Pre-trade transparency and market quality

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Abstract

There is no consensus in the literature on whether an increase in pre-trade transparency results in an improvement or deterioration in market quality. Two discrete changes in pre-trade transparency on the Korea Exchange (KRX), an electronic order-driven market, allow us to address this question. We find that market quality is increasing and concave in pre-trade transparency, with significantly diminishing returns above a certain point. We argue that previous event studies of the effect of transparency have been econometrically flawed, propose a procedure to correct this flaw, and show that this procedure can reverse the result of an event study.

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Pre-trade transparency and market quality

1. Introduction

Pre-trade transparency in stock markets is generally defined as a measure of the public release of information concerning participants' buy and sell orders before these orders are executed.[1] In this paper, we study the effect of pre-trade transparency on market quality using an event study.

Changes in pre-trade transparency have an effect on stock market quality through the following two channels. First, each trader adjusts his/her inferences concerning the true value of the stock and optimal strategy in direct response to the change in the quote disclosure rule. Second, each trader must further adjust his/her optimal strategy in response to the changes in the strategies of other agents; eventually, the market will reach a new equilibrium state in which traders make no further adjustments in their strategies.

The appropriate level of pre-trade transparency is a policy variable that can be freely set by an exchange or by regulators. The fundamental economic question to be addressed in setting this policy variable is whether an increase in pre-trade transparency results in an improvement or a deterioration in market quality.

Because there have been relatively few real-world events in which the disclosure policy changed, there have been relatively few studies of the effects of pre-trade transparency on market quality. Moreover, the few previous studies disagree on whether an increase in pre-trade transparency results in an increase or a decrease in market quality. Madhavan, Porter, and Weaver (2005) analyze pre-trade transparency using real-world data. Analyzing the effects of the event in which the Toronto Stock Exchange (TSX) started to publicly disclose the limit order book of both the floor and the Computer Aided Trading System (CATS), Madhavan, et al. (2005) found that the increase in pre-trade transparency had detrimental effects on market quality. Specifically, they found that the increased transparency resulted in higher trade execution costs and volatility, and that the effects were concentrated in floor stocks where pre-trade transparency was previously low and not in CATS stocks

that already featured a high degree of information disclosure. Their analysis controlled for certain relevant variables such as volume and volatility in cross-section, but since these control variables are endogenous, the cross-sectional analysis is misspecified. In contrast, Baruch (2005) developed a theoretical model in which he argued that an increase in pre-trade transparency increases market quality by reducing spreads and increasing the informational efficiency of the price. Using the introduction of NYSE's OpenBook "for payment" in 2002 as an event, Boehmer, Saar, and Yu (2005) found that greater pre-trade transparency of the limit order book is a win-win situation, the opposite to the finding of Madhavan, et al. (2005). Hendershott and Jones (2005a) found that a reduction in the transparency of the order book of the Island ECN, the dominant market for the three most active ETF's, decreased market quality.[2] Thus, there is no consensus in the literature on whether increasing pre-trade transparency results in an improvement in market quality.

Our study makes use of two events on the Korea Exchange (KRX)[3], an electronic order-driven market. The KRX publicly discloses a specified number of the best buy and sell prices and the number of shares desired or offered at those prices. On March 6, 2000, the number of publicly disclosed prices (and the number of shares at each price) was increased from 3 (the bid and the next two best buy prices, the ask and the next two best sell prices) to 5 (hereafter, "2000 event"), and from 5 to 10 on January 2, 2002 (hereafter, "2002 event"). These two discrete changes in the disclosure policy allow us to address the effect of pre-trade transparency on market quality.

We have three main findings:

- Market quality is increasing in pre-trade transparency.
- Market quality is concave in pre-trade transparency, and the benefits of providing additional pre-trade disclosure are significantly diminishing above a certain point.
- Previous event studies have obtained mixed results on the sign of the effect of pre-trade transparency on market quality. We argue that this may be due to a methodological flaw in those studies, propose a procedure to correct this flaw, and show that this procedure can reverse the result of an event study.

