise.

- *BidRisesAbove500* is 1 for all trades after the best bid rises from (xx000,xx500) to above xx500 until the best bid leaves (xx500,xy000) where y=x+1, and 0 otherwise.

In the above regression, we also include firm fixed effect, month fixed effect, price level fixed effect where we distinguish prices below 50,000 and above 50,000, as well as the trade size fixed effects, where we distinguish small trades to be less than 500 shares, mid-size trades to be between 500 and 2,000 shares, and large trades to be above 2,000 shares.

[Insert Table 3 about here]

We report the conditional regression in Table 3 by showing the difference in the coefficients that are related.[3] Overall, our results show that in the cases of price cross (rows 1 to 5 and 16 to 20), we find significant results. However, in the cases of price reach (rows 6 to 15), we do not find most of the results to be insignificant. Thus, we find strong evidence of the cluster undercutting effect.

3.4 Conditional Stock Price Movements

To see whether the biases lead to negative returns, we test if the trades around round numbers exhibit any price patterns. Our regression specification is as follows:

$$Dep_j = \Sigma_k[\beta_{k1} AskFallsBelow10KBuys_j \times I_k + \beta_{k2} AskFallsBelow500Buys_j \times I_k$$
$$+\beta_{k3} AskFallto10KBuys_j \times I_k + \beta_{k4} AskFallsto500Buys_j \times I_k$$

[3] We report $\beta_{k\ell} - \beta_{k\ell+1}$ for *k*=1, 3, 5, and 7, so that we report the abnormal amount around 10K.

$$+\beta_{k5} BidRisesto10KSells_j \times I_k + \beta_{k6} BidRisesto500Sells_j \times I_k$$

$$+\beta_{k7} BidRisesAbove10KSells_j \times I_k + \beta_{k8} BidRisesAbove500Sells_j \times I_k$$

$$+\beta_{k9} AskFallsBelow10KSells_j \times I_k + \beta_{k10} AskFallsBelow500Sells_j \times I_k$$

$$+\beta_{k11} AskFallto10KSells_j \times I_k + \beta_{k12} AskFallsto500Sells_j \times I_k$$

$$+\beta_{k13} BidRisesto10KBuys_j \times I_k + \beta_{k14} BidRisesto500Buys_j \times I_k$$

$$+\beta_{k15} BidRisesAbove10KBuys_j \times I_k + \beta_{k16} BidRisesAbove500Buys_j \times I_k + I_k]$$

$$+Controls + \varepsilon_j \quad (3)$$

where the dependent variable is the price change. The price change is calculated as the price (or midpoint) at the close minus the price it was executed. The dummy variables are similar to those in equation (2) except that we further separate each trade dummies into buys and sells. We report the abnormal coefficients in Table 4.

[Insert Table 4 about here]

We show that HFTs are trading in the right direction, that is, the coefficients are positive and, in most cases, significant at buys and negative and significant at sells on all price points of our interest. Non-HFTs results are mixed, but they tend to show opposite signs compared to HFTs. Our results imply that HFTs take advantage of the round number bias that non-HFTs exhibit.

3.5 Tick Size Event Study

As mentioned earlier in subsection 2.3, KRX modified the tick size for some of the stocks in January 25, 2023, which is in the middle of our sample. Specifically, for stocks that are in the

10,000 to 20,000 Korean Won, tick size decreased from 50 Korean Won to 10 Korean Won. When we observe 15 trading days before (January 2, 2023 to January 24, 2023) and 15 trading days after (January 25, 2023, to February 14, 2023) the tick size change, we have 18 stocks that experience price levels between 10,000 and 20,000 Korean Won for both pre- and post-periods.

For these 18 stocks, we run the regression similar to equation (2) with some modification. First, we include *Post* dummy variable in all specifications. As the price level for these stocks are within 10,000 to 20,000 Korean Won, we use 1K instead of 10K dummies as we would not observe the far left-digit changes. Also, we drop the month fixed effect as the sample period is short. We report our results in Table 5.

[Insert Table 5 about here]

First, when we look at abnormal coefficients for pre-period (rows 21 to 40) our result show that round number biases exist for most of our specifications for non-HFTs prior to the tick size change and HFTs trade in the opposite direction. Specifically, the bias is mainly driven by the domestic retail investors. However, when we observe the coefficients with *Post* dummy, coefficients on cross trades (rows 1 to 5, and rows 16 to 20) show opposite signs when compared to relevant pre-period coefficients (rows 21 to 25, and rows 36 to 40). This shows that the round number bias, especially the cluster undercutting effect is alleviated after the tick size change.

4 Conclusion

Our results confirm the round number bias that was shown in Bhattacharya et al. (2012) in recent Korean Exchange. However, while Bhattacharya et al. (2012) show that left-digit effect and

threshold trigger effect clearly exist, we do not find significant evidence of the two effects existing in our sample. Most of the round number bias that we observe seem to be driven by the cluster undercutting effect. Similar to Lee (2023), we find that HFTs show opposite trading behavior to those of non-HFTs. Further, we show that the biggest driver of round number bias is coming from the domestic retail investors.

Our results show that market policy can alleviate the behavioral biases that some investors have when trading in stock markets. When the tick size decreases, the cluster undercutting effect decreases in our sample.

