The Effects of a Transparency Change in the Preopening Session on Price discovery[#]

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Abstract

This paper examines how price discovery efficiency is affected by changes in the pre-trade transparency level on the Korea Exchange (KRX) on October 6, 2003. The preopening session on the KRX has experienced three policy changes related to pre-trade transparency of the open limit order book. We find that KRX stocks composing the KOSPI200 index have significant price learning about 10 minutes before the opening. We document that the transparency level change has reduced informed traders' participation in the preopening, but has enhanced the information transfer efficiency for uninformed traders. The information loss from the decreased informed participation is canceled out by the increased information transfer efficiency for the uninformed. The total amount of market price discovery shows no significant difference after the transparency change. Overall, we conclude that the pre-trade transparency level change did not increase preopening informativeness of the intrinsic price.

JEL Classification: G1; G14; G18

Keywords: Preopening period, Price discovery, weighted price contribution, pre-trade transparency

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The Effects of a Transparency Change in the Preopening Session on Price Discovery

1. Introduction

This paper examines how price discovery efficiency is affected by changes in the pre-trade transparency level on the Korea Exchange (KRX) on October 6, 2003. The preopening session on the KRX has experienced three policy changes related to pre-trade transparency of the open limit order book. Only the best bid and best offer of the outstanding orders with the total bid and order volumes were disclosed before October 6, 2003, while the three best bid prices and three best offer prices with order volumes relative to prices were disclosed afterwards. In addition, the indicative opening price has been disclosed since October 6, 2003, though information about total bid and offer order volume has been excluded from the disclosure. Finally, after-hours trading before the preopening period has been allowed since December 1, 2003. These policy changes intend to share more information with individual traders. This paper attempts to answer the question of how changes in transparency level have affected the efficiency of price discovery.

Our sample covers the period from August 18, 2003, to November 23, 2003, which is divided into two sub-periods: 1) the best bid and offer period and 2) the three best bids and offer period. By comparing the characteristics of the preopening period for the pre-event period with those for the post-event period, we hope to find out useful information on how informed traders behave during a Walrasian tâtonnement.

Most stock exchanges use a single-price auction method during the preopening period that allows market participants to order, revise and cancel freely without any cost. The main role of the preopening period is to discover the intrinsic value of each stock before actual trading. Large block orders are usually noticeable under an open limit book system. If the transparency level is high, traders can get a hunch about what the opening price will be. Informed traders thereby will use false orders to misguide the opening price to a profitable level. At the last moment before the opening, informed traders will then submit their true orders and reveal private information.

Several studies have noted such characteristics of the preopening period in a stock market with

informed traders. Biais, et al. (1999) show that most informed traders submit informative orders within 15 minutes before the opening of the Paris Bourse. Also, by estimating the speed of learning during the reopening period, the researchers argue that learning speed increases until the opening. Barclay and Hendershott (2003) use the probability of an informed trade (hereby, PIN) and weighted price contribution analysis to show that the preopening period plays a great role in the price discovery process with NASDAQ ECN after-hours trading data. (See Glosten and Harris (1988), Hasbrouck (1988, 1991), Easley et al. (1996), Cao et al. (2000), and Barclay and Hendershott (2005) for further empirical results.)

This paper has several distinctive features compared to previous research. While Madhavan et al. (2000) and Boehmer et al. (2005) provide empirical results for how pre-trade transparency changes in trading periods affect the market, no research has been conducted on the preopening period transparency changes. In case of the trading-period analyses, measures such as bid and offer spread, trading cost, and information decomposing VAR are used to analyze the effects of transparency changes. However, these methods are not usable in this study because no actual trades are made during the preopening period. We employ unbiasedness regressions in order to see whether there is sufficient price discovery.

After dividing 200 sample stocks into quartiles by total traded won volume, we find that the speed of learning is steady for most actively traded stocks. Since most of the actively traded stocks have much information leakage before the opening, the speed of learning increases from the top percentile to the lowest. Using a PIN value, we show that the participation behavior of informed traders is influenced by disclosure policy changes of interest. The overall price discovery efficiency is not statistically different between the pre-event and post-event periods when we look at weighted price contributions.

The remainder of this paper is as follows: section 2 presents discussion and hypotheses about price discovery in the preopening period. In section 3, we provide descriptions of our sample data and in section 4 report unbiasedness regression results and speed of learning GMM estimations. In section 5, the behaviors of informed traders are investigated. Section 6 compares overall price discovery efficiency, and section 7 concludes this paper.

2. Hypothesis

2.1 Price discovery in preopening periods

There is no trading activity between the previous day's after-hours trading and the next day's

preopening period on the KRX, which creates discontinuity of information flow. Thus, information asymmetry will increase after the close of the KRX, and the indicative price in the preopening period will be a noisy estimate of the intrinsic price. Biais, et al. (1999) suggest that informed traders may place their orders just before the opening to minimize price impact. Strategic behaviors by informed traders, such as placing false orders, add noise to the indicative prices. For example, if an informed trader has information that an individual stock's return will be positive during the trading period, the informed trader may place false large offer orders during the preopening period to lower the indicative price. After the indicative price drops, he will cancel or revise the previous orders to bidding orders just before the opening, which enables him to achieve additional positive returns. Uninformed traders who assume high adverse selection loss would also participate just before the opening, hoping to collect information from the informed traders' true orders. Thus, the strategic behavior of informed traders and uninformed traders will increase the orders placed before the opening. Such a market is referred to as a noisy market. We test whether orders placed during the preopening period lack efficient information with a null hypothesis: the 'noise hypothesis.'

Informed traders disguise their true orders and prefer to place false orders when the cost of order revision is negligible with enough time to revise or cancel them. However, when using false orders, informed traders face the risk of failing to settle trades at the opening due to events such as system break-downs or circuit break regulations[1]. Such risks induce informed traders to place their true orders sometime before the end of the preopening period for safety reasons. Gradually, the weight of true orders placed by informed traders will increase as it becomes closer to the opening. Ultimately, the informative orders placed by informed traders in the preopening period will guide the indicative price to the intrinsic value, and uninformed traders will learn the intrinsic value from the information. Biais, et al. (1999) call this alternative hypothesis the 'learning hypothesis.'

If the noise hypothesis is true and learning does not occur during the preopening period, uninformed traders may wait until the opening starts since investors' adverse selection risk will be high during the preopening period. After the opening, when adverse selection risk is reduced, bid and offer

[1] Circuit break is a rule in the KRX. If the return changes more than 15% in a five-minute interval, then trading of the stock is automatically stopped for five minutes.

orders will keep growing as the participation of informed traders increases. On the other hand, if the learning hypothesis is true, adverse selection risk will decrease as the opening approaches, which encourages uninformed traders to participate in the preopening period. Stock prices will converge to their intrinsic value faster under this learning hypothesis than under the noise hypothesis.

The existing literature documents empirical evidence supporting the learning hypothesis in the Paris Bourse (Biais, Hillion, and Spatt, 1999), NASDAQ (Cao, Ghysels, and Hatheway, 2000; Barclay and Hendershott, 2003, 2005), and NYSE (Madhavan and Panchapagesan, 2000). This paper examines the issue in the KRX.

2.2 Effects of changes in transparency level on price discovery during preopening period

The main reason that the KRX changed the disclosure policy during the preopening period was to increase information sharing among investor groups[2]. Thus, the impact of the changes in publicly disclosed information on the market can be estimated by comparing price discovery efficiencies. Price discovery efficiency is the amount of information that can be extracted within the preopening period about the intrinsic value of a stock. The price discovery efficiency of the opening price is the combination of two parts. The first one is 'how fast true information can be extracted from the market,' which can be thought of as the speed of convergence (or learning) to the intrinsic value. Baruch (2005) presents a theoretical model implying that increased transparency improves informational efficiency. However, Madhavan et al. (2005) disagree by developing a model and using the Toronto Stock Exchange data they show that spreads widen and volatility becomes higher after market transparency change. The second one is 'when sufficiently true information is available in the market,' i.e., the time that informed traders place their true orders by canceling or revising false orders previously placed. When informed traders place their true orders, the proportion of the informed orders to the total orders will increase. The risks of exposed limit orders noted by Harris (1996) suggest that when speed of learning increases due to policy change, the proportion of informed traders will decrease.

The speed of convergence shows how fast the investors learn the intrinsic value of a stock from the disclosed prices before the opening price is settled. During the preopening period, orders related to

[2] 'Understanding the trade mechanism of the Korean Stock Exchange' p 29, October 2003, irregular issue.

true information are concentrated just before the market opens. When sufficient information about the intrinsic value is available, uninformed traders' participation will increase. Our hypothesis suggests the speed of convergence increased after the disclosure policy changed to a higher transparency level. Disclosing three best bid and offer prices and respective volumes related to those prices instead of only the total bid and offer volume may facilitate better identification of false orders. When only the total bid and offer volume is disclosed, traders can manipulate the net order pressure easily by placing large buy (sell) orders with a very low (high) price. We estimate the speed of convergence in Vives's (1995) framework by employing the GMM method proposed by Biais, et al (1999). In sum, our first hypothesis about the change in transparency level during the preopening period is the following:

H1: The speed of convergence in period 1 is slower than the one in period 2.

Even if greater pre-trade transparency increases the speed of learning, it is difficult for uninformed traders to learn from submitted orders when the proportion of the informed orders to the total orders is small. Thereby, not only the timing when the informed traders start to revise their orders but also the proportion of informed orders placed during each time interval throughout the preopening period is important when trying to gain sufficient information. In order to compare the price discovery efficiency between the two periods, we test the second part that influences the level of learning. We test whether the informed traders' participation is different between the two periods using the opening trade volume and the Easley, Kiefer, and O'Hara (1996, 1997a,b) structural model to estimate the probability of informed trading (hereafter, PIN).

H2: The probability of informed trading in a more transparent period (period 2) is smaller than the one in a less transparent period (period 1).

3. Data

3.1 Quote data and trade data

All orders on the KRX are matched and executed through an automated system according to price

priority followed by time priority. There are no designated market makers on the KRX. Most of the market data and information are disclosed on a real-time basis through the KRX computer system. Call auction is used for the preopening and closing sessions, whereas continuous auction is used for the regular trading session. The preopening session starts at 8:00 AM and lasts for an hour while the trading session starts at 9:00 AM and ends at 3:00 PM after a 10-minute closing session. Also, there are a pre-hour session from 7:30 AM to 8:30 AM[3] and an after-hours trading session from 3:10 PM to 4:00 PM. Only the amount of the bid or offer orders can be submitted during the pre-hour session, whereas the order price as well as the amount of orders can be submitted during the preopening session. During the after-hours session, the trading price is locked at the same day's closing price, and only the amount of the bid or offer orders can be submitted.

On average, 684 stocks were listed on the KRX in the year 2003. Stocks with large trading volume per day usually have active preopening order submissions, and so we use only the stocks in the KOSPI 200 index, which contains 200 blue-chip stocks from eight industry groups[4]. Selection and realignment of the constituents of the KOSPI 200 index take place every half-year. Throughout the sample period, three stocks were replaced due to acquisition and lack of trading volume. Those three stocks are excluded from our sample.

The stock market data set used for this study has been provided by the KRX. The KRX stock data contain information regarding the orders placed, modified, and canceled as well as all the trades executed, The first price and volume disclosure starts 10 minutes after the beginning of order submissions, which is normally 8:10 AM, except for two days, the first trading day of the year and the day of the annual national college entrance exams. Although the indicative price is reported every day, the KRX does not record and supply it. We use the quoted data set to calculate the indicative prices every time they change from 8:10 AM every day. The trading data are used for the probability of informed trading analysis.

3.2 The preopening session on the KRX

The preopening session on the KRX has experienced three policy changes related to the

[3] Note that the pre-hour session has a 30-minute overlap with the preopening session.