The rationale for the 2000 event was very simple: the KRX viewed the level of quote disclosure as too low. In increasing the disclosure, they were following the widespread belief among policy makers that increasing transparency leads to a fairer and informationally more efficient market (see U.S. SEC (1994)). In contrast, the 2002 event involved two changes, with different motivations. The main change, as noted above, was to increase the number of publicly disclosed quotes on each side of the market from 5 to 10; this was motivated by the belief that increasing transparency improves market quality. The second change involved a reduction in disclosure. Prior to the 2002 event, the KRX publicly disclosed the sum of the numbers of shares offered or sought at all prices on each side of the order book, without disclosing the prices associated with those orders unless those prices were among the 5 best on each side. This policy allowed traders to post misleading information by placing large limit orders at prices far from the market price, creating the impression of a large order imbalance with very little risk that the orders would be executed.[4] At the 2002 event, the KRX stopped disclosing this information in order to prevent the public posting of misleading information.[5]

Using standard event-study methodology, we find that the 2000 event unambiguously increased market quality. By contrast, using standard event-study methodology, the 2002 event appears on balance to decrease market quality. Only two of the tests, using relative spread and full-information trade cost, show improvement in market quality, while the other test statistics are mostly positive, indicating a decline in market quality, with some statistically significant and others not.

Event studies are based on the assumption that other relevant variables do not change from before to after the event, or if they do change, they can be adequately controlled. If that assumption is not satisfied, then changes in these other relevant variables may contaminate the event study. If the other relevant variables are exogenous, then controlling is straightforward. However, in market microstructure event studies, critical variables are endogenously determined, so that cross-sectional control methods are inapplicable. In particular, in event studies of market quality, variables such as volume and price are known to affect market quality; however, because they are determined

endogenously, some studies have not bothered to control for them, while other studies have controlled for them using inapplicable procedures; in either case, the results of the event studies are contaminated.

We reran our analyses of the two events, controlling for volume and price using a panel-data design. We computed the standard errors in two ways: OLS, and the clustered standard errors method (Rogers (1993)), clustering by time.[6] We confirmed our uncontrolled finding that market quality was unambiguously improved by the 2000 event. However, our uncontrolled finding that market quality was probably decreased by the 2002 event is reversed. Using appropriate controls, we find evidence that market quality improved following the 2002 event; the evidence appears convincing using the OLS standard errors, but weaker using the Rogers standard errors. We conclude that market quality is an increasing concave function of pre-trade transparency, with significantly decreasing returns to transparency above the level of disclosure established by the 2000 event.

Like those earlier empirical papers, our paper examines the relationship between pre-trade transparency and market quality using real-world data around a specific change in disclosure regime. However, our paper differs from those papers in the following ways. First, we analyze an electronic order-driven market in which there is no market maker. The pre-trade transparency in the electronic order-driven market provides a public measure of traders' willingness to supply liquidity to the market using limit orders. Since there are no specialists or dealers, this is only source of liquidity in this type of market. Second, we examine whether pre-trade transparency and market quality are monotonically related using a series of events. Third, following Madhavan, Richardson, and Roomans (1997, hereafter MRR), we decompose the trade execution cost into two components: adverse selection cost from asymmetric information among traders and transitory cost, and analyze the effect of pre-trade transparency on each component. The MRR decomposition was previously used to study the effect of pre-trade transparency by Madhavan, et al. (2005), but only to analyze one component (adverse selection cost).