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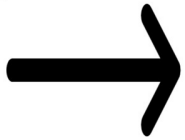
Figures and Tables

Figure 1. Tick Size Change (January 25, 2023)

Before

Price level (in KRW)	Tick Size (in KRW) KOSPI	KOSDAQ
<1,000	1	1
1,000~5,000	5	5
5,000~10,000	10	10
10,000~50,000	50	50
50,000~100,000	100	100
100,000~500,000	500	100
>500,000	1,000	100



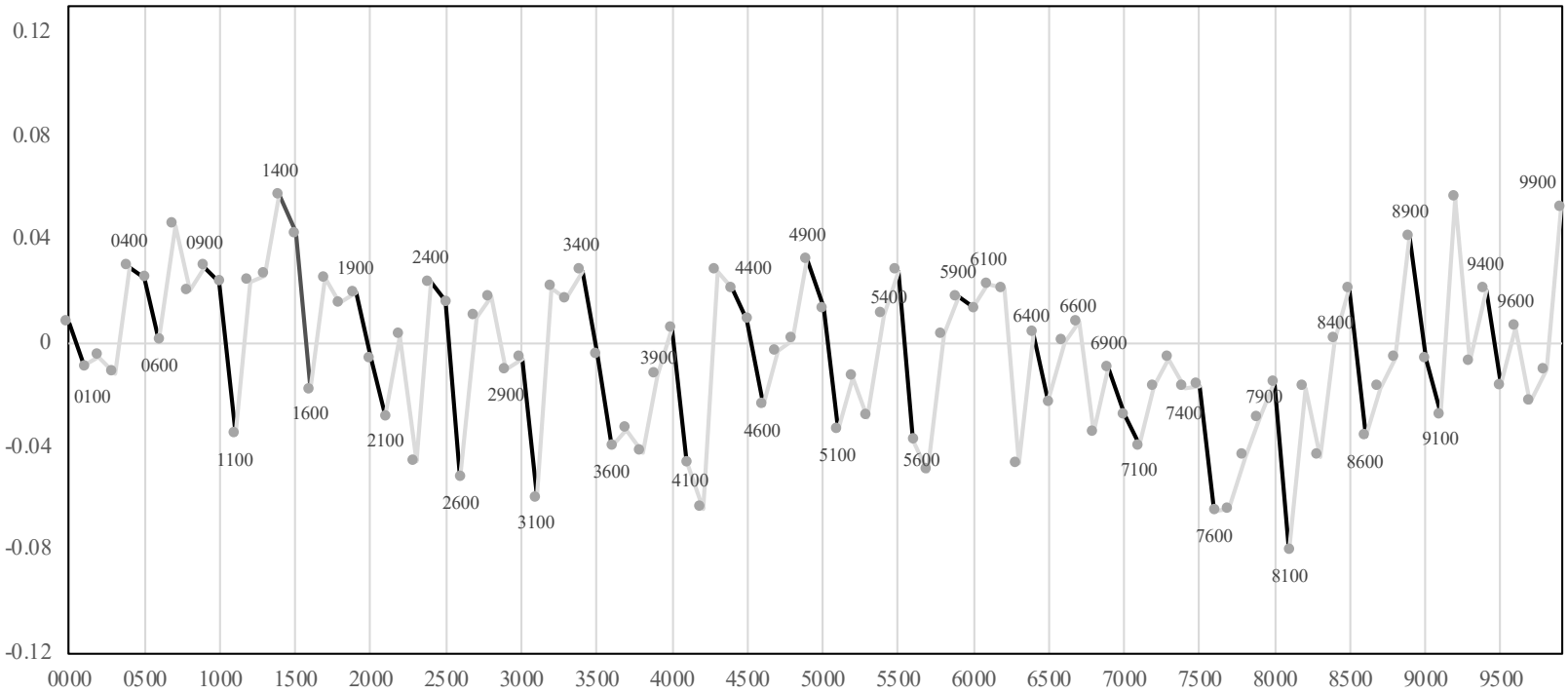
After

Price level (in KRW)	Tick Size (in KRW) KOSPI	KOSDAQ
<2,000	1	1
2,000~5,000	5	5
5,000~20,000	10	10
20,000~50,000	50	50
50,000~200,000	100	100
200,000~500,000	500	500
>500,000	1,000	1,000

Figure 2. Median Buy-Sell Ratio of HFTs and Non-HFTs Trades at Price Points.