[4] The eight industry groups are fisheries, mining, manufacturing, electricity and gas, construction, services, post and communication, and finance.

transparency of the open limit order book. On October 6, 2003, the KRX decided to disclose the three best bids and offer prices and volume instead of only the best bid and offer price and volume that had been disclosed before the date to supply more information to investors thanks to the improvement in system conditions[5]. This change makes the transparency level of the KRX preopening session comparable to that of other exchanges. For example, NASDAQ reports the five best bids and offers quoted by the market makers, and the Paris Bourse reports the four best bids and offer prices and volume.

Since July 1, 2003, the indicative KOSPI index and KOSPI200 index have been distributed every 10 seconds through the KRX data transferring system for 30 minutes starting from 8:30 AM for the preopening session, and for 10 minutes before the regular trading session closes at 3:00 PM[6]. In addition, the pre-hours trading session was established on December 1, 2003. These two changes may not directly affect the transparency level but contribute to efforts to reduce information asymmetry among market participants.

We divide our sample data by the policy changing event. Period 1 is for 27 trading days between August 18 and September 28 of 2003, while period 2 is for 30 trading days between October 13 and November 23 of 2003. We use the mid-points of the bid-offer prices for individual stock prices observed every minute instead of the trading prices to avoid trading price bouncing problems[7] during the regular trading session. To be consistent with the data used in the regular trading time, we also use the best bid-offer mid-prices during the preopening session instead of the indicative prices.

3.3 Descriptive statistics of data

For the sample period, the KOSPI200 index increased from 93.39 points to 99.94 points. Monthly returns were all positive except for September. In period 1, daily returns are mostly positive

[5] Before the preopening session transparency level change, the indicative price and volume were also reported. The regular trading session transparency level was the 10 best bid and offer prices and related volume for each price. The first preopening bid and offer prices and volumes are reported starting 10 minutes after the preopening session begins (8:10 AM).

[6] The KOSPI200 index related options and futures are two of the world's most actively traded derivatives. The indicative index plays a great role on discovering the derivatives opening and closing price.

[7] For example, if bid-offer prices are \$85-\$95, then a sell-side-initiated market orders trading price would be \$85 while the mid-price would be \$90. With the bid-offer prices not changed, a buy-side-initiated market order would make the trading price rise to \$95 whereas the mid-price would be still \$90.

during the first half followed by a series of negative returns resulting in a -4.15% return for the whole period. Period 2 has a similar return pattern as period 1 but has an overall 2.2% positive return. The daily log return volatility is similar for the two periods, and the daily returns for both periods are distributed between -2.01% and 1.05%, meaning that there is no major index change during our sample period.

Figure 1.a shows the average one-minute bid and offer volume per stock from 8:00 AM to 3:00 PM in period 2. Most of the orders are concentrated near the opening and closing of the trading session. The difference between bid volume and offer volume is mostly positive with some high peaks near the opening (9:00 AM) and closing (3:00 PM). This net positive bidding volume may be because most of the stocks have positive returns for the sample period. Actually, as period 1 has negative returns in general, the net bidding volume for period 1 is negative for most of the one-minute intervals.

Figure 1.b shows the average five-minute revised and canceled order volume per stock. The revised offer order volume is much higher than the bid order volume. Most of the offer revisions are changes to lower offering prices than the prices originally offered, while the bid order revisions are changes to higher prices than the prices originally bid.

[Insert Figures 1.a and 1.b here]

Figure 2.a and Figure 2.b show the executable orders, which are ask (bid) orders with prices lower (higher) or equal to the opening price, placed in one-minute intervals during the preopening period. In these figures, executable orders are divided into two groups depending on whether the order price is equal to the opening price or not. These figures show that executable bid orders have different patterns compared to executable offer orders. The number of executable bid orders is negligible up to approximately 8:50 AM (10 minutes before opening) and soar suddenly around one minute before 9:00. The ratio of the volume of executable orders to total ordered volume is 0.33 for bid orders and 0.84 for offer orders. The difference is due to higher executable bid orders with prices equal to the opening price. Also, the percentage of orders executed at the end of the preopening session is 32.7% for bid orders and 28.3% for offer orders. When traders pursue a long position during the preopening period, they seem to submit false orders, which would not be executed at the opening. The high bid order cancellation and the executable bid orders average volume show that large portion of submitted orders before 8:50 AM are

false orders. The traders try to manipulate the preopening bid prices to get prices lower than their intrinsic value, and then place their true orders just before the opening. On the other hand, when traders intend to sell their stocks, they are exposed to more risk than investors who are planning to buy stocks. If investors know that stock prices will go down, they will surely lose when the stocks are not sold.

The offer orders that end up being executed increase steadily till 8:50 AM and then leap considerably at the opening. If investors know that stock prices will go up, they may lose the opportunity to make money, but the risk is limited. Since the KRX uses time priority when sorting the orders with the same price, submitting orders that are executable during the early hours within the preopening period is important when stock prices are expected to drop. Another reason could be that uninformed traders constantly place executable orders irrelevant to time, trying to follow the misleading bid offer prices created by the informed traders who expect stock prices to rise. If so, the orders from the uninformed will climb up the ladder of the open limit book, adding more volume to executable offer orders as time passes by, and executable offering orders equal to opening prices will have low volume until the uninformed stop climbing up the ladder near the opening price.

[Insert Figures 2.a and 2.b and Table 1 here]

Using the quoted data set, we divide each order into individual investors, institutional investors, and foreign investors[8]. For each 10-minute intervals we divided the bid and offer orders which are normally placed, revised, and canceled by the total volume within the interval. The results are shown in panel A of table 1. Assuming that foreign investors and institutional investors have information superiority over individual investors, we focus on these two investor groups and exclude the individual investor group's ratio. The sum of foreign and institutional investors' normally placed bid orders ratios in period 1 maintain 6% level for all intervals after 8:30 AM, whereas the offer orders ratio increase from 4.5% at 8:30 AM to 9% at the opening. In period 2, normal placed order ratios show higher ratios after 8:40 AM except for the bid orders at the first 10 minutes and offer orders at 8:20~8:30 AM. Revision and

[8] The KRX submitted orders data set categorize investors into nine groups: i) securities company, ii) insurance company, iii) investment trust company, iv) bank, v) investment bank, vi) fund, vii) national investor, viii) individual, xi) and foreigner. The nationalities of the foreign investors are provided in a separate data category.

cancellation ratios are higher in period 2 than in period 1 for most of the time intervals. The revision and cancellation ratio of foreign investors near 8:30 AM, which are at least over 10%, is notable. After the preopening period, the normal placed ratios for informed traders show similar participation percentages in both periods.

We sort the KOSPI 200 index constituents by each period's average won volume and divide the sample into four groups. The proportion of the first quartile's total order volume to the overall order volume is about 70% for all order types with similar investor proportion patterns to panel A. Panel B shows the ratios for the last quartile. The last quartile order portion is lower than 3% of the total volume. The normally placed orders' informed participation percentage is about 3% ~ 4% in the last quartile, which is only half the value of the overall ratios. The foreign investors' revision and cancellation ratios both increase in period 2, while the institutional investors have opposite movements. A notable change in the last quartile is that the institutional investors' cancellation participation ratio increases after the opening to at most 34% between 9:20 AM and 9:30 AM. Even though the institutional investors' normal order ratio in the last quartile is similar to the first quartile, the cancellation ratio sharply increases during the second period. Panel C shows the total volume orders for each investor group during the preopening and their 10-minute participation proportion.

We also investigate the proportion of each hour intervals' normally placed, revised, and canceled orders volume compared to the same day's total volume. Most of the orders placed take place near the opening and closing of the regular trading session. Almost 36% of the bid and offer orders are placed before 10:00 AM. The revision and cancellation proportions are also high near the opening and closing one-hour interval with the highest value during the 9:00 AM to 10:00 AM interval. The first hour following the opening of the market seems to play a great role in adjusting misplaced orders.

4. Speed of convergence

4.1 Unbiasedness regression

Biais, Hillion, and Spatt (1999) suggest the following unbiased regressions to test the noise and learning hypotheses:

$$R_{T,s} = \alpha + \beta_{t,s} R_{t,s} + \varepsilon_{t,s} \quad (1)$$

Where $R_{T,s}$ is the close-to-close return on stock s and $R_{t,s}$ is close to time t return on stock s. The regressions are run for each one-minute interval of the preopening session. The standard errors and confidence intervals are calculated from the time series of the average value of $\beta_{t,s}$ over stocks. The return values are used to control for heteroskedasticity among firms. When the disclosed prices maintain full information about the true values, thereby the conditional expectation of the current price is equal to the true value, $\beta_{t,s}$ will have a value near one. Barclay and Hendershott (2003, 2005) interpret the slope coefficient $\beta_{t,s}$ as a signal-to-noise (or more precisely, signal-to-signal-plus-noise ratio). By looking at the extent to which $\beta_{t,s}$ is less than one, we can estimate how much noise the close to time t return contains.

Figure 3 shows the time series of the average value of the regression coefficients for period 2. The results of period 1 are qualitatively similar to those of period 2 from the point of testing the noise and learning hypotheses.[9] The average slope coefficient increases sharply between 8:50 AM and 9:00 AM to about 0.9. It is much higher than the values reported by Biais, et al. (1999) but similar to the values shown in Barclay and Hendershott's (2003) work. Though Barclay and Hendershott (2003) attribute the high values to ECN trading on NASDAQ, our sample shows that preopening orders may provide efficient price discovery without any trades. After 9:00 AM, the average regression coefficient fluctuates near one with the confidence interval width decreasing. We also show the bid-ask spread averaged across stocks in Figure 3. The spread value decreases to about 220 won at 9:00 AM, which is about one-eighth of the starting value near 8:10 AM. Even though the informativeness of the price within the trading session might change, resulting in a larger or smaller bid-ask spread, this difference is minimal compared to the one-hour spread change in the preopening period. The regression shows that using the return earlier than the opening can explain only a part of the close-to-close return.

[Insert Figure 3 here]

[9] The equally weighted average coefficients for period 1 are greater than for period 2, and the difference is significant at the 5% level using paired t-test statistics from 8:10 AM till 8:54 AM. After the opening, period 2 has greater average coefficient values, and the difference is significant from 9:08 AM till 9:30 AM.

The average values of the unbiasedness regression's adjusted R-square for the 198 stocks categorized into four groups using the daily traded won volume show that the R-square is highest at the top quartile group; the rest of the groups' R-squares are also in the same order as the quartile after 8:50 AM. The traded won volume is a variable capturing the daily trading activity and the market value. Thus, the first quartile group consists of the most actively traded stocks, which implies that price discovery, if it exists, is more efficient compared to other groups.

[Insert Table 2 here]

Table 2 shows the two periods' regression coefficients for each five-minute interval starting from 8:10 AM. Both periods' average coefficients are lower than 0.4 until 8:45 AM, which increase to about 0.9 at the opening within the last 15 minutes of the preopening. Period 1's overall regression coefficient is higher than the coefficient for period 2 for all the intervals except for the last five minutes. The paired t-test for each period's 198 regression coefficients is different at the 5% level for four intervals from 8:40 AM till 8:55 AM. The statistical difference after 8:40 AM shows that more price learning occurred during period 1 till 8:55 AM. However, the last five minutes' overall average ordering for the two periods is reversed, with a higher value for period 2. Although the last five minutes do not show a statistical difference between the two periods, the results indicate that price discovery after the policy change has been delayed to the last five minutes with higher informativeness.

Next, for each period the coefficient declines from the highest won volume quartile (quartile 1) to the lowest won volume quartile (quartile 4). The cross-sectional average in period 1 has mostly the same ordering as the quartile, while in period 2, quartile 4 has higher values than quartile 3 from 8:25 AM till 8:55 AM. When a stock's won volume is small, the informativeness at a certain time is lower than higher won volume stocks. Comparing with time, the top three quartiles have similar results to the overall sample, except that the second quartile result at 9:00 AM is not reversed. The last quartile average values for period 2 are higher than period 1 starting from 8:25 AM. After the policy change, the informativeness of the last five minutes for most of the quartiles have increased.