In order to analyze comprehensively the relationship between pre-trade transparency and market quality, we set up six null hypotheses on market stability and informational efficiency of the price, reflecting the multi-faceted characteristics of market quality.[7] Each of the six hypotheses has the following basic structure: market quality is unchanged after the event compared to before the event. Negative rejections indicate a statistically significant improvement in market quality, while positive rejections indicate a statistically significant deterioration. In our tests, we use six measures of market quality (bid-ask spread (hereafter spread) and relative spread, market depth, transient volatility, market-to-limit order ratio, Bandi and Russell (2006, hereafter BR) full-information trade cost (FITC), and MRR implied spread); and two components of the MRR implied spread (adverse selection cost and transitory cost).[8] We analyze the changes in the variables from before to after each of the two events. Since we have two events in the same market, we are able to assess whether the effect of pre-trade transparency on market quality is monotonic, and whether it is concave or convex. We use two methods: a standard event-study method, without controlling for other relevant variables; and a panel-data analysis, controlling for the endogenous variables volume and price.

Since regulatory changes in stock markets generally are relatively rare, one-time, events, two factors could possibly limit the significance of our results. The first is the statistical power of the test results. As Boehmer, et al. (2005) point out, "this is an investigation of [two events] and therefore our statistical ability to attribute changes to the [events is] limited." This is an intrinsic limitation in the analysis of events that occur very rarely (see Schwert (1981)). The second factor comes from the slight heterogeneity of our two events. As we mentioned above, the 2002 event is like the 2000 event in the sense that it expanded the number of publicly disclosed quotes and sizes. However, unlike the 2000 event, it also reduced disclosure in a minor way: it stopped disclosing the sum of the numbers of shares offered or sought at all prices on each side of the order book. The decision to reduce disclosure in this way was based on a concern that some traders were manipulating the information flow by placing large orders that had little chance of being executed because they were

far from the current market price. Since the elimination of this possible manipulation was intended to improve the quality of the pre-trade disclosure,[9] we view it as an increase of pre-trade transparency.

With these caveats, our results are as follows. First, when we correct for endogenous variables using a panel-data analysis, market quality improves following both the 2000 and 2002 events, indicating that market quality is monotonically increasing in pre-trade disclosure. Second, the improvement in market quality following the 2002 event is much lower than that following the 2000 event, indicating that market quality is a concave function of pre-trade transparency, with significantly diminishing returns above the level of disclosure established by the 2000 event. Third, using standard event-study methodology without correcting for relevant variables, the analysis of the 2000 event shows an improvement in market quality, but the 2002 event shows a mixed picture which, on balance, suggests a decrease in market quality. Thus, it is important in market microstructure event studies to correct for relevant endogenous variables using a panel-data analysis.

The remainder of this paper is organized as follows. Section 2 describes our standard event-study and panel-data methodologies. Section 3 details our testable hypotheses. Section 4 describes the sampling of firms and provides descriptive statistics of our data. Section 5 presents and interprets the empirical results and their implications. Section 6 provides a summary of our results and some suggestions for further research.

2. Methodology

To test whether or not our two events improved market quality of the KRX, we compare measures of market quality before and after the events. We do this in two different ways. The first is a standard event-study, without controlling for other relevant variables, using the (parametric) paired *t*-test and the (nonparametric) Wilcoxon signed-rank test. The second method uses a panel-data analysis to control for the endogenous variables volume and price.

We measure market quality using the following variables: spread and relative spread, market depth, transient volatility, market-to-limit order ratio (measured both in terms of number of shares and number of orders), BR FITC and MRR implied spread (including the breakdown of the implied spread into its adverse selection and transitory cost components). The advantage of the first measure is that market statistics such as liquidity and volatility are relatively easily observable and are familiar to investors. The advantage of the second measure is that it provides a much more comprehensive picture of market quality, based on market microstructure models.

As mentioned in the Introduction, the 2002 event involved two changes: increasing the number of disclosed quotes on each side of the market from 5 to 10; and stopping disclosing the sum of the number of shares offered or sought at all prices on each side of the order book. The second change is a reduction in *disclosure*, but because it forecloses an opportunity for traders to publicly post misleading information at little cost, we argued above that it should be viewed as an increase in the quality of disclosure, and thus an increase in *transparency*. We also studied the informational content of the total size of the order book, and found that the incremental information, over and above the information contained in the size of the 5 best bid (ask) orders, was quite small, so the second change certainly could not have involved a significant reduction of transparency.[10] As a consequence, the effect of the compound 2002 event should clearly be viewed as an increase in pre-trade transparency.