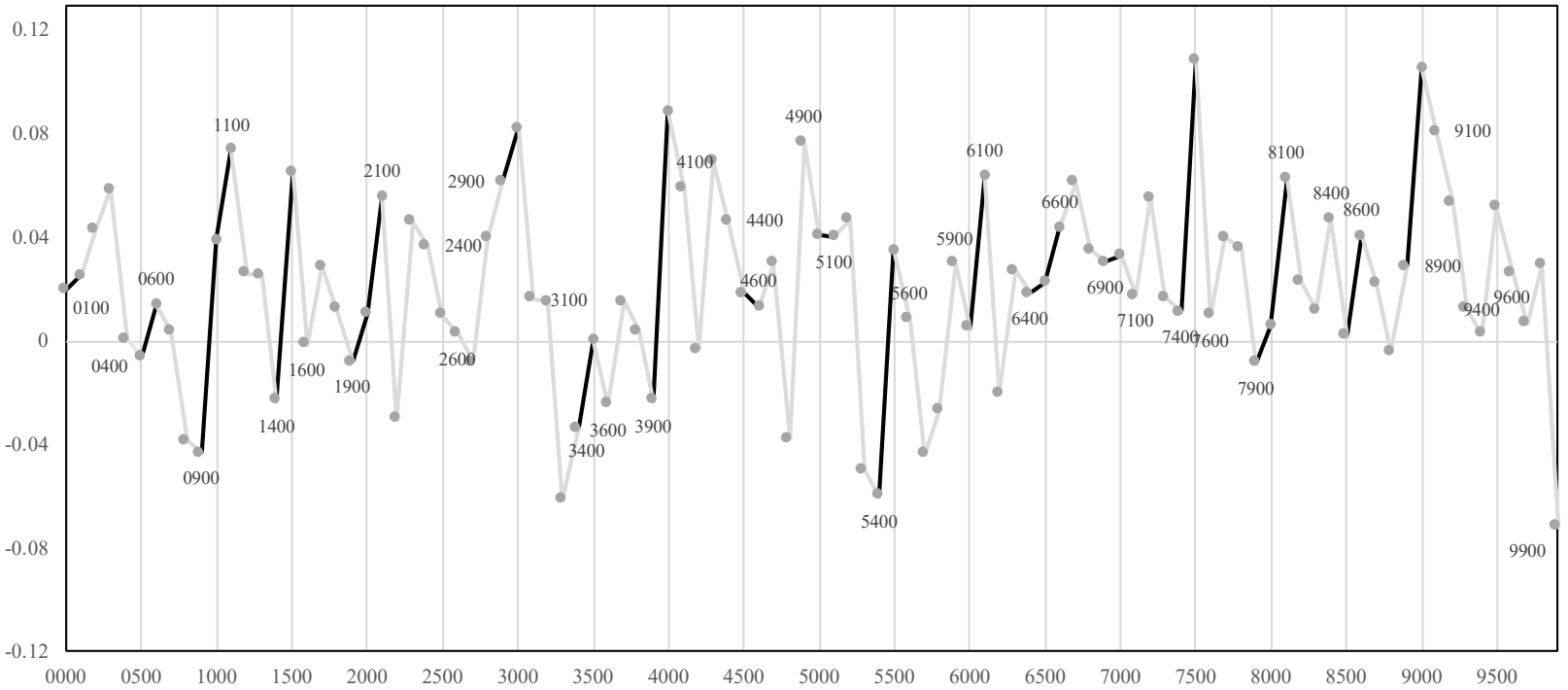
This figure presents the median buy-sell imbalances within the 50,000 to 99,000 KRW range (1st digit∈{5, 6, 7, 8, 9}), with a price increment of 100 KRW, at each price point from 0000 to 9900 (based on the 2nd digit onward). Panel A shows the median buy-sell imbalance for non-high frequency traders, while Panel B shows it for high frequency traders.

Panel A: Non-High Frequency Traders (Non-HFTs)



	Below threshold (s400, s900)	Above threshold (s100, s600)	Overall
Num. of Buy Imbalance	**15 (31.9%)**	5 (10.6%)	47 (100%)
Num. of Sell Imbalance	5 (9.4%)	**15 (28.3%)**	53 (100%)

Panel B: High Frequency Traders (HFTs)



	Below threshold (x40, x90)	Above threshold (x10, x60)	Overall
Num. of Buy Imbalance	12 (15.6%)	**17 (22.1%)**	77 (100%)
Num. of Sell Imbalance	**8 (34.8%)**	3 (13.0%)	23 (100%)

Figure 1. Tick Size Change (January 25, 2023)

Before

Price level (in KRW)	Tick Size (in KRW) KOSPI	KOSDAQ
<1,000	1	1
1,000~5,000	5	5
5,000~10,000	10	10
10,000~50,000	50	50
50,000~100,000	100	100
100,000~500,000	500	100
>500,000	1,000	100

After

Price level (in KRW)	Tick Size (in KRW) KOSPI	KOSDAQ
<2,000	1	1
2,000~5,000	5	5
5,000~20,000	10	10
20,000~50,000	50	50
50,000~200,000	100	100
200,000~500,000	500	500
>500,000	1,000	1,000

Table 1. Trader Type Statistics.

This table reports stock-day-account average trading, orders, and positions for HFTs and non-HFTs for the 128 listed stocks in the KOSPI200. The sample period is from October 4, 2022 to March 15, 2023. Account IDs are classified as HFTs based on the following criteria:

(i) make up more than 0.01% of trading volume;
(ii) have an end-of-day inventory of less than 40% of their trading volume;
(iii) exhibit a median stock-day order-to-cancel time below 250-millisecond;

Number of Accounts refers to the number of trading entities considered in each trader group. *Number of Messages* refers to the number of limit orders posted, canceled, and modified. *Percentage of Messages* refers to the ratio of the message size of each group to the total message size for each stock-day. *Number of Trades* refers to the number of trades (marketable orders) conducted by a trader. *Number of Shares Traded* refers to the number of shares traded by a trader. *KRW Volume Traded* refers to the number of shares traded by a trader multiplied by share price. *Percentage of Trade Volume* refers to the ratio of the trading volume of each group to the total trading volume for each stock-day. *Messages-to-Trade Ratio* is the ratio of the messages size to the executed trade volume. Inventory Ratio is the absolute value of a trader's end-of-day won volume inventory scaled by that trader's won volume traded.