[Insert Figures 4.a and Figure 4.b and Table 3 here]

Figure 4.a and Figure 4.b are the time-series of the indicative prices of the market equally weighted index[10]. Although the KRX provides the indicative KOSPI200 index for every 10 seconds starting from 8:30 AM till the opening, the indicative index value is calculated from 8:10 AM till the opening in this study. We divide each period into two sub-periods: one for days with positive close-to-close returns and the other for days with negative close-to-close returns. At 8:10 AM, the index returns have negative values whether we look at the positive return days or the negative return days, but the average close-to-open return turns positive at the positive days, making the index return in the preopening a U-shaped figure. Though the average close to time t return becomes positive around 8:50 AM and stays positive during period 1, period 2 has a few minutes' delay before the return turns positive. For the negative return period, the average close to time t returns have negative signs for period 1 and period 2. Period 1's returns for both positive and negative return days reach their minimum value (-0.1.05%, -1.4%) before 8:20 AM and increase to the opening return while period 2 has slower increasing returns, making the return difference between the two periods widest near 8:40 AM. Since the index price return and momentum are headed to the average close-to-close return, the gap shows that the informativeness at the same time for the two periods is different, which is similar to the results from Table 2.

Next, we test whether the average 10-minute returns of the market weighted index is difference in period 1 and period 2. Table 3 shows the p-values of the tests for positive return and negative return periods and the average index return differences[11]. First, the tests within the periods' negative days' returns and positive days' returns have similar difference value signs. The difference is mostly positive except for the negative values from 8:20 AM to 8:25 AM and from 8:45 AM to 8:50 AM with statistical significance at the 5% level. Second, the test results across the periods both have negative differences till 8:40 AM, and a significant difference at the 5% level around 8:20 AM for positive days. The overall, positive, and negative results are statistically significant at the 5% level at 8:50 AM. Although the positive difference at 8:45 AM is not significant, at least three or four of the five-minute returns just before the

[10] Although the KOSPI 200 index disclosed is a market value weighted index, an index with equal weighted returns is used here to be consistent with other test methods.

[11] The difference within each period is the average index returns for positive days minus the average index returns for negative days. The difference between periods is period 2's values minus period 1's values.

opening are significant at the 5% level. Larger positive returns (negative returns) in five minutes for positive days (negative days) does not necessary mean more information is imbedded in the market; however, one of the periods had lacked sufficient information between 8:45 AM and 8:55 AM but had at least had enough information gathered at the last five minutes, making the return difference non-significant. Such results are subordinate to the results of the unbiased regression.

4.2 Speed of learning

Biais, Hillion, and Spatt (1999) suggest that the asymptotic speed of learning may be measured by γ in the following equation:

$$t^{\gamma}(v - P_t) \rightarrow N(0, \sigma^2), \quad t \rightarrow \infty \tag{2}$$

where v and P_t are the intrinsic value and time-t price of a stock, respectively. They also suggest that γ can be estimated from the following moment conditions and GMM. We follow Biais, et al. (1999) and use the same moments and number of instrumental variables. However, we vary the time interval for the instrumental variables due to the different preopening time period length between the Paris Bourse and the KRX.

Table 4 reports the results of the GMM estimations using a five-minute time interval for time t, t-1, …, t-4. Consistent with hypothesis H1, the GMM estimation results in panel A show that the gamma value for period 2 is higher in all the quartiles. Quartile 4 is omitted due to the lack of sufficient trading volume. Quartile 1's gamma value cannot reject the hypothesis that there is no learning, but is near the square root value implied in Vives (1995). For quartile 2 and quartile 3, the estimated value of gamma in period 2 is about twice the value in period 1, implying that price discovery during the last 10 minutes of the preopening session is facilitated by more transparency for the mid-size and small-size firms in our sample. The estimated value of K can be interpreted as noise within the observed intrinsic value proxy, which is similar for both periods and quartiles. The results in gamma estimations for the two periods in panel B are the opposite of those in panel A in that period 1 has a faster speed of learning compared to period 2. The difference between gamma estimations has, however, mostly decreased, and quartile 1's speed of learning reported in panel B is much higher than that in panel A. Since the stocks in quartile 1 are the most actively traded stocks with more informed orders than other quartile stocks, the prices of the

stocks in quartile 1 converge faster to the intrinsic prices. This faster convergence enables more information to be gathered before the opening for quartile 1 stocks. It might account for the higher gamma value in panel B than in panel A compared to quartile 2. The higher gamma estimates in panel B than in panel A, show that less information is gathered in the final 10 minutes of the preopening period than the next final 10 minutes for these stocks. None of the gamma estimates in period 1 stocks in panel A and B are statistically significant at the 5% significance level. The gamma values in period 2 have decreased in panel B for quartile 1 and 2 while quartile 3 has the fastest value in Table 4. The decrease in gamma shows that the policy change has shifted a high portion of the price discovery ability to the last five minutes of the preopening. We also examine gamma estimates in the periods before 8:40 AM, but all of the gamma estimates have slower speed than panel B in period 1. For period 2, the gamma for quartile 1 is similar to period 1 but has somewhat faster learning in the other quartiles.

[Insert Table 4 here]

5. The probability of information trades

We use the Easley, Kiefer, and O'Hara structural model to examine whether the ratio of informed orders during the preopening period has changed since October 6, 2003. Figure 5 shows the EKO model structure assumed in our study.

[Insert Figure 5 here]

The EKO model assumes that the tree structure in Figure 5 repeats, and that there is at most one information event in each period. During the start of each period, an information event occurs with probability α, and informed traders receive the information. An information event contains good news with probability $(1-\delta)$ and bad news with probability δ. Informed traders will place buy (sell) orders with the arrival rate of μ when the information is good (bad). Uninformed traders place buy (sell) orders with

the arrival rate of ε_b (ε_s) without observing the information. Assuming that order arrival processes follow Poisson processes, Easley, et al. (2002) provide the following measure of the probability of information-based trading (PIN):

$$PIN = \frac{\alpha\mu}{\alpha\mu + \varepsilon_b + \varepsilon_s} \tag{3}$$

α, μ, ε_b, and ε_s in (3) are estimated from maximizing the likelihood function.

$$L\left((B,S)\,|\,\alpha,\delta,\mu,\varepsilon\right) = (1-\alpha)e^{-\varepsilon_b T}\frac{(\varepsilon_b T)^B}{B!}e^{-\varepsilon_s T}\frac{(\varepsilon_s T)^S}{S!}$$

$$+\alpha\delta e^{-\varepsilon_b T}\frac{(\varepsilon_b T)^B}{B!}e^{-(\mu+\varepsilon_s)T}\frac{((\mu+\varepsilon_s)T)^S}{S!} + \alpha(1-\delta)e^{-\varepsilon_s T}\frac{(\varepsilon_s T)^S}{S!}e^{-(\mu+\varepsilon_b)T}\frac{((\mu+\varepsilon_b)T)^B}{B!} \tag{4}$$

where B and S represent total buy orders and sell orders for the period, respectively.

PIN values are estimated and averaged across firms for each quartile group over the time intervals of [8:00, 9:00], (9:00, 9:30], (9:30, 10:00] and (10:00, 10:30]. Table 5 provides the cross-sectional averages and standard deviations of the estimated PIN values for period 1 and period 2 as well as the p-values of the difference of the average PIN values for the two periods.

To examine whether the ratio of informed trades decreases after policy change, we test whether the average PIN value in period 2 is smaller than the one in period 1. The test is done by using the Mann-Whitney test, and Table 5 reports the one tailed p-values. Consistent with hypothesis H2, the average PIN value of the total sample for period 2 is smaller than the one for period 1 in the preopening session. However, the difference is not statistically significant even at the 10% significance level. Even when we look at the average PIN values of the four quartile groups, the differences of the average PIN values for the two periods are not statistically significant, though the period 2 value is smaller than the period 1 value except for the quartile 1 group. Therefore, we cannot say that the probability of informed trading becomes smaller after the increase in transparency in the preopening session.

[Insert Table 5 here]

Table 5 also shows the average PIN value of the 30-minute interval estimations in the trading session after the policy change. One thing notable is that the average PIN value for the trading session is the

opposite direction to those in the preopening session. We can see in Table 5 that the ratio of informed traders to uninformed traders is higher for small firms than for large firms during the trading session. In the first 30-minute interval after the opening, the average PIN value for every quartile group in period 1 is bigger than the ones in period 2, and the difference of the overall sample PIN values for the two periods is statistically significant at the 1% significance level. The next 30 minutes of the trading session reverses the trend; the PIN value for period 1 is bigger than for period 2, and the difference is statistically significant at the 5% significance level. Noting that there were no important macroeconomic events during our sample period and that the average trading volume in period 2 is not statistically different from the one in period 1[12], these PIN value changes in the trading session can be interpreted as more concentration of the participation of informed traders on the first 30 minutes in the trading session. After the increase of transparency in the preopening session, resulting in increasing information dissemination speed, informed traders move their trades or orders from the preopening session to the first 30 minutes in the trading session to keep an advantageous position. When information is disseminated faster to uninformed traders after the transparency increase, informed traders might want to keep their information until the last minute at the preopening and act fast on their private information after the opening, thereby concentrating their orders to the first 30 minutes after the trading session opens instead of participating in the preopening or after 9:30 AM. After 10:00 AM, the overall and quartile PIN values show no significant difference throughout the day (we only show the 10:00 AM to 10:30 AM values).

[Insert Table 6 here]

Table 6 shows the PIN estimation for each time period regressed upon post-event dummies and firm control dummies. This table shows that the preopening period has different characteristics compared to the regular trading session. In the preopening, the intercept value is negative while the log value of the trading volume coefficient is positive; all values are significant at the 1% significance level. High trading volume and market value stocks induce more informed trading in the preopening. When stock return volatilities are high, the impact of a price change by informed traders' true order can be disguised with

[12] The bid and offer trade volume difference after the policy change was tested using the Mann-Whitney, but none of the samples show a significant difference at the 10% level.

other noise. Indeed, the log return volatility coefficients are significant only during the preopening session when disguising is most important. The post-event and quartile 4 shows negative coefficient values, meaning that the policy change drove out informed trading in the lowest won volume group. After the opening, the log value of the trading volume and market value coefficients turns negative for all the 30-minute time intervals. The post-event and quartile 4 group show high positive informed trading increases within the first 30-minute trading session after the opening compared to the negative and significant values in the preopening. All the other post-event and quartile dummies show negative coefficient values after 9:30 AM.

6. Weighted price contribution

We use the weighted price contribution, first proposed by Barclay and Warner (1993), to measure the amount of new information incorporated into stock prices during a given time interval. Also, the cumulative weighted price contribution is calculated.

$$WPC_s = \sum_{i=1}^{T} \left(\frac{|r_{s,i}|}{\sum_{i=1}^{T} r_{s,i}} \right) \times \left(\frac{r_{s,i}}{r_{s,T}} \right) \tag{5}$$

$$CWPC = \sum_{s=1}^{S} \left[\sum_{i=1}^{T} \left(\frac{|r_{s,i}|}{\sum_{i=1}^{T} r_{s,i}} \right) \times \left(\frac{r_{s,i}}{r_{s,T}} \right) \right] \tag{6}$$

Equation (6) is the cumulative weighted price contribution (hereafter, CWPC) where $r_{s,i}$ is the close to time i log return for stock s instead of a given time period, and $r_{s,T}$ is the close-to-close return for stock s. The fraction of the price change until time t relative to the close-to-close price change is weighted by the daily contribution to the cumulative absolute price change over the entire sample period. The first weighting term downweights return observations when the absolute value of the daily price change is small[13]. We calculate the cumulative WPC for each stock every day and report the average value for each

[13] Our definition of CPWC is similar to the one given in Barclay and Warner (1993) and Cao, Ghysels, and Hatheway (2000) in the sense that CPWC is calculated first stock by stock and then averaged over the stocks. Barclay and Hendershott (2003, 2005) calculate WPC first for a period by weighting over stocks and then averaging out over the sample period.

quartile categorized by the total traded won volume ordering.