Our standard event-study method presumes that, apart from the specific change in pre-trade transparency, other things are the same before as after each event. Market quality is affected by other relevant variables, notably volume and price, so we should control for these.[11] Volume and price are determined endogenously, and the Hausman test rejects the random effects specification, indicating that the cross-sectional model using them as controls is misspecified. Previous event studies have either omitted the controls, or have used them in cross-section despite the misspecification. Instead, we use a panel-data setting and obtain the coefficients and *t*-values using fixed effects estimation, which is robust to endogeneity problems. Because there are insufficiently

many trades per day to accurately estimate MRR on a daily basis within the small- and medium-size firms, we aggregate each five-day period into a single period; for the other variables, we use daily data. Thus, the number of observations for each measure of market quality is about 20 per firm per event for MRR, and 100 per firm per event for the other measures of market quality. For each of our market quality measures *y*, the specification is as follows:

$$y_{it} = \beta_0 + \beta_1 D_{it} + \beta_2 \log(Vol_{it}) + \beta_3 \log(P_{it}) + \alpha_i + \varepsilon_{it} \quad (1)$$

where the subscript *i* indexes individual firms, *t* indexes the period, *D* is a dummy variable (if a sample point is after the event, then *D*=1), *Vol* denotes average daily volume, and *P* denotes average daily price, α_i denotes individual firm-specific effects, and ε_{it} is independently and identically distributed with zero mean and σ_ε^2. We take the logarithm of *Vol* and *P* since their distributions are skewed to the right.

3. Hypotheses

3.1. Changes in market statistics

3.1.1. Liquidity: bid-ask spread

According to a theoretical model of Baruch (2005) and an empirical analysis of Boehmer, et al. (2005), informational efficiency is increasing in pre-trade transparency, and consequently, spread is decreasing in pre-trade transparency. In contrast, according to the theoretical analysis of Madhavan (1996) and the empirical analysis of Madhavan, et al. (2005), both quoted and effective spreads are *increasing* in pre-trade transparency; this is possible because expanding the publicly available quote disclosure induces a benefit to market order traders but a cost to limit order traders. Thus, there is no consensus on the relationship between pre-trade transparency and spread.

We test the following pair of Null Hypotheses:

H1A: $sp_1 - sp_0 = 0$

H1B: $spr_1 - spr_0 = 0$

where *sp* and *spr* denote spread and relative spread (the spread divided by the mid-price of the best bid and ask quotes), respectively. The subscripts 0 and 1 denote before and after the events, respectively. A negative (positive) rejection indicates that spread or relative spread declined (increased), and hence market quality improved (declined).

3.1.2. Liquidity: market depth

Market depth is usually defined as the sum of the order size at the best bid price and the order size at the best ask price; see Madhavan, et al. (2005). This definition is potentially problematic: the arrival of a new order that increases (decreases) the best bid (ask) ought to be viewed as increasing market depth, but if the newly arriving order is for a smaller number of shares than the previous best bid (ask), it would under the usual definition be read as decreasing market depth.[12] In this paper, we use market depth measured at a constant spread. First, we obtain the mid-price of the best bid and ask quotes.[13] Next, we sum all trade sizes of limit orders priced within 5 ticks of the mid-price on either side of the order book, plus any unmatched market orders, and divide the sum by 2. An increase in market depth indicates an increase in market quality.

Our Null Hypothesis for the relationship between pre-trade transparency and market depth is the following:

H2: $md_0 - md_1 = 0$

where *md* denotes market depth. The subscripts 0 and 1 denote before and after the events, respectively. A negative (positive) rejection indicates that market depth increased (decreased), and hence market quality improved (declined).