	HFTs			Non-HFTs			
	Criteria (i)	Criteria (i) & (ii)	All criteria (i) & (ii)& (iii)	Overall	Domestic retail investors	Domestic institutions	Foreign investors
Number of Accounts	223,601	13,625	56	5,586,092	5,531,370	28,971	25,751
Number of Messages	47.0	42.5	94.6	6.4	3.4	52.3	138.8
Percentage of Messages (%)	0.25	0.28	0.49	0.02	0.01	0.12	0.57
Number of Trades	28.6	18.1	35.4	4.1	2.1	43.6	71.4
Number of Shares Traded (thousands)	3.2	5.8	5.4	0.3	0.1	2.3	6.7
KRW Volume Traded (₩millions)	140.0	303.4	274.2	11.4	5.0	109.3	293.2
Percentage of Trade Volume (%)	0.28	0.24	0.37	0.02	0.01	0.18	0.61
Messages-to-Trade Ratio	1.93	2.81	4.08	1.61	1.61	1.47	2.17
Inventory Ratio (%)	82.4	26.5	16.2	90.9	90.9	92.4	90.3

Table 2. Buy-Sell Imbalance Regressed on Price Point Dummies.

	HFTs		Non-HFTs							
	All criterion		Overall		Domestic retail investors		Domestic institutions		Foreign investors	
	Coef.	p-value	Coef.	p-value	Coef.	p-value	Coef.	p-value	Coef.	p-value
Panel A: Number of Buys and Sells										
Below Tens of Thousands (Below10K)	**-0.044**	**0.12**	0.036 *	0.10	**0.051** **	**0.02**	0.016	0.64	-0.037	0.18
Above Tens of Thousands (Above10K)	0.034	0.25	0.032	0.14	-0.000	0.99	0.006	0.85	0.039	0.16
Below Halves of 10K (Below5K)	0.047 *	0.09	0.049 **	0.02	0.041 **	0.05	0.038	0.24	0.070 ***	<0.01
Above Halves of 10K (Above5K)	-0.010	0.74	-0.013	0.54	-0.012	0.57	-0.029	0.38	-0.007	0.79
Below Thousands (Below1K)	-0.008	0.45	0.036 ***	<0.01	0.036 ***	<0.01	0.028 **	0.02	0.033 ***	<0.01
Above Thousands (Above1K)	0.021 *	0.05	-0.006	0.46	-0.027 ***	<0.01	0.002	0.90	0.001	0.92
Below Halves of 1K (Below500)	**-0.021** **	**0.03**	0.038 ***	<0.01	**0.016** **	**0.02**	0.042 ***	<0.01	0.041 ***	<0.01
Above Halves of 1K (Above500)	0.020 **	0.04	0.002	0.76	-0.003	0.68	-0.005	0.68	-0.002	0.80
Intercept	-0.009 ***	< 0.01	-0.044 ***	<0.01	-0.083 ***	<0.01	-0.047 ***	<0.01	0.044 ***	<0.01
N	27,042		32,692		32,464		31,701		31,930	
Panel B: Shares Bought and Sold										
Below Tens of Thousands (Below10K)	**-0.061** **	**0.04**	0.032 *	0.10	**0.040** *	**0.09**	0.054	0.12	-0.049 *	0.07
Above Tens of Thousands (Above10K)	0.003	0.90	0.014	0.50	0.003	0.90	-0.005	0.88	0.031	0.26
Below Halves of 10K (Below5K)	0.032	0.26	0.058 ***	<0.01	0.057 **	0.01	0.044	0.19	0.063 **	0.02
Above Halves of 10K (Above5K)	-0.027	0.35	0.000	0.99	-0.013	0.57	-0.033	0.34	-0.000	0.99
Below Thousands (Below1K)	-0.028 ***	<0.01	0.039 ***	<0.01	0.038 ***	<0.01	0.026 **	0.04	0.034 ***	<0.01
Above Thousands (Above1K)	0.017 *	0.10	-0.014 *	0.05	-0.030 ***	<0.01	-0.002	0.91	-0.016 *	0.10
Below Halves of 1K (Below500)	**-0.024** **	**0.01**	0.034 ***	<0.01	**0.016** **	**0.04**	0.042 ***	<0.01	0.029 ***	<0.01
Above Halves of 1K (Above500)	0.024 **	0.01	0.002	0.82	-0.003	0.67	-0.008	0.49	-0.011	0.22
Intercept	0.026 ***	<0.01	-0.033 ***	<0.01	-0.131 ***	<0.01	-0.006 *	0.06	0.077 ***	<0.01
N	27,042		32,692		32,464		31,701		31,930	
Panel C: KRW Bought and Sold										
Below Tens of Thousands (Below10K)	-0.062 **	0.03	0.033 *	0.10	0.041 *	0.08	0.054	0.12	-0.049 *	0.07
Above Tens of Thousands (Above10K)	0.005	0.86	0.014	0.49	0.003	0.90	-0.004	0.90	0.030	0.26
Below Halves of 10K (Below5K)	0.032	0.25	0.059 ***	<0.01	0.056 **	0.01	0.045	0.18	0.063 **	0.02
Above Halves of 10K (Above5K)	-0.027	0.35	0.000	1.00	-0.013	0.57	-0.032	0.35	-0.001	0.97
Below Thousands (Below1K)	-0.028 ***	<0.01	0.040 ***	<0.01	0.038 ***	<0.01	0.027 **	0.03	0.034 ***	<0.01
Above Thousands (Above1K)	0.017 *	0.10	-0.014 *	0.05	-0.030 ***	<0.01	-0.001	0.92	-0.016 *	0.10
Below Halves of 1K (Below500)	-0.024 **	0.01	0.034 ***	<0.01	0.015 **	0.05	0.042 ***	<0.01	0.029 ***	<0.01
Above Halves of 1K (Above500)	0.024 **	0.01	0.002	0.80	-0.004	0.64	-0.007	0.52	-0.011	0.21
Intercept	0.026 ***	<0.01	-0.033 ***	<0.01	-0.131 ***	<0.01	-0.004	0.17	0.077 ***	<0.01
N	27,042		32,692		32,464		31,701		31,930	

Table 3. Conditional Buy-Sell Imbalance Regressed on Price Point Dummies.