[Insert Tables 7.a and 7.b here]

Table 7.a is the 10-minute close-to-open WPC results, and Table 7.b is the close-to-close WPC. In Table 7.a, period 1 shows 58% of close-to-open returns are discovered before 8:20 AM using the overall sample. Price discovery is faster in higher won volume quartiles. However, the price movement overreacts for most of the quartiles, making the last 10-minute WPC values negative. Period 2's WPC values show similar movements as period 1 except that quartile 4 has no negative values. The decreased PIN value in period 2's quartile 4 implies that quartile 4 stocks could have had insufficient information until the opening, making WPC values positive.

In Table 7.b, the close-to-close WPC is reported. The close-to-close WPC shows how much price discovery of the closing price (intrinsic value) occurs in each interval. The results have mostly positive WPC values before 8:30 AM but have several negative values until the opening in period 1. In period 2, the overall WPC values are all positive, and the number of negative value intervals in each quartile decreases.

[Insert Figures 6.a and 6.b here]

Figure 6.a and Figure 6.b show the CWPC for periods 1 and 2, respectively. The CWPC at the opening time (9:00 AM) is around 20% for both periods. For period 1, the preopening CWPC shows higher values than the opening for most quartiles after 8:35 AM, although some fluctuation exists. At the opening, about 20% of the close-to-close returns can be explained. After the opening, the CWPC increases to 35% till 9:30 AM and maintains a steady increment. In period 2, the preopening CWPC shows mostly lower values compared to period 1 and only the highest won volume quartile reaches up to 20% near the opening. After the opening, CWPC values between each quartile widen compared to period 1, meaning that the informativeness difference between quartiles has increased in period 2.

[Insert Table 8 here]

Table 8 is the average five-minute close-to-close CWPC value difference between period 2 and period 1 with unpaired t-test statistics for both periods shown by asterisks. The difference for quartile 1 has mostly positive values after 8:45 AM, which widen with time. After the opening, the differences have significant values at the 5% level. Keeping in mind that informed traders concentrated on the first 30 minutes after the opening, the positive and large difference for high won volume stocks can be explained by more information incorporated for price discovery in period 2. On the other hand, decreased and delayed informed traders' participation in the preopening for the small won volume stocks in period 2 made price discovery more miserable with a bad start at the opening. The overall CWPC has higher values in period 1 (difference is negative) throughout the preopening until 8:55 AM, with the widest difference at 8:45 AM. After 8:45 AM, the difference narrows until it turns positive at 9:00 AM, showing that period 2's CWPC values start catching up with period 1's CWPC at 8:45 AM. From the opening, period 2's overall CWPC are all positive and increase to 0.0346 at 9:30 AM. The policy change did not improve preopening informativeness near 8:45 AM. However, informed trades are concentrated just before and after the opening, giving a high CWPC for the overall sample.

We also calculate but do not show the five-minute close-to-close CWPC value difference between period 2 and period 1 using a stock by stock average as Barcley and Warner (1993) and Cao et al. (2000) proposed. Comparing period 1 and period 2's CWPC values, at 9:00 AM for the overall sample, period 2's CWPC is higher but not statistically significant[14].

7. Conclusion

[14] The results show no difference with the Barclay and Hendershott (2003) WPC method, so the method that has advantage in statistical inference, as noted by Barcley and Hendershott (2003), has been shown mainly in this paper. Using the stock by stock averaged WPC, we estimate a regression model similar to Barcley and Hendershott (2005). The results shown below are the close to open WPC for the whole preopening session.

$$WPC_{i,t} = -0.168 + 0.024 \cdot \left(Dummy_{Post-event} \cdot Dummy_{Quartile1} \right) - 0.018 \cdot \left(Dummy_{Post-event} \cdot Dummy_{Quartile2} \right)$$
$$+0.041 \cdot \left(Dummy_{Post-event} \cdot Dummy_{Quartile3} \right) - 0.020 \cdot \left(Dummy_{Post-event} \cdot Dummy_{Quartile4} \right)$$
$$+0.008 \cdot \log(Trade\ Volume_i) + 0.022 \cdot \log(Market\ Value_i) + 0.031 \cdot \log(Stock\ Retrun\ Volatility_i) + \varepsilon_{i,t}$$

In the preopening period, the WPC has positive coefficients for the log of trade volume, market value, and stock return volatility; only the coefficients of market value and stock return volatility are significant at the 5% level. The positive coefficients for the PIN regression and WPC regression share the same insight into how stock specific factors affect the amount of information provided and gathered during the preopening session.

This article examines how the transparency level change in the preopening session of the KRX affects the efficiency of price discovery. Increase in transparency in the preopening session has been believed to reduce the information asymmetry among traders and to improve price discovery in the preopening session. Our empirical results confirm the popular belief partially in the sense that the speed of learning increases for small and mid-size stocks in the preopening session after October 6, 2003, when the transparency of order displayed in the preopening session increases.

Our study documents that an increase in transparency during the preopening session reduces the participation of the informed in the preopening session. When information becomes disseminated faster after October 6, 2003, through the increase in transparency, informed traders seem to move their trading participation into the first 30 minutes of the trading session. This move-out of informed investors hinders the price discovery in the preopening session, but this negative effect seems to be offset by less information asymmetry between the informed and the uninformed. Change in transparency also affected the trading session by enhancing the price discovery amount for large size stocks due to the concentration of informed traders' activity in the first 30 minutes.

The price discovery amount made till the opening after change is slightly higher but not statistically supported. After the policy change, the time when sufficient price discovery is made has been delayed to the last five minutes before opening. Overall, we conclude that a higher transparency level induced to the market increased information flow between traders, but the small-size stock suffers from loss of sufficient information made public during the preopening.

References

Bandi, Federico M. and Russell, Jeffrey R., 2004, Full-information transaction costs, *Working Paper*, Graduation School of Business, University of Chicago.

Barclay, Miachel J., Hendershott, Terrence, 2003, Price discovery and trading after hours, *The Review of Financial Studies* 16 1041-1073

Barclay, Miachel J., Hendershott, Terrence, 2005, A comparison of trading and non-trading mechanisms for price discovery, *Working Paper*

Baruch, Shmuel, 2005, Who benefits from an open limit-order book*?, Journal of Business*, vol. 78 , 1267-1306.

Biais, Bruno, Hillion, Pierre; Spatt, Chester, 1999, Price discovery and learning during the preopening period in the Paris Bourse, *The Journal of Political Economy* 107, 1218-1248

Boehmer, Ekkehart, Saar, Gideon, and Yu, Lei, 2005, Lifting the "Veil": An analysis of pre-trade transparency at the NYSE, *Journal of Finance* 60, 783-815

Cao, Charles, Ghysels, Eric, Hatheway, Frank. 2000, Price discovery without trading: evidence from the Nasdaq preopening, *Journal of Finance* 55, 1339-1365

Easley, David, Kiefer, Nicholas M., O'Hara, Maureen, and Paperman, Joseph, 1996, Liquidity, information an infrequently traded stocks, *Journal of Finance* 51, 1405-1436.

Easley, David, Kiefer, Nicholas M., O'Hara, Maureen, 1997a, The information content of the trading process, *Journal of Empirical Finance* 4, 159-186.

Easley, David, Kiefer, Nicholas M., O'Hara, Maureen, 1997b, One day in the life of a very common stock, *Review of Financial Studies* 10, 805-835.

Easley, David, Kiefer, Nicholas M., O'Hara, Maureen, 1997, The Information Content of the Trading Process, *Journal of Empirical Finance* 4, 159-186

Easley, David, Hvidkjaer, Soeren, O'Hara, Maureen, 2002, Is information risk a determinant of asset returns, *Journal of Finance* 57, 2185-2221

Glosten, Lawrence, and Harris, Lawrence, 1988, Estimation the components of the bid/ask spread, *Journal of Financial Economics* 21, 123-142

Harris, Lawrence E., 1996, Does a large minimum price variation encourage order exposure?, *Working Paper*,University of Southern California

Hasbrouck, Joel, 1988, Trades, quotes, inventories, and information*, Journal of Financial Economics* 22, 229-252

Hasbrouck, Joel, 1991, Measuring the information content of stock trades, *Journal of Finance* 46, 179-207

Madhavan, Ananth, Richardson, Matthew and Roomans, Mark, 1997, Why do security prices change?: A transaction-level analysis of NYSE stocks?, *Reviews of Financial Studies* 10, 1035-1064

Madhavan, Ananth, and Panchapagesan, Venkatesh, 2000, Price discovery in auction markets: A look inside the black Box, *Review of Financial Studies* 13:672–58.

Madhavan, Ananth, Porter, David, Weaver, Daniel, 2005, Should securities markets be transparent?, *Journal of Financial Markets* 8, 266-288

O'Hara, Maureen, 1995, Market Miscrostructure, Blackwell, Oxford.

Park, Jong-ho, Eom, Kyong Shik, 2005, The effect of expanding publicly available quote disclosure on Korean Stock Markets, *The Korean Journal of Finance* 18, 157-198

Park, Kyung Suh, Lee, Eunjung, Jang, Hasung, 2003, Manipulative order behavior and price discovery in the pre-opening market of the Korea Stock Exchange, *Asia-Pacific Journal of Financial Studies* 32, 209-244

Vives, Xavier, 1995, The speed of information revelation in a financial market mechanism", Journal of Economic Theory 67, 178-204

Table 1. Bid order and offer order ratio for foreign investors and institutional investors

Panel A	Time	8:00~8:10am	8:10~8:20am	8:20~8:30am	8:30~8:40am	8:40~8:50am	8:50~9:00am	9:00~9:10am	9:10~9:20am	9:20~9:30am
Period 1 Bid Normal	Foreign	2.94%	2.50%	2.32%	4.33%	3.73%	3.35%	4.04%	4.02%	4.21%
	Institutional	8.98%	2.24%	2.55%	1.86%	2.34%	3.57%	5.26%	7.05%	6.15%
Period 2 Bid Normal	Foreign	3.11%	4.27%	3.65%	4.65%	5.81%	2.39%	3.40%	3.51%	3.82%
	Institutional	11.68%	3.37%	5.54%	2.98%	4.08%	3.44%	4.29%	5.38%	7.15%
Period 1 Offer Normal	Foreign	1.00%	3.78%	2.70%	1.88%	3.15%	3.31%	2.24%	2.44%	2.68%
	Institutional	3.02%	1.58%	1.76%	3.04%	3.10%	5.67%	6.75%	7.04%	6.87%
Period 2 Offer Normal	Foreign	1.30%	4.91%	9.28%	2.63%	4.16%	3.60%	2.80%	2.84%	3.13%
	Institutional	3.39%	2.10%	2.62%	3.96%	5.47%	6.42%	5.88%	6.31%	7.03%
	Time	8:00~8:10am	8:10~8:20am	8:20~8:30am	8:30~8:40am	8:40~8:50am	8:50~9:00am	9:00~9:10am	9:10~9:20am	9:20~9:30am
Period 1 Bid Revised	Foreign	63.11%	0.11%	0.36%	1.04%	0.49%	1.11%	2.50%	3.59%	3.77%
	Institutional	0.04%	0.02%	0.18%	1.99%	1.91%	1.76%	3.28%	6.51%	5.60%
Period 2 Bid Revised	Foreign	1.56%	21.25%	1.81%	14.42%	14.84%	1.19%	2.26%	3.36%	4.05%
	Institutional	0.06%	0.22%	0.01%	0.01%	0.94%	1.74%	3.19%	4.89%	6.92%
Period 1 Offer Revised	Foreign	40.88%	1.12%	0.52%	1.81%	0.99%	1.58%	1.47%	1.31%	1.40%
	Institutional	0.11%	0.05%	0.41%	0.51%	2.35%	2.01%	2.12%	4.92%	3.41%
Period 2 Offer Revised	Foreign	1.45%	9.28%	0.69%	7.19%	5.71%	0.90%	1.22%	1.39%	1.58%
	Institutional	1.03%	0.15%	0.07%	0.47%	1.61%	3.48%	2.96%	4.81%	6.48%
	Time	8:00~8:10am	8:10~8:20am	8:20~8:30am	8:30~8:40am	8:40~8:50am	8:50~9:00am	9:00~9:10am	9:10~9:20am	9:20~9:30am
Period 1 Bid Cancel	Foreign	0.00%	0.07%	1.95%	1.88%	0.94%	3.24%	1.41%	1.50%	1.47%
	Institutional	0.02%	0.03%	0.19%	0.16%	0.18%	1.75%	3.45%	7.07%	4.63%
Period 2 Bid Cancel	Foreign	0.02%	3.09%	0.00%	27.23%	0.14%	1.11%	1.12%	1.62%	1.85%
	Institutional	0.17%	0.00%	3.52%	10.55%	2.47%	2.49%	3.05%	4.56%	3.91%
Period 1 Offer Cancel	Foreign	9.32%	0.36%	3.50%	2.37%	2.35%	5.26%	3.29%	2.24%	1.98%
	Institutional	0.00%	0.35%	1.28%	2.49%	1.35%	7.73%	5.55%	4.95%	3.96%
Period 2 Offer Cancel	Foreign	23.48%	2.90%	37.07%	15.78%	5.97%	3.85%	2.42%	2.31%	2.25%
	Institutional	0.46%	0.12%	0.60%	1.29%	7.07%	10.13%	6.04%	4.95%	8.90%