3.1.3. Transient volatility

It has generally been believed that informational asymmetry is decreasing in pre-trade transparency, and consequently, that volatility of stock returns should also be decreasing in pre-trade transparency. However, Madhavan (1996) developed a theoretical market microstructure model in which the volatility of stock returns can be *increasing* in pre-trade transparency, provided that the market is not sufficiently large. Madhavan, et al. (2005) confirmed this prediction using an event on the TSX. Currently, there is no consensus on the relationship between volatility and pre-trade transparency.

Our Null Hypothesis is as follows:

H3: $\sigma_1 - \sigma_0 = 0$

where σ_0 and σ_1 denote the volatility of stock returns before and after the event, respectively. A negative (positive) rejection indicates that volatility declined (increased), and hence market quality improved (declined).

To test Null Hypothesis H3, we use "transient volatility" using a "transaction time" of 20 trades, as in Ranaldo (2004). For a given transaction *t* on a given day, we consider the 20 transactions *t*, *t*-1, *t*-2, …, *t*-19, which yield 19 continuously-compounded returns; the transient volatility at transaction *t* is defined to be the standard deviation of these 19 returns. The transient volatility for the day is defined to be the average of the transient volatilities of all transactions (beginning with the twenty-first) that occurred on that day. The transient volatility for the sample period is defined to be the average of the transient volatilities for the days in the sample period. We use transient volatility for several reasons. First, the transient volatility directly measures a component of the spread between the efficient price at the moment a trader decides to initiate a transaction and the price at which the transaction eventually takes place.[14] Second, the transaction time indicates a different interval of time at different order-submission times; when there are many frequent transactions, the time interval is shorter. For example, it is an empirical stylized fact that trading intensity is higher (and hence the interval between transactions will be shorter) near the opening and closing times. Third, the problem

of heteroskedasticity of stock returns is reduced through the use of transaction time (see Hasbrouck (1993) for details).

3.1.4. Market-to-limit order ratio

Another measure of market quality is the ratio of market orders to limit orders (market-to-limit order ratio). The market-to-limit order ratio measures the relative demand and supply of liquidity. In markets with a market maker, the market maker is charged with supplying liquidity and maintaining an orderly market. In electronic order-book markets, like the KRX, there is no market maker charged with supplying liquidity; instead, liquidity is supplied solely by traders, so the effects of transparency on liquidity are likely to be more pronounced than in markets with a market maker.

When a trader places a limit order, he or she commits to trading at a specified price. Thus, placing a limit order amounts to granting a free option to any other trader to trade at the specified price. The limit order can be withdrawn, but unless and until it is withdrawn, it can be exercised by any trader. If there is a thick book of limit orders, it means that traders can, by placing a market order, make a large transaction knowing exactly how much the price will move as a result; typically, the price will not move very much. A trader who needs to trade for liquidity reasons is unlikely to place a limit order, because of the risk that the transaction will not be executed. A trader placing a limit order usually obtains a slightly better price than can be obtained by placing a market order. Thus, people placing market orders indirectly compensate people placing limit orders for supplying liquidity to the market and a free option to trade. People placing market orders are liquidity demanders, while those placing limit orders are liquidity suppliers. A thick book of limit orders is associated with a relatively liquid market, so a high market-to-limit order ratio is an indication of low market quality.

However, the relationship between market-to-limit order ratio and market quality is complex. An informed trader who knows a stock is undervalued is unlikely to place a limit order, since the risk that the trade will not be executed before the price of the stock adjusts to its true value outweighs the

small potential gain that could be obtained in the transaction price. People who place limit orders face an adverse selection cost, because informed traders will selectively pick off the favorable trades. Informed traders are able to do this, in part, because liquidity traders provide camouflage for the informed traders (Kyle (1985)).