	(+) shares bought or (–) shares sold				(+) KRW bought or (–) KRW sold			
	Coef.	p-value	Coef.	p-value	Coef.	p-value	Coef.	p-value
Ask Falls below 10K – Ask Falls below Halves of 1K (HFTs)	-0.616***	<0.01	-0.596***	<0.01	-18,996***	<0.01	-19,109***	<0.01
Ask Falls below 10K – Ask Falls below Halves of 1K (Non-HFTs)	1.230***	<0.01			64,022***	<0.01		
Ask Falls below 10K – Ask Falls below Halves of 1K (Non-HFTs: Retail)			0.952***	<0.01			41,117***	<0.01
Ask Falls below 10K – Ask Falls below Halves of 1K (Non-HFTs: Institutions)			1.460***	<0.01			78,715***	<0.01
Ask Falls below 10K – Ask Falls below Halves of 1K (Non-HFTs: Foreign)			1.269***	<0.01			75,172***	<0.01
Ask Falls to 10K – Ask Falls to Halves of 1K (HFTs)	0.204	0.58	0.147	0.69	-2,759	0.88	-5,934	0.74
Ask Falls to 10K – Ask Falls to Halves of 1K (Non-HFTs)	0.077	0.84			29,017	0.11		
Ask Falls to 10K – Ask Falls to Halves of 1K (Non-HFTs: Retail)			-0.397	0.32			9,844	0.61
Ask Falls to 10K – Ask Falls to Halves of 1K (Non-HFTs: Institutions)			0.303	0.44			34,337*	0.07
Ask Falls to 10K – Ask Falls to Halves of 1K (Non-HFTs: Foreign)			0.209	0.62			41,571**	0.04
Bid Rises to 10K – Bid Rises to Halves of 1K (HFTs)	0.346	0.35	0.278	0.46	10,328	0.57	6,987	0.70
Bid Rises to 10K – Bid Rises to Halves of 1K (Non-HFTs)	-0.875**	0.02			-40,917**	0.03		
Bid Rises to 10K – Bid Rises to Halves of 1K (Non-HFTs: Retail)			-1.200***	<0.01			-53,078***	<0.01
Bid Rises to 10K – Bid Rises to Halves of 1K (Non-HFTs: Institutions)			-0.515	0.20			-23,675	0.22
Bid Rises to 10K – Bid Rises to Halves of 1K (Non-HFTs: Foreign)			-0.456	0.29			-24,793	0.23
Bid Rises above 10K – Bid Rises above Halves of 1K (HFTs)	2.105**	0.03	2.335**	0.01	32,478	0.48	40,601	0.38
Bid Rises above 10K – Bid Rises above Halves of 1K (Non-HFTs)	-1.911**	0.05			-7,363	0.87		
Bid Rises above 10K – Bid Rises above Halves of 1K (Non-HFTs: Retail)			-1.490	0.17			-67,148	0.71
Bid Rises above 10K – Bid Rises above Halves of 1K (Non-HFTs: Institutions)			-4.472***	<0.01			-19,600	0.19
Bid Rises above 10K – Bid Rises above Halves of 1K (Non-HFTs: Foreign)			0.877	0.43			83,866	0.12
D(Non-HFTs)	0.885***	<0.01			-87,573***	<0.01		
D(Non-HFTs: Retail)			-2.036***	<0.01			-87,573***	<0.01
D(Non-HFTs: Institutions)			1.735***	<0.01			80,221***	<0.01
D(Non-HFTs: Foreign)			4.001***	<0.01			171,252***	<0.01
Firm fixed	Yes		Yes		Yes		Yes	
Month fixed	Yes		Yes		Yes		Yes	
Price level fixed	Yes		Yes		Yes		Yes	
Trade size fixed	Yes		Yes		Yes		Yes	
N	216,628,363		216,628,363		216,628,363		216,628,363	

Table 4. Stock Returns by Price Point Dummies.