Panel B	Time	8:00~8:10am	8:10~8:20am	8:20~8:30am	8:30~8:40am	8:40~8:50am	8:50~9:00am	9:00~9:10am	9:10~9:20am	9:20~9:30am
Period 1 Bid Normal	Foreign	6.14%	0.42%	1.65%	0.83%	1.37%	1.10%	0.53%	0.35%	0.25%
	Institutional	0.34%	1.33%	3.20%	4.39%	0.86%	1.61%	6.33%	7.39%	5.76%
Period 2 Bid Normal	Foreign	4.05%	11.64%	11.46%	5.51%	4.89%	2.36%	1.25%	0.83%	0.68%
	Institutional	4.78%	9.12%	3.42%	3.07%	2.69%	1.28%	3.00%	8.31%	7.97%
Period 1 Offer Normal	Foreign	0.70%	0.96%	0.34%	0.36%	0.36%	0.77%	0.70%	0.35%	0.58%
	Institutional	0.70%	0.23%	0.96%	0.86%	2.06%	1.60%	3.59%	4.92%	5.03%
Period 2 Offer Normal	Foreign	0.00%	0.45%	2.32%	1.54%	1.34%	0.45%	0.22%	0.29%	0.51%
	Institutional	0.00%	0.04%	0.28%	1.60%	0.56%	1.78%	3.77%	6.09%	6.76%
	Time	8:00~8:10am	8:10~8:20am	8:20~8:30am	8:30~8:40am	8:40~8:50am	8:50~9:00am	9:00~9:10am	9:10~9:20am	9:20~9:30am
Period 1 Bid Revised	Foreign	72.09%	0.00%	0.00%	0.82%	0.00%	0.06%	0.00%	0.14%	0.17%
	Institutional	0.04%	0.00%	0.02%	0.00%	0.02%	0.31%	1.40%	16.32%	6.11%
Period 2 Bid Revised	Foreign	0.00%	1.35%	1.09%	5.61%	38.64%	1.96%	0.07%	0.10%	0.54%
	Institutional	0.00%	0.00%	0.00%	0.41%	0.20%	0.23%	6.29%	2.97%	3.95%
Period 1 Offer Revised	Foreign	36.11%	7.02%	0.30%	0.30%	0.76%	0.77%	0.11%	0.12%	0.18%
	Institutional	0.02%	0.00%	0.03%	0.00%	0.45%	0.46%	0.56%	3.11%	5.96%
Period 2 Offer Revised	Foreign	0.00%	3.29%	0.00%	4.16%	2.30%	0.41%	0.72%	0.69%	0.13%
	Institutional	0.01%	0.00%	0.00%	0.10%	0.24%	0.22%	1.84%	16.86%	14.20%
	Time	8:00~8:10am	8:10~8:20am	8:20~8:30am	8:30~8:40am	8:40~8:50am	8:50~9:00am	9:00~9:10am	9:10~9:20am	9:20~9:30am
Period 1 Bid Cancel	Foreign	0.00%	0.00%	0.44%	0.67%	0.91%	0.03%	0.26%	2.76%	0.21%
	Institutional	0.00%	0.00%	0.00%	0.00%	0.00%	0.16%	1.31%	13.23%	9.00%
Period 2 Bid Cancel	Foreign	0.00%	0.82%	0.00%	10.17%	0.00%	0.28%	0.12%	0.30%	0.15%
	Institutional	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.23%	2.85%	2.76%
Period 1 Offer Cancel	Foreign	0.03%	0.00%	0.01%	0.08%	0.13%	0.45%	0.48%	0.11%	0.00%
	Institutional	6.00%	10.04%	15.32%	11.05%	21.43%	12.40%	12.65%	21.46%	22.63%
Period 2 Offer Cancel	Foreign	0.43%	0.30%	10.75%	6.85%	0.17%	1.02%	0.13%	0.07%	0.05%
	Institutional	0.00%	0.00%	0.06%	0.00%	1.68%	0.90%	8.85%	11.85%	33.99%

Panel C	Time	8:00~8:10am	8:10~8:20am	8:20~8:30am	8:30~8:40am	8:40~8:50am	8:50~9:00am	Total Volume
Period 1 Bid Normal	Foreign	16.54%	5.26%	5.32%	12.60%	16.01%	44.26%	951,884
	Institutional	40.79%	3.81%	4.72%	4.38%	8.10%	38.21%	1,177,532
Period 2 Bid Normal	Foreign	18.66%	8.61%	7.93%	12.77%	23.46%	28.57%	1,268,857
	Institutional	45.30%	4.39%	7.79%	5.28%	10.65%	26.58%	1,961,754
Period 1 Offer Normal	Foreign	15.19%	9.20%	8.09%	8.34%	18.82%	40.36%	734,732
	Institutional	29.31%	2.47%	3.39%	8.62%	11.87%	44.34%	1,146,653
Period 2 Offer Normal	Foreign	14.00%	8.27%	20.49%	7.89%	16.83%	32.53%	1,150,599
	Institutional	26.50%	2.57%	4.20%	8.60%	16.05%	42.09%	1,585,458
	Time	8:00~8:10am	8:10~8:20am	8:20~8:30am	8:30~8:40am	8:40~8:50am	8:50~9:00am	Total Volume
Period 1 Bid Revised	Foreign	61.60%	0.26%	1.35%	5.55%	3.43%	27.82%	65,019
	Institutional	0.05%	0.07%	0.96%	15.33%	19.24%	64.35%	44,861
Period 2 Bid Revised	Foreign	0.24%	18.97%	1.49%	24.21%	45.11%	9.98%	275,562
	Institutional	0.05%	1.10%	0.07%	0.10%	16.25%	82.43%	48,573
Period 1 Offer Revised	Foreign	46.71%	2.67%	1.73%	9.35%	8.25%	31.29%	169,105
	Institutional	0.20%	0.20%	2.16%	4.16%	30.73%	62.55%	107,413
Period 2 Offer Revised	Foreign	0.52%	20.05%	1.84%	27.39%	35.84%	14.36%	293,326
	Institutional	0.54%	0.47%	0.29%	2.58%	14.70%	81.41%	201,133
	Time	8:00~8:10am	8:10~8:20am	8:20~8:30am	8:30~8:40am	8:40~8:50am	8:50~9:00am	Total Volume
Period 1 Bid Cancel	Foreign	0.00%	0.13%	6.22%	8.48%	7.29%	77.88%	34,199
	Institutional	0.09%	0.12%	1.35%	1.64%	3.12%	93.69%	15,325
Period 2 Bid Cancel	Foreign	0.02%	3.00%	0.00%	81.08%	0.57%	15.33%	70,958
	Institutional	0.15%	0.00%	7.88%	38.19%	11.85%	41.93%	58,390
Period 1 Offer Cancel	Foreign	6.96%	0.56%	9.67%	9.03%	10.94%	62.83%	89,840
	Institutional	0.00%	0.50%	3.14%	8.44%	5.61%	82.31%	100,694
Period 2 Offer Cancel	Foreign	6.47%	1.32%	38.49%	21.25%	11.98%	20.49%	304,412
	Institutional	0.18%	0.08%	0.88%	2.46%	20.11%	76.29%	214,885

Panel A and panel B are the order volume for each investor group divided by the total order volume within the same time interval. The bid and offer normal placed order, revised order, and canceled order volume is accumulated for each 10 minutes and is used as the total order volume for all the investor groups. The time interval starts from 8:00 AM till 9:30 AM, which is 30 minutes past the opening (end of the preopening). Investors are categorized into three groups by nationality (foreign investor) and investor type (individual investor and institutional investor) provided by the KRX submitted orders data set. Panel C reports the total volume for each order type and investor group with the ratio of each 10-minute interval order volume to the total volume.

Table 2. Unbiasedness regression coefficient paired t-test

	8:10am	8:15am	8:20am	8:25am	8:30am	8:35am	8:40am	8:45am	8:50am	8:55am	9:00am
Period1 - Quartile1	0.2976	0.3218	0.3395	0.3545	0.3678	0.3628	0.4181	0.4697	0.5862	0.7271	1.0617
Period2 - Quartile1	0.2296	0.2970	0.2900	0.3298	0.3465	0.3369	0.3396	0.3982	0.5165	0.6608	1.0633
	(31.55%)	(69.52%)	(47.23%)	(71.18%)	(77.38%)	(72.35%)	(27.55%)	(35.38%)	(37.59%)	(43.75%)	(98.54%)
Period1 - Quartile2	0.2264	0.2159	0.2583	0.2294	0.2679	0.3052	0.3743	0.4205	0.4559	0.6509	0.9576
Period2 - Quartile2	0.1445	0.1876	0.1700	0.2057	0.2058	0.2301	0.2950	0.3319	0.3701	0.4894	0.9056
	(33.37%)	(74.07%)	(23.66%)	(71.72%)	(37.57%)	(25.57%)	(23.03%)	(22.45%)	(30.49%)	(6.68%)	(57.50%)
Period1 - Quartile3	0.1159	0.1090	0.1685	0.2083	0.2350	0.2338	0.2903	0.3715	0.4276	0.5245	0.8857
Period2 - Quartile3	0.1129	0.0933	0.1104	0.1190	0.1491	0.1416	0.1546	0.1910	0.2238	0.3538	0.9975
	(94.68%)	(70.52%)	(21.33%)	(8.29%)	(12.74%)	(10.14%)	(3.11%)	(1.49%)	(0.95%)	(5.97%)	(29.99%)
Period1 - Quartile4	0.1493	0.1856	0.2091	0.1693	0.1632	0.1876	0.1997	0.2498	0.2704	0.3518	0.6194
Period2 - Quartile4	0.1275	0.1325	0.1650	0.1964	0.2094	0.2358	0.2480	0.2701	0.3110	0.3780	0.6288
	(63.88%)	(32.97%)	(40.26%)	(59.46%)	(36.42%)	(37.62%)	(39.41%)	(72.78%)	(51.78%)	(71.03%)	(90.73%)
Period1 - Overall	0.1978	0.2083	0.2442	0.2411	0.2595	0.2732	0.3218	0.3792	0.4367	0.5657	0.8837
Period2 - Overall	0.1539	0.1780	0.1841	0.2129	0.2279	0.2361	0.2594	0.2981	0.3558	0.4714	0.9015
	(16.95%)	(34.97%)	(5.51%)	(35.13%)	(33.01%)	(24.61%)	(5.81%)	(2.47%)	(4.01%)	(3.10%)	(71.56%)

The unbiasedness regression coefficient for each 10-minute interval starting from 8:10 AM is used. The sample stocks are divided into four groups, where quartile 1 is the highest won volume group. We compare the average regression coefficient of the firms in each quartile for period 1 and period 2. P-value results for the paired t-test are given inside the round bracket.