The relationship between pre-trade transparency and the market-to-limit order ratio is more complex than the relationship to other market statistics because the ratio is determined in equilibrium, given the informational asymmetry and the liquidity needs of traders. The transparency of the order book affects all traders' willingness to demand or supply liquidity in complex ways, and the market-to-limit order ratio is determined by equilibrating the supply and demand for liquidity, so an increase in market quality could in principle result in either an increase or decrease in the market-to-limit order ratio; see the discussion on page 270 of Madhavan, et al. (2005), and the many references cited there. Thus, an increase in the market-to-limit order ratio usually but not always represents a deterioration in market quality. No previous study has examined the effect of pre-trade transparency on the market-to-limit order ratio.

We test the following pair of Null Hypotheses:

H4A: $MLRS_1 - MLRS_0 = 0$

H4B: $MLRN_1 - MLRN_0 = 0$

where *MLRS* and *MLRN* denote market-to-limit order ratio in terms of numbers of share and number of orders, respectively. The subscripts 0 and 1 denote before and after the events, respectively. A negative (positive) rejection indicates that the market-to-limit order ratio declined (increased), and hence market quality improved (declined).

3.2. Changes in informational efficiency using trade execution costs

3.2.1. Full-information transaction cost

Trade execution cost is the most popular way to measure market quality in stock markets. Although details vary from paper to paper,[15] the basic approach to measuring trade execution cost assumes that the trading price consists of the true price and an error term arising from market microstructure effects. The true price is defined as the expected value of the risk-adjusted future cash flows, conditional on all available information. The market microstructure error term includes errors resulting from price discreteness, inventory costs the market maker passes on to traders in the form of the bid-ask spread, and the systematic losses that uninformed traders incur when trading with the better informed. Given this framework, different models of trade execution cost come from different proxies for the true price, and whether or not the noise can be decomposed into informational (or adverse selection) and non-informational (or transitory) components. BR focus on a proxy for the true price, FITC, while MRR focus on the decomposition of the implied spread into its adverse selection and transitory cost components.

BR define the true price as the full-information price reflecting both public and private information at a given time. The trade execution cost is equal to the difference between the actual trading price and the full-information price, which BR call FITC. Weakening some assumptions in Roll (1984) and Hasbrouck (1993)[16] about the trading price process and the market microstructure effect, BR provide a consistent estimator (based on intraday data) to measure FITC, namely the standard deviation of the market microstructure effect $\hat{\sigma}_\eta$:

$$\hat{\sigma}_\eta = \sqrt{\left(\frac{k+1}{2}\right)\left(\frac{\sum_{i=1}^{N}\tilde{r}_i^{\,2}}{N}\right) + \sum_{s=0}^{k-1}(s+1)\left(\frac{\sum_{i=k-s+1}^{N}\tilde{r}_i\tilde{r}_{i-k+s}}{N-k+s}\right)} \qquad (2)$$

where k is a parameter of bandwidth which we take to be 6 (see section 5.1.5 for details).[17] N is the number of observations. $\tilde{r}_i$ denotes the return of trading price. We estimate $\hat{\sigma}_\eta$'s on a daily basis, and then average them separately before and after the events.

Baruch (2005) theoretically predicted that the informational efficiency of price improves as pre-trade transparency increases, and Boehmer, et al. (2005) confirmed his prediction using the Hasbrouck (1993) trade execution cost.

We test the following Null Hypothesis:

H5: $FITC_1 - FITC_0 = 0$

where *FITC* denotes the BR full-information transaction cost. The subscripts 0 and 1 denote before and after the events, respectively. A negative (positive) rejection indicates that the FITC declined (increased), and hence market quality improved (declined).

3.2.2. Implied spread, and its adverse selection and transitory cost components

An advantage of the BR FITC method is that it measures price inefficiency arising from both public and private information. In contrast, the efficient price method that has been most widely used to measure market quality considers only public information (see Hasbrouck (1993), among many others). Both approaches are derived from reduced-form models, so they cannot provide detailed information about the sources of the trade execution cost.