	Trade Price		Midpoint	
	Coef.	p-value	Coef.	p-value
Ask Falls below 10K Buys – Ask Falls below Halves of 1K Buys (HFTs)	0.0501%***	<0.01	0.0491%***	<0.01
Ask Falls below 10K Buys – Ask Falls below Halves of 1K Buys (Non-HFTs: Retail)	-0.0093%***	<0.01	-0.0093%***	<0.01
Ask Falls below 10K Buys – Ask Falls below Halves of 1K Buys (Non-HFTs: Institutions)	-0.0208%***	<0.01	-0.0213%***	<0.01
Ask Falls below 10K Buys – Ask Falls below Halves of 1K Buys (Non-HFTs: Foreign)	-0.0442%***	<0.01	-0.0446%***	<0.01
Ask Falls to 10K Buys – Ask Falls to Halves of 1K Buys (HFTs)	0.0962%***	<0.01	0.0955%***	<0.01
Ask Falls to 10K Buys – Ask Falls to Halves of 1K Buys (Non-HFTs: Retail)	0.0671%***	<0.01	0.0676%***	<0.01
Ask Falls to 10K Buys – Ask Falls to Halves of 1K Buys (Non-HFTs: Institutions)	-0.0710%***	<0.01	-0.0709%***	<0.01
Ask Falls to 10K Buys – Ask Falls to Halves of 1K Buys (Non-HFTs: Foreign)	-0.0696%***	<0.01	-0.0694%***	<0.01
Bid Rises to 10K Sells– Bid Rises to Halves of 1K Sells (HFTs)	-0.1468%***	<0.01	-0.1471%***	<0.01
Bid Rises to 10K Sells – Bid Rises to Halves of 1K Sells (Non-HFTs: Retail)	0.1188%***	<0.01	0.1195%***	<0.01
Bid Rises to 10K Sells – Bid Rises to Halves of 1K Sells (Non-HFTs: Institutions)	0.1036%***	<0.01	0.1041%***	<0.01
Bid Rises to 10K Sells – Bid Rises to Halves of 1K Sells (Non-HFTs: Foreign)	0.0788%***	<0.01	0.0794%***	<0.01
Bid Rises above 10K Sells – Bid Rises above Halves of 1K Sells (HFTs)	-0.8215%***	<0.01	-0.8198%***	<0.01
Bid Rises above 10K Sells – Bid Rises above Halves of 1K Sells (Non-HFTs: Retail)	0.6257%***	<0.01	0.6285%***	<0.01
Bid Rises above 10K Sells – Bid Rises above Halves of 1K Sells (Non-HFTs: Institutions)	-0.0853%***	<0.01	-0.0872%***	<0.01
Bid Rises above 10K Sells – Bid Rises above Halves of 1K Sells (Non-HFTs: Foreign)	0.3006%***	<0.01	0.3019%***	<0.01
Ask Falls below 10K Sells – Ask Falls below Halves of 1K Sells (HFTs)	-0.0740%***	<0.01	-0.0749%***	<0.01
Ask Falls below 10K Sells – Ask Falls below Halves of 1K Sells (Non-HFTs: Retail)	0.0478%***	<0.01	0.0476%***	<0.01
Ask Falls below 10K Sells – Ask Falls below Halves of 1K Sells (Non-HFTs: Institutions)	0.0603%***	<0.01	0.0597%***	<0.01
Ask Falls below 10K Sells – Ask Falls below Halves of 1K Sells (Non-HFTs: Foreign)	0.0520%***	<0.01	0.0520%***	<0.01
Ask Falls to 10K Sells – Ask Falls to Halves of 1K Sells (HFTs)	-0.0587%***	<0.01	-0.0594%***	<0.01
Ask Falls to 10K Sells – Ask Falls to Halves of 1K Sells (Non-HFTs: Retail)	0.0034%	0.66	0.0036%	0.64
Ask Falls to 10K Sells – Ask Falls to Halves of 1K Sells (Non-HFTs: Institutions)	0.0103%	0.18	0.0103%	0.17
Ask Falls to 10K Sells – Ask Falls to Halves of 1K Sells (Non-HFTs: Foreign)	-0.0022%	0.79	-0.0022%	0.79
Bid Rises to 10K Buys – Bid Rises to Halves of 1K Buys (HFTs)	0.0116%	0.12	0.0120%	0.11
Bid Rises to 10K Buys – Bid Rises to Halves of 1K Buys (Non-HFTs: Retail)	0.0417%***	<0.01	0.0414%***	<0.01
Bid Rises to 10K Buys – Bid Rises to Halves of 1K Buys (Non-HFTs: Institutions)	0.0172%**	0.03	0.0165%**	0.04
Bid Rises to 10K Buys – Bid Rises to Halves of 1K Buys (Non-HFTs: Foreign)	-0.0024%	0.78	-0.0029%	0.74
Bid Rises above 10K Buys – Bid Rises above Halves of 1K Buys (HFTs)	0.7462%***	<0.01	0.7458%***	<0.01
Bid Rises above 10K Buys – Bid Rises above Halves of 1K Buys (Non-HFTs: Retail)	-0.6903%***	<0.01	-0.6871%***	<0.01
Bid Rises above 10K Buys – Bid Rises above Halves of 1K Buys (Non-HFTs: Institutions)	0.0095%	0.67	0.0125%	0.57
Bid Rises above 10K Buys – Bid Rises above Halves of 1K Buys (Non-HFTs: Foreign)	-0.1827%***	<0.01	-0.1805%***	<0.01
D(Non-HFTs: Retail)	-0.1550%***	<0.01	-0.1550%***	<0.01
D(Non-HFTs: Institutions)	-0.1189%***	<0.01	-0.1190%***	<0.01
D(Non-HFTs: Foreign)	-0.0430%***	<0.01	-0.0431%***	<0.01
Firm fixed	Yes		Yes	
Month fixed	Yes		Yes	
Price level fixed	Yes		Yes	
Trade size fixed	Yes		Yes	
N	216,628,363		216,628,363	

Table 5. Event Study.