Table 3. T-test for difference between two period indicative indices' five-minute return.

	P1 and P2 Overall		**P1 Negative and Positive**		**P2 Negative and Positive**		**P1 and P2 Positive**		**P1 and P2 Negative**	
Time	P-value	Difference	P-value	Difference	P-value	Difference	P-value	Difference	P-value	Difference
8:15am	81.94%	-0.01%	4.24%	0.17%	0.18%	0.23%	80.12%	0.02%	58.47%	-0.05%
8:20am	23.06%	-0.06%	82.98%	-0.01%	2.31%	-0.15%	4.60%	-0.13%	95.14%	0.00%
8:25am	41.31%	0.03%	3.76%	-0.12%	32.76%	0.05%	3.71%	0.11%	31.11%	-0.05%
8:30am	24.72%	-0.04%	15.69%	0.08%	0.27%	0.15%	89.70%	-0.01%	16.01%	-0.08%
8:35am	10.04%	-0.06%	11.92%	0.08%	37.39%	0.05%	12.99%	-0.08%	41.78%	-0.04%
8:40am	3.52%	-0.08%	30.75%	0.06%	11.56%	0.07%	9.50%	-0.08%	13.53%	-0.08%
8:45am	5.33%	0.06%	69.96%	-0.02%	0.08%	-0.15%	94.77%	0.00%	0.47%	0.13%
8:50am	0.47%	0.10%	7.26%	-0.09%	2.75%	-0.09%	2.77%	0.10%	4.49%	0.10%
8:55am	4.44%	-0.07%	21.45%	0.05%	43.17%	-0.03%	0.49%	-0.11%	57.89%	-0.02%
9:00am	99.73%	0.00%	23.48%	0.06%	4.86%	0.09%	77.21%	0.01%	79.68%	-0.01%

Each period is divided into close-to-close positive return days and negative days. T-test statistics for period 1's negative and positive return days' cross-sectional average value differences for five-minute intervals between are reported in the left section followed by period 2's statistics. The positive return days' difference for each period and negative return days' difference for each period are also tested, and the statistics are provided in the right section.

Table 4. GMM estimation of the speed of learning for 8:50 AM ~ 9:00 AM and 8:40 AM~9:00 AM with quartiles ordered by total traded won volume
Table 4 reports the GMM estimations for the speed of learning (γ) from the equation below.

$$t^{\gamma}(v-P_t) \to N(0,\sigma^2), \quad t \to \infty$$

Where v is the intrinsic price and P_t is the observed price at time t. We proxy the intrinsic value using the close-to-close return, and K is the constant variance of proxy noise, which is estimated. Two moment conditions are used with five-minute time intervals.

$$E\left[(r_t - \hat{r}_T)^2 - \left(\frac{t-1}{t}\right)^{2\gamma} (r_{t-1} - \hat{r}_T)^2 - K\left\{1 - \left(\frac{t-1}{t}\right)^{2\gamma}\right\} \middle| I_{t-2} \right] = 0 \text{ and } E\left[(r_{t-1} - \hat{r}_T)^2 - \left(\frac{t-2}{t-1}\right)^{2\gamma} (r_{t-2} - \hat{r}_T)^2 - K\left\{1 - \left(\frac{t-2}{t-1}\right)^{2\gamma}\right\} \middle| I_{t-2} \right] = 0$$

Table 5. Mann-Whitney test for PIN estimation

	8:00am ~ 9:00am			9:00am ~ 9:30am			9:30am ~ 10:00am			10:00am ~ 10:30am		
	period1 mean	period2 mean	test	period1 mean	period2 mean	test	period1 mean	period2 mean	test	period1 mean	period2 mean	test
Quartile 1	0.1741	0.1869	0.1937	0.1297	0.1389	0.2293	0.1433	0.1333	0.0922	0.1571	0.1402	0.0814
	(0.0423)	(0.0630)		(0.0621)	(0.0590)		(0.0558)	(0.0621)		(0.0575)	(0.0541)	
Quartile2	0.1602	0.1588	0.4465	0.1403	0.1586	0.0519	0.1669	0.1617	0.4794	0.1686	0.1689	0.4904
	(0.0626)	(0.0651)		(0.0542)	(0.0492)		(0.0516)	(0.0457)		(0.0465)	(0.0419)	
Quartile3	0.1426	0.1478	0.4360	0.1702	0.1858	0.0537	0.1853	0.1769	0.1358	0.1838	0.1919	0.4384
	(0.0598)	(0.0747)		(0.0496)	(0.0556)		(0.0460)	(0.0606)		(0.0614)	(0.0616)	
Quartile 4	0.0839	0.0565	0.0079	0.2096	0.2685	0.0918	0.2354	0.2317	0.2133	0.2441	0.2318	0.3639
	(0.0786)	(0.0790)		(0.0999)	(0.1559)		(0.1086)	(0.1279)		(0.1262)	(0.1124)	
Overall	0.1401	0.1376	0.3683	0.1621	0.1871	0.0130	0.1822	0.1753	0.0274	0.1878	0.1827	0.2687
	(0.0709)	(0.0850)		(0.0751)	(0.1022)		(0.0769)	(0.0870)		(0.0849)	(0.0790)	

Table 5 is the cross-sectional average and standard deviation of the PIN estimation for each period. The PIN estimation after opening is also presented to analyze how the transparency level affected the informed traders' participation behavior. We use the Mann-Whitney test and report the one tailed p-values to test for the difference of each period's mean PIN value.

Table 6. PIN estimation regression

independent variable	8:00 ~ 9:00am	9:00 ~ 9:30am	9:30 ~ 10:00am	10:00 ~ 10:30am
intercept	-0.2425***	0.4868***	0.6228***	0.4814***
	(0.0645)	(0.0778)	(0.0755)	(0.0765)
post*quartile1	0.0002	0.02414**	-0.0018	-0.0090
	(0.0115)	(0.0138)	(0.0134)	(0.0136)
post*quartile2	0.0052	0.0084	-0.0094	-0.0086
	(0.0102)	(0.0122)	(0.0119)	(0.0120)
post*quartile3	0.0198**	0.0139	-0.0205*	-0.0054
	(0.0103)	(0.0124)	(0.0120)	(0.0122)
post*quartile4	-0.0307***	0.0540***	0.0027	0.0020
	(0.0115)	(0.0139)	(0.0135)	(0.0137)
log(trade volume)	0.0386***	-0.0514***	-0.0307***	-0.0371***
	(0.0052)	(0.0063)	(0.0061)	(0.0062)
log(market value)	0.0141***	-0.0059	-0.0248***	-0.0092
	(0.0058)	(0.0070)	(0.0067)	(0.0068)
log(return volatility)	0.0139**	-0.0120	0.0053	0.0068
	(0.0072)	(0.0087)	(0.0084)	(0.0085)
Adj R-square	0.3504	0.2979	0.1939	0.1708
RMSE	0.0630	0.0759	0.0738	0.0747

This table shows the results for firm i's PIN estimation in period t regressed by post-event dummy, won volume ordered quartile dummies, and the log of trading volume size.

$$PIN_{i,t} = \alpha_0 + \alpha_1 \left(Dummy_{Post-event} \cdot Dummy_{Quartile1} \right) + \alpha_1 \left(Dummy_{Post-event} \cdot Dummy_{Quartile2} \right)$$
$$+\alpha_3 \left(Dummy_{Post-event} \cdot Dummy_{Quartile3} \right) + \alpha_4 \left(Dummy_{Post-event} \cdot Dummy_{Quartile4} \right)$$
$$+\alpha_5 \log(Trade\ Volume_i) + \alpha_6 \log(Market\ Value_i) + \alpha_7 \log(Stock\ Retrun\ Volatility_i) + \varepsilon_{i,t}$$

Table 7.a Close-to-open WPC

Period 1	~ 8:10am	~ 8:20am	~ 8:30am	~8:40am	~ 8:50am	~ 9:00am
Quartile 1	0.0288	0.7222**	0.243**	0.1393**	-0.0131	-0.1202
Quartile 2	0.0345	0.5231**	0.3599**	0.1166**	0.0098	-0.0439
Quartile 3	0.0409	0.6917**	0.1897**	0.0665	-0.0229	0.0342
Quartile 4	0.0321	0.3722**	0.2772*	0.1442	0.1746	-0.0004
Overall	0.0373*	0.5854**	0.26*	0.1173	0.0317*	-0.0318
Period 2	~ 8:10am	~ 8:20am	~ 8:30am	~8:40am	~ 8:50am	~ 9:00am
Quartile 1	0.1662**	0.5358**	0.2514**	0.0715	-0.0238	-0.0010
Quartile 2	0.0610	0.6717**	0.3398**	0.1061	-0.0796	-0.0990
Quartile 3	0.0542	0.4908**	0.3773**	0.0952	0.0072	-0.0247
Quartile 4	0.0533	0.3993**	0.2564**	0.1833*	0.0232	0.0846
Overall	0.0984**	0.5438**	0.3012**	0.1021*	-0.0204	-0.0251

This table shows the previous day's closing price to today's opening price WPC values. Since the opening price is used, the last observation time is the opening at 9:00 AM. The p-values for each 10-minute interval WPC values are shown with ** for 1% statistical significance and * for 5% statistical significance.

Table 7.b Close-to-close WPC

Period 1	~ 8:10am	~ 8:20am	~ 8:30am	~8:40am	~ 8:50am	~ 9:00am	Total
Quartile 1	0.0126	0.1611	-0.0030	0.0310	-0.0296	-0.0041	0.1679
Quartile 2	-0.0048	0.0713	0.1272**	-0.0277	-0.0202	0.0061	0.1519
Quartile 3	0.0015	0.1938*	0.0717	-0.0225	-0.0062	-0.0747	0.1636
Quartile 4	0.0270*	0.0252	-0.0019	0.1187*	-0.0125	-0.0053	0.1512
Overall	0.0110	0.1136*	0.0525*	0.0177	-0.0208	-0.0140	0.1600
Period 2	~ 8:10am	~ 8:20am	~ 8:30am	~8:40am	~ 8:50am	~ 9:00am	Total
Quartile 1	0.0572	0.1337	0.0399	-0.0354	0.0225	-0.0007	0.2172
Quartile 2	0.0035	0.0345	0.0438	0.0361	-0.0156	0.0356	0.1378
Quartile 3	-0.0019	0.0621	0.0285	0.0615	0.0102	0.0206	0.1810
Quartile 4	0.0057	0.0634	0.0045	0.0569	-0.0038	-0.0123	0.1144
Overall	0.0202	0.0774	0.0348	0.0229	0.0038	0.0107	0.1699

This table shows the previous day's closing price to today's closing price WPC values. The p-values for each 10-minute interval WPC values are shown with ** for 1% statistical significance and * for 5% statistical significance.

Table 8. Close-to-close cumulative weighted price contribution difference between periods 2 and 1

Time	Quartile 1	Quartile 2	Quartile 3	Quartile 4	Overall
8:30	0.0602	-0.1119	-0.1782	0.0233	-0.0446
8:35	0.0332	-0.0579	-0.0474	-0.0058	-0.0158
8:40	-0.0063	-0.0481	-0.0942	-0.0386	-0.0394
8:45	0.0319	-0.1117	-0.1205	-0.0703	-0.0568
8:50	0.0458	-0.0435	-0.0779	-0.0299	-0.0148
8:55	0.0360	-0.0560	-0.0180	-0.0388	-0.0085
9:00	0.0492	-0.0141	0.0174	-0.0369	0.0099
9:05	0.0695*	0.0036	-0.0142	0.0036	0.0206
9:10	0.0546	0.0140	-0.0236	-0.0036	0.0174
9:15	0.0619*	0.0297	-0.0253	-0.0093	0.0223
9:20	0.0613*	0.0257	-0.0341	-0.0146	0.0193
9:25	0.0653*	0.0310	-0.0303	-0.0126	0.0236
9:30	0.0870**	0.0394	-0.0214	-0.0165	0.0346

This table shows the difference between period 2's CWPC and period 1's CWPC values for each five-minute interval. Single asterisk is for the 10% p-value, and double asterisks are for the 5% p-value. The overall sample and the won volume ordering quartile group results are shown from 8:30 AM till 9:30 AM.