Using a structural-form model, MRR derived the implied spread and its two components, adverse selection and transitory costs. Even though the MRR model uses only public information, it helps us to understand the sources of trade execution cost and the changes in market quality after our two events.

To obtain a testable implied spread, the following three equations in equation (3) are used:

$$\begin{aligned} p_t &= \mu_t + \phi x_t + \xi_t \\ \mu_t &= \mu_{t-1} + \theta\left(x_t - E\left[x_t \middle| x_{t-1}\right]\right) + \varepsilon_t \\ p_t - p_{t-1} &= (\phi + \theta)x_t - (\phi + \rho\theta)x_{t-1} + \varepsilon_t + \xi_t - \xi_{t-1} \end{aligned} \tag{3}$$

where p_t is the trading price of a stock at *t*. μ_t, x_t, and ξ_t are the expected value of the stock, order flow (if buying (selling) order x_t = 1 (-1))[18], and the rounding error caused by the price discreteness, respectively. θ denotes a permanent impact of unexpected order flow on the expected value of a stock, adverse selection cost arising from the asymmetric information among the traders. ϕ denotes transitory cost, including costs attributed to the limit order trader. ρ and ε_t denote the autocorrelation of the order flow and the new information that arrives in period *t*, respectively. The MRR implied spread is $2(\phi+\theta)$.

To estimate the MRR model, we define $u_t = p_t - p_{t-1} - (\phi+\theta)x_{t-1} + (\phi+\rho\theta)x_{t-1}$ and introduce the constant term α. We also estimate γ which reflects the succession of order flow, using the relation $2\gamma - 1 = \rho$ as in MRR. We estimate all parameters using the generalized method of moments (GMM).

We test the following Null Hypotheses:

H6A: $IS_1 - IS_0 = 0$

H6B: $\theta_1 - \theta_0 = 0$

H6C: $\phi_1 - \phi_0 = 0$

where IS, θ, and ϕ denote the MRR implied spread, adverse selection cost, and transitory cost, respectively. The subscripts 0 and 1 denote before and after the events, respectively. A negative (positive) rejection indicates that implied spread, adverse selection cost, or transitory cost declined (increased), and hence market quality improved (declined).

As noted in Section 2 above, we perform all our tests in two ways: first, using a standard event-study without controlling for volume or price; and as a panel-data analysis, controlling for these variables.

4. Data

For this study, we analyze 50 trading days before and after each of the 2000 and 2002 events. The sample periods for the 2000 event are December 17, 1999 to March 3, 2000 and March 6, 2000 to May 19, 2000 (hereafter "2000 sample"). The sample periods for the 2002 event are October 19, 2001 to December 28, 2001 and January 2, 2002 to March 18, 2002 (hereafter "2002 sample").[19]

We drew our sample firms for each event based on the following criteria:

- We selected the sample from the set of KRX-listed common stocks for non-financial firms.
- We required the sample firms to be traded more than 10 times a day during the continuous trading session on at least 40 of the 50 trading days in both the before-the-event and the after-the-event period. The pre-trade disclosure for the opening and closing call auctions did not change during our data periods.
- We removed firms whose minimum tick size changed during the sample period. The change in minimum tick size affects quote (or trading) spread and other measures of market statistics, so including such firms would have contaminated our analysis.
- Trading volume is very high on the KRX stock market. The market is entirely order-driven; there is no market maker. At certain times, many transactions are reported simultaneously; these are clearly the executions of a single order on one side of the market against multiple orders on the other side. We treat these separate transactions as a single trade, whose trade size is the sum of the trade size of the individual transactions, and whose price is the price of the volume-weighted price as Gourieroux, Jasiak, and Le Fol (1999) do.

By applying the selection criteria, we obtain 145 and 245 sample firms for the 2000 and 2002 events, respectively.[20] We use intraday transaction and quote data provided by the KRX. The KRX data have the advantage that, unlike data from most major world stock markets, they explicitly classify each transaction as either buyer- or seller-initiated. We also use daily closing returns data provided by the Korea Securities Research Institute (KSRI), and the market capitalization data for each firm provided by the KRX.