Panel A: (+) shares bought or (–) shares sold	Coef.	p-value	Coef.	p-value
Post × (Ask Falls below 1K – Ask Falls below Halves of 1K) (HFTs)	12.903***	<0.01	12.995***	<0.01
Post × (Ask Falls below 1K – Ask Falls below Halves of 1K) (Non-HFTs)	1.248	0.39		
Post × (Ask Falls below 1K – Ask Falls below Halves of 1K) (Non-HFTs: Retail)			-4.248***	<0.01
Post × (Ask Falls below 1K – Ask Falls below Halves of 1K) (Non-HFTs: Institutions)			9.390***	<0.01
Post × (Ask Falls below 1K – Ask Falls below Halves of 1K) (Non-HFTs: Foreign)			-7.460***	<0.01
Post × (Ask Falls to 1K – Ask Falls to Halves of 1K) (HFTs)	2.254	0.72	1.081	0.86
Post × (Ask Falls to 1K – Ask Falls to Halves of 1K) (Non-HFTs)	10.858*	0.08		
Post × (Ask Falls to 1K – Ask Falls to Halves of 1K) (Non-HFTs: Retail)			6.305	0.32
Post × (Ask Falls to 1K – Ask Falls to Halves of 1K) (Non-HFTs: Institutions)			15.046**	0.02
Post × (Ask Falls to 1K – Ask Falls to Halves of 1K) (Non-HFTs: Foreign)			10.334	0.13
Post × (Bid Rises to 1K – Bid Rises to Halves of 1K) (HFTs)	-6.346	0.34	-7.405	0.27
Post × (Bid Rises to 1K – Bid Rises to Halves of 1K) (Non-HFTs)	12.606*	0.06		
Post × (Bid Rises to 1K – Bid Rises to Halves of 1K) (Non-HFTs: Retail)			14.766**	0.04
Post × (Bid Rises to 1K – Bid Rises to Halves of 1K) (Non-HFTs: Institutions)			21.015***	<0.01
Post × (Bid Rises to 1K – Bid Rises to Halves of 1K) (Non-HFTs: Foreign)			-8.644	0.25
Post × (Bid Rises above 1K – Bid Rises above Halves of 1K) (HFTs)	2.693	0.94	10.380	0.77
Post × (Bid Rises above 1K – Bid Rises above Halves of 1K) (Non-HFTs)	0.902	0.98		
Post × (Bid Rises above 1K – Bid Rises above Halves of 1K) (Non-HFTs: Retail)			11.494	0.75
Post × (Bid Rises above 1K – Bid Rises above Halves of 1K) (Non-HFTs: Institutions)			-24.892	0.49
Post × (Bid Rises above 1K – Bid Rises above Halves of 1K) (Non-HFTs: Foreign)			-2.918	0.94
Ask Falls below 1K – Ask Falls below Halves of 1K (HFTs)	-14.838***	<0.01	-14.735***	<0.01
Ask Falls below 1K – Ask Falls below Halves of 1K (Non-HFTs)	4.476***	<0.01		
Ask Falls below 1K – Ask Falls below Halves of 1K (Non-HFTs: Retail)			8.417***	<0.01
Ask Falls below 1K – Ask Falls below Halves of 1K (Non-HFTs: Institutions)			-1.297	0.28
Ask Falls below 1K – Ask Falls below Halves of 1K (Non-HFTs: Foreign)			10.922***	<0.01
Ask Falls to 1K – Ask Falls to Halves of 1K (HFTs)	-12.830***	<0.01	-11.380***	<0.01
Ask Falls to 1K – Ask Falls to Halves of 1K (Non-HFTs)	5.423	0.11		
Ask Falls to 1K – Ask Falls to Halves of 1K (Non-HFTs: Retail)			9.415***	<0.01
Ask Falls to 1K – Ask Falls to Halves of 1K (Non-HFTs: Institutions)			4.946	0.15
Ask Falls to 1K – Ask Falls to Halves of 1K (Non-HFTs: Foreign)			-1.638	0.65
Bid Rises to 1K – Bid Rises to Halves of 1K (HFTs)	7.663**	0.02	9.027***	<0.01
Bid Rises to 1K – Bid Rises to Halves of 1K (Non-HFTs)	-12.725***	<0.01		
Bid Rises to 1K – Bid Rises to Halves of 1K (Non-HFTs: Retail)			-15.123***	<0.01
Bid Rises to 1K – Bid Rises to Halves of 1K (Non-HFTs: Institutions)			-18.767***	<0.01
Bid Rises to 1K – Bid Rises to Halves of 1K (Non-HFTs: Foreign)			4.017	0.27
Bid Rises above 1K – Bid Rises above Halves of 1K (HFTs)	-2.091	0.95	-9.264	0.80
Bid Rises above 1K – Bid Rises above Halves of 1K (Non-HFTs)	-7.643	0.83		
Bid Rises above 1K – Bid Rises above Halves of 1K (Non-HFTs: Retail)			-12.081	0.74
Bid Rises above 1K – Bid Rises above Halves of 1K (Non-HFTs: Institutions)			7.407	0.84
Bid Rises above 1K – Bid Rises above Halves of 1K (Non-HFTs: Foreign)			6.199	0.87
Post × D(Non-HFTs)	-3.196***	<0.01		
Post × D(Non-HFTs: Retail)			0.477	0.36
Post × D(Non-HFTs: Institutions)			-6.963***	<0.01
Post × D(Non-HFTs: Foreign)			-4.412***	<0.01
D(Non-HFTs)	0.649	0.13		
D(Non-HFTs: Retail)			-5.101***	<0.01
D(Non-HFTs: Institutions)			1.472***	<0.01
D(Non-HFTs: Foreign)			9.698***	<0.01
Post	-7.846 ***	<0.01	-7.278***	<0.01
Firm fixed	Yes		Yes	
Trade size fixed	Yes		Yes	
N	6,569,211		6,569,211	