Figure 1.a Average placed orders for period 2

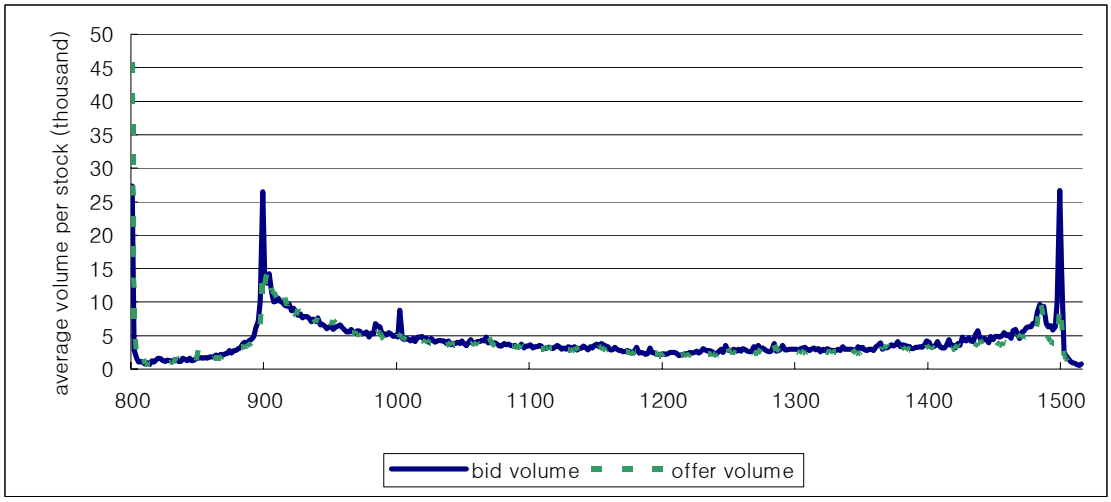


Figure 1.b Average revised and canceled order volumes for period 2

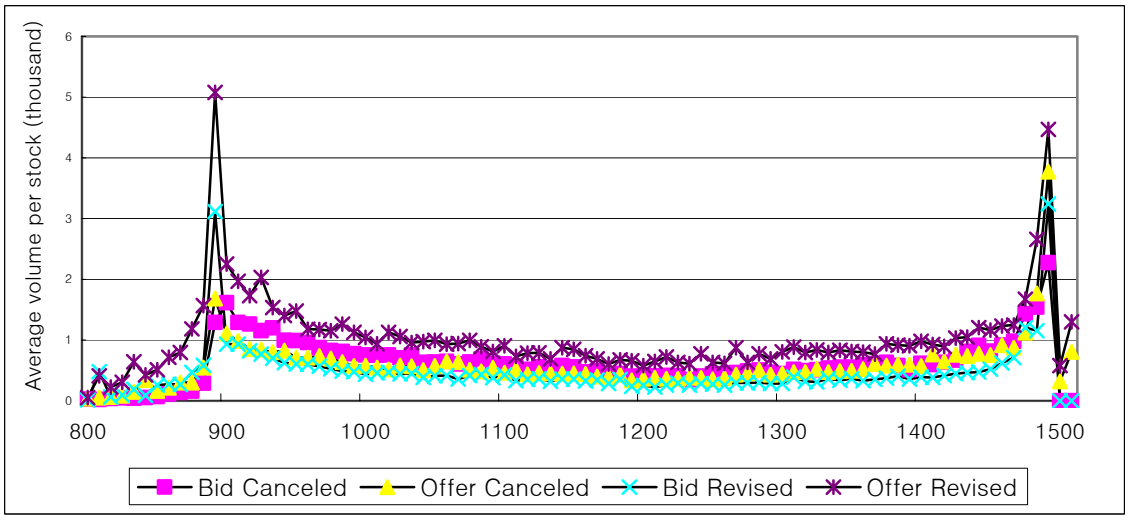


Figure 1.a shows the average volume of bid and offer orders per stock for one-minute intervals for the 198 stocks composing the KOSPI200 index for period 2 for the whole day. Figure 1.b is the average volume per stock for revised and canceled orders. 8:00 AM till 9:00 AM is the preopening session, 9:00 AM until 2:50 PM is the trading session, and 2:50 PM till 3:00 PM is the closing session.

Figure 2.a Executable bid order volume for period 2

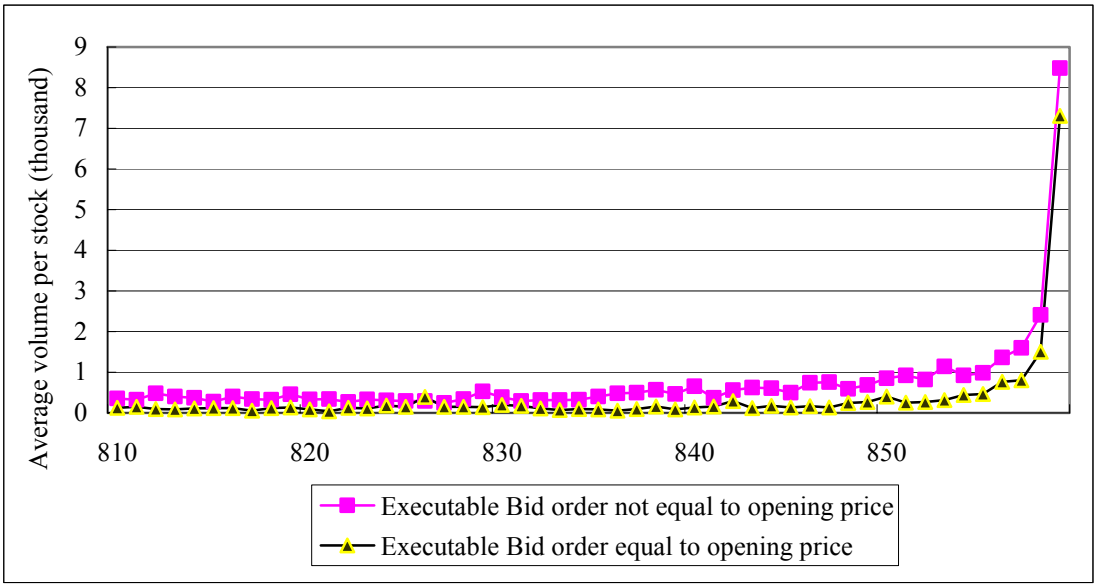
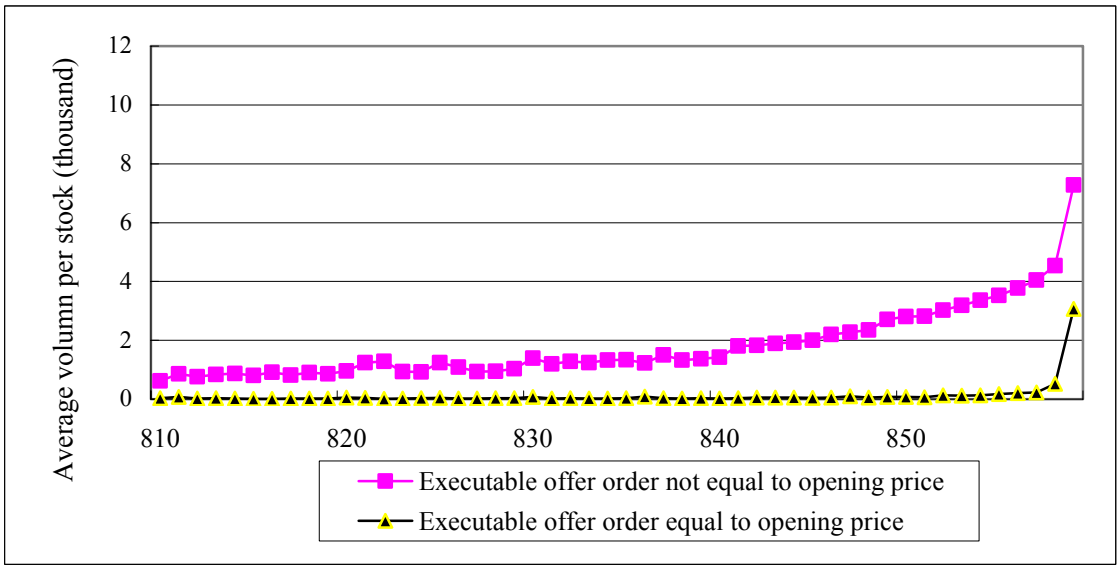
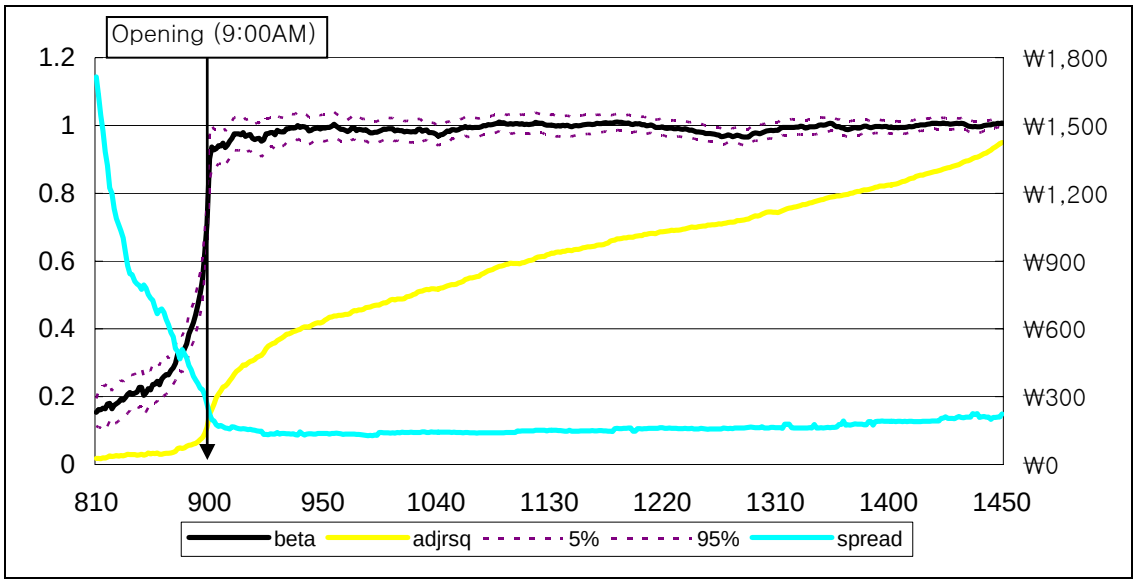


Figure 2.b Executable offer order volume for period 2



Figures 2.a and 2.b are the executable bid and offer orders categorized by whether they equal to the opening price or not. We use the term 'executable orders' for the total number of pre-existing orders, which, if the transaction is made at a certain time for the auction market period, can be executed at the opening.

Figure 3 Unbiasedness regression for period 2



Beta is the regression coefficient for the unbiasedness regression. The daily close-to-close return is regressed by the return of close to time return. For the 198 stocks composing the KOSPI200 index during the period, one unbiasedness regression is performed for each stock. The cross-sectional coefficient mean value is plotted with the 95% confidence intervals using the standard errors of the same time return regression. The spread is the absolute best bid-offer spread divided by 2000 for scaling purposes.