Panel B: (+) KRW bought or (–) KRW sold	Coef.	p-value	Coef.	p-value
Post × (Ask Falls below 1K – Ask Falls below Halves of 1K) (HFTs)	136,866***	<0.01	135,668***	<0.01
Post × (Ask Falls below 1K – Ask Falls below Halves of 1K) (Non-HFTs)	50,145**	0.01		
Post × (Ask Falls below 1K – Ask Falls below Halves of 1K) (Non-HFTs: Retail)			-59,467***	<0.01
Post × (Ask Falls below 1K – Ask Falls below Halves of 1K) (Non-HFTs: Institutions)			184,875***	<0.01
Post × (Ask Falls below 1K – Ask Falls below Halves of 1K) (Non-HFTs: Foreign)			-53,360**	0.02
Post × (Ask Falls to 1K – Ask Falls to Halves of 1K) (HFTs)	-15,330	0.86	-35,360	0.68
Post × (Ask Falls to 1K – Ask Falls to Halves of 1K) (Non-HFTs)	172,660**	0.04		
Post × (Ask Falls to 1K – Ask Falls to Halves of 1K) (Non-HFTs: Retail)			103,059	0.25
Post × (Ask Falls to 1K – Ask Falls to Halves of 1K) (Non-HFTs: Institutions)			268,963**	0.02
Post × (Ask Falls to 1K – Ask Falls to Halves of 1K) (Non-HFTs: Foreign)			137,750	0.15
Post × (Bid Rises to 1K – Bid Rises to Halves of 1K) (HFTs)	-105,152	0.26	-118,918	0.20
Post × (Bid Rises to 1K – Bid Rises to Halves of 1K) (Non-HFTs)	192,876**	0.04		
Post × (Bid Rises to 1K – Bid Rises to Halves of 1K) (Non-HFTs: Retail)			211,494**	0.03
Post × (Bid Rises to 1K – Bid Rises to Halves of 1K) (Non-HFTs: Institutions)			330,661***	<0.01
Post × (Bid Rises to 1K – Bid Rises to Halves of 1K) (Non-HFTs: Foreign)			-116,227	0.26
Post × (Bid Rises above 1K – Bid Rises above Halves of 1K) (HFTs)	-99,297	0.84	12,341	0.98
Post × (Bid Rises above 1K – Bid Rises above Halves of 1K) (Non-HFTs)	154,279	0.76		
Post × (Bid Rises above 1K – Bid Rises above Halves of 1K) (Non-HFTs: Retail)			320,371	0.53
Post × (Bid Rises above 1K – Bid Rises above Halves of 1K) (Non-HFTs: Institutions)			-220,880	0.66
Post × (Bid Rises above 1K – Bid Rises above Halves of 1K) (Non-HFTs: Foreign)			87,617	0.87
Ask Falls below 1K – Ask Falls below Halves of 1K (HFTs)	-195,845***	<0.01	-193,273***	<0.01
Ask Falls below 1K – Ask Falls below Halves of 1K (Non-HFTs)	58,740***	<0.01		
Ask Falls below 1K – Ask Falls below Halves of 1K (Non-HFTs: Retail)			129,641***	<0.01
Ask Falls below 1K – Ask Falls below Halves of 1K (Non-HFTs: Institutions)			-31,586*	0.06
Ask Falls below 1K – Ask Falls below Halves of 1K (Non-HFTs: Foreign)			143,651***	<0.01
Ask Falls to 1K – Ask Falls to Halves of 1K (HFTs)	-180,124***	<0.01	-160.970***	<0.01
Ask Falls to 1K – Ask Falls to Halves of 1K (Non-HFTs)	80,995*	0.08		
Ask Falls to 1K – Ask Falls to Halves of 1K (Non-HFTs: Retail)			119,342**	0.01
Ask Falls to 1K – Ask Falls to Halves of 1K (Non-HFTs: Institutions)			81,234*	0.09
Ask Falls to 1K – Ask Falls to Halves of 1K (Non-HFTs: Foreign)			782	0.98
Bid Rises to 1K – Bid Rises to Halves of 1K (HFTs)	99,105**	0.04	116,754**	0.01
Bid Rises to 1K – Bid Rises to Halves of 1K (Non-HFTs)	-156,217***	<0.01		
Bid Rises to 1K – Bid Rises to Halves of 1K (Non-HFTs: Retail)			-194,397***	<0.01
Bid Rises to 1K – Bid Rises to Halves of 1K (Non-HFTs: Institutions)			-231,392***	<0.01
Bid Rises to 1K – Bid Rises to Halves of 1K (Non-HFTs: Foreign)			70,936	0.16
Bid Rises above 1K – Bid Rises above Halves of 1K (HFTs)	130,235	0.79	27,387	0.96
Bid Rises above 1K – Bid Rises above Halves of 1K (Non-HFTs)	-255,786	0.61		
Bid Rises above 1K – Bid Rises above Halves of 1K (Non-HFTs: Retail)			-332,269	0.51
Bid Rises above 1K – Bid Rises above Halves of 1K (Non-HFTs: Institutions)			-39,010	0.94
Bid Rises above 1K – Bid Rises above Halves of 1K (Non-HFTs: Foreign)			-41,275	0.94
Post × D(Non-HFTs)	-39,438***	<0.01		
Post × D(Non-HFTs: Retail)			9,657	0.18
Post × D(Non-HFTs: Institutions)			-94,485***	<0.01
Post × D(Non-HFTs: Foreign)			-49,338***	<0.01
D(Non-HFTs)	-4,175	0.48		
D(Non-HFTs: Retail)			-78,345***	<0.01
D(Non-HFTs: Institutions)			7,715	0.21
D(Non-HFTs: Foreign)			110,066***	<0.01
Post	-140,559***	<0.01	-132,111***	<0.01
Firm fixed	Yes		Yes	
Trade size fixed	Yes		Yes	
N	6,569,211		6,569,211	