Figure 4.a Indicative index for positive daily returns

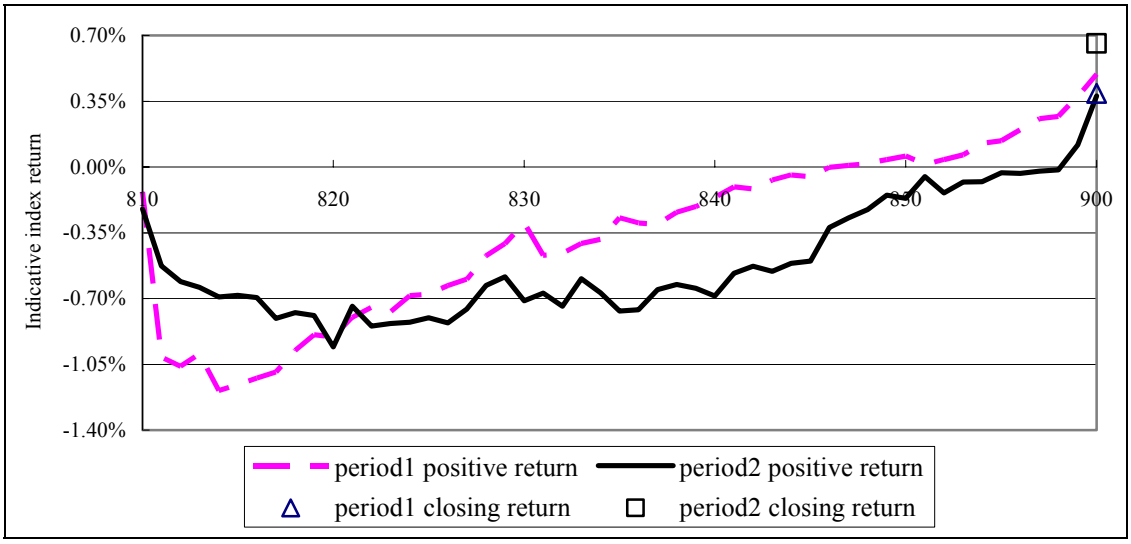
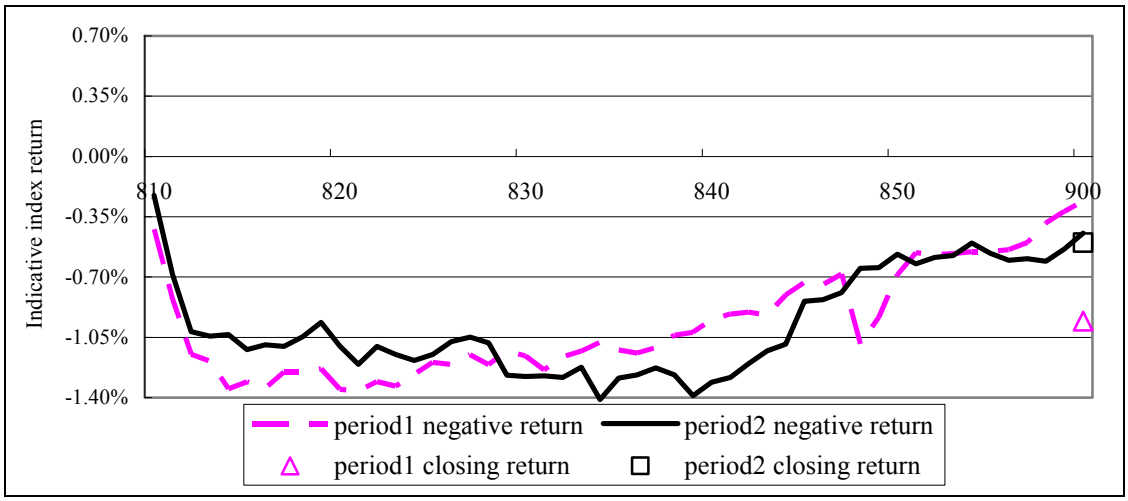


Figure 4.b Indicative index for negative daily returns



For each period, we divide it into two groups depending on the close-to-close return sign for each day. Using the indicative price for each stock, we calculate the equally weighted index per minute during the preopening and report the average the values for each group. Figure 4.a is the figure for the positive return group indicative index for period 1 and period 2, and Figure 4.b is the figure for the negative return group's indicative index for period 1 and period 2.

Figure 5. Tree diagram in the Easley, Kiefer, and O'Hara model

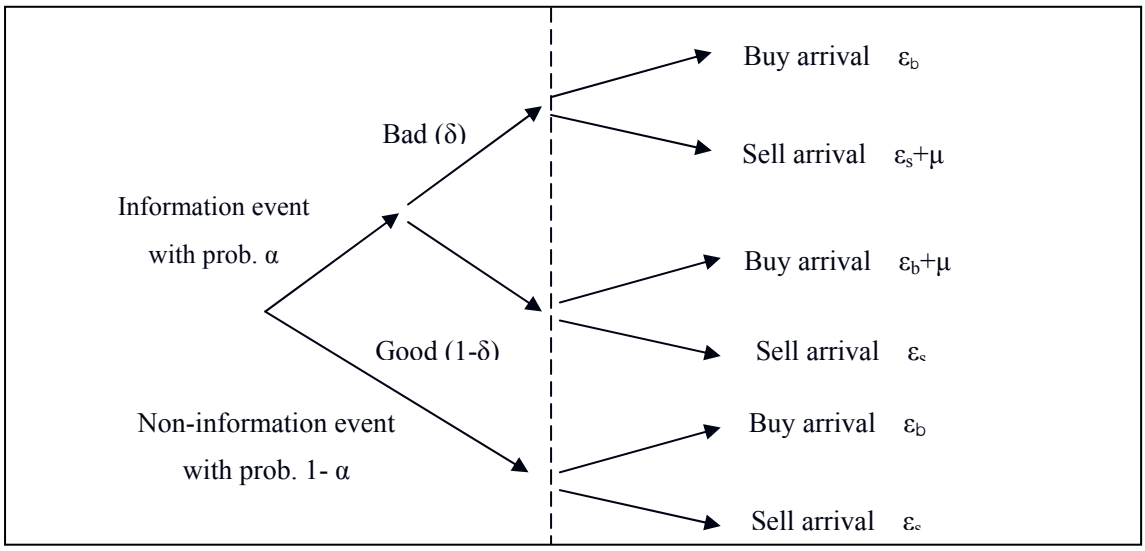


Figure 5 is the tree diagram for the trading process in the EKO model. α is the probability of an information event, δ is the probability that an information event contains bad news, μ is the arrival rate of orders from informed traders, and ε_b (ε_s) is the arrival rate of buy (sell) orders from uninformed traders. Assuming that order arrival processes follow Poisson processes, Easley, et al. (2002) provide the following measure of the probability of information-based trading (PIN):

$$PIN = \frac{\alpha\mu}{\alpha\mu + \varepsilon_b + \varepsilon_s}$$

α, μ, ε_b, and ε_s in (3) are estimated from maximizing the likelihood function

$$\begin{aligned} L\left((B,S)\,|\,\alpha,\delta,\mu,\varepsilon\right) = {} & (1-\alpha)e^{-\varepsilon_b T}\frac{(\varepsilon_b T)^B}{B!}e^{-\varepsilon_s T}\frac{(\varepsilon_s T)^S}{S!} \\ & + \alpha\delta e^{-\varepsilon_b T}\frac{(\varepsilon_b T)^B}{B!}e^{-(\mu+\varepsilon_s)T}\frac{((\mu+\varepsilon_s)T)^S}{S!} \\ & + \alpha(1-\delta)e^{-\varepsilon_s T}\frac{(\varepsilon_s T)^S}{S!}e^{-(\mu+\varepsilon_b)T}\frac{((\mu+\varepsilon_b)T)^B}{B!}, \end{aligned}$$

where B and S represent total buy orders and sell orders for the period, respectively.

Figure 6.a Cumulative weighted price contribution for period 1

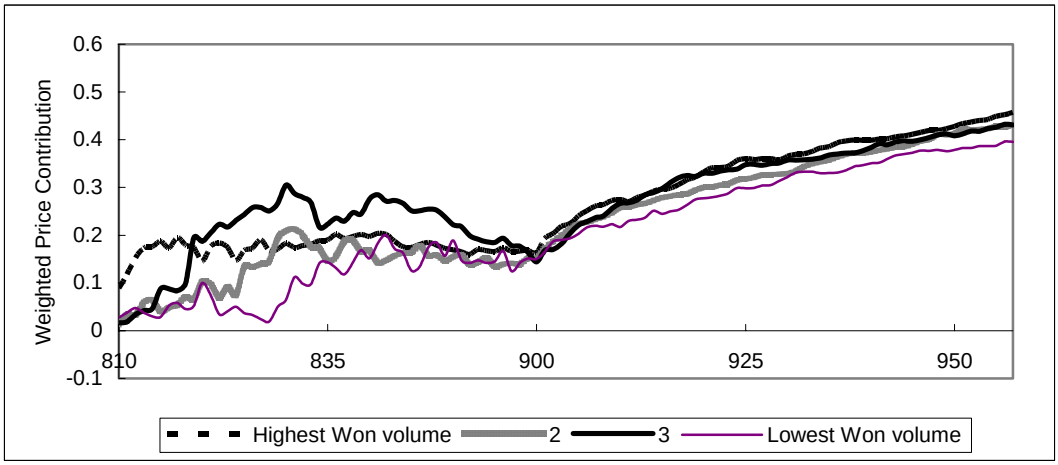
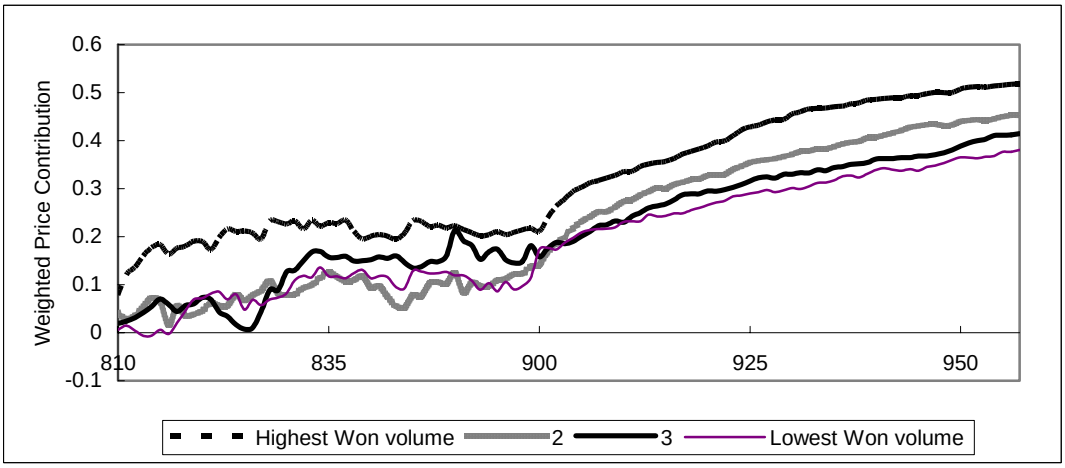


Figure 6.b Cumulative weighted price contribution for period 2



Figures 6.a and 6.b plot the cumulative weighted price contribution for period 1 and period 2. The weighted price contribution measures the amount of new information incorporated into stock prices during a given time period used by Barclay and Hendershott (2003).

$$CWPC = \sum_{s=1}^{S}\left[\sum_{i=1}^{T}\left(\frac{|r_{s,i}|}{\sum_{i=1}^{T} r_{s,i}}\right)\times\left(\frac{r_{s,i}}{r_{s,T}}\right)\right]$$

$r_{s,i}$ is the close to time i log return for stock s instead of a given time period, and $r_{s,T}$ is the close-to-close return for stock s. The fraction of the price change till time i relative to the close-to-close log return is weighted by the daily contribution to the cumulative absolute price change over the entire sample period. The first weighting term downweights return observations when the absolute value of daily price change is small.