During our 2000 and 2002 sample periods, the KRX opened the market at 9:00 at an opening price set by using a call auction. After the market opening, it traded stocks using a continuous double auction ending at 14:50, electronically matching orders based on price and time priority. From 14:50 until 15:00, it received orders without matching them. At 15:00, the market closed at a closing price set by a call auction. During the 2000 sample period, however, the KRX had in place a no-trading-during-the-lunch-hour-rule. The continuous trading was suspended from 12:00pm until 13:00, and call auctions were conducted at 13:00. Accordingly, the duration of the continuous trading sessions during the 2000 and 2002 sample periods are 290 minutes (9:00~12:00 and 13:00~14:50) and 350 minutes (9:00~14:50), respectively.

Table 1 reports descriptive statistics of our sample firms stratified into each of three groups: small, medium, and large firms. Since we analyze the detailed market statistics associated with the market quality of the KRX in section 5, here we briefly describe the firms' average market capitalizations (in billions of won), average daily trading volume (in thousands of shares), average daily number of trades, and average daily closing price.

The total market value of the 2000 (2002) sample firms is 107 (132) trillion won (approx. 103.9 (128.2) billion US dollar), consisting of 36.6% (65.8%) of the total market value of all firms listed on the KRX at the end of 1999 (2001). The numbers of Table 1 reflect the diversity of sample firms used in this study. The firms' average market values for the 2000 (2002) sample range from 43.2 (44.7) billion won to 1,665.4 (1,119.7) billion won.[21] As a note, the average firm's market capitalization is smaller in the 2002 sample than in the 2000 sample: this reflects the fact that the Korea Stock Price Index (KOSPI) declined from about 900 during the 2000 sample period to about 750 during the 2002 sample period. The Table shows that, for both sample periods, there is a slight decrease in trading volume from before to after the event. Around the 2000 event, prices are decreasing, while around the 2002 event, prices are increasing. The decrease in trading volume after the 2002 event comes entirely from a single firm, Hynix. Without Hynix, the average daily trading volume increases from 445,000 shares to 621,000 shares after the 2002 event.

Table 1 also reports that the average daily number of trades decreases from 542.9 to 452.3 for the 2000 sample period whereas it increases from 559.7 to 726.6 for the 2002 sample period. Converting the number of trades into the duration between trades, the average daily trading duration is 32.1 (38.5) seconds before (after) the 2000 event whereas it is 37.5 (28.9) seconds before (after) the 2002 event.

The prices in Table 1 confirm the market trend shown in Fig. 1: the 2000 event occurred in the midst of a monotonically declining market while the 2002 event occurred in the midst of a monotonically rising market.

<Insert Table 1>

<Insert Fig. 1>

5. Empirical results

5.1. Standard event-study, without controlling for volume or price

Table 2 shows the results from the standard event-study, without controlling for volume or price. The market quality variables are spread, relative spread; market depth; transient volatility; market-to-limit order ratio (number of shares and number of orders); BR FITC; MRR implied spread and its adverse selection and transitory cost components. Table 2 reports results for the group of all firms.

5.1.1. Liquidity: bid-ask spread

The daily spread on a given day is the time-average, over the course of the day, of the spread between the best bid and ask quotes. The relative spread is defined as the spread divided by the mid-price of the best bid and ask quotes. The daily relative spread on a given day is the time-average of relative spread within a day. We average the daily spread and daily relative spread over the sample before-the-event and after-the-event periods.

For daily spread, Null Hypothesis H1A is negatively rejected (so average daily spread decreases and market quality increases) for the 2000 event, but *positively* rejected for the 2002 event, which

seems to indicate a decline in market quality.[22] However, this finding could result solely from the steadily rising stock price during the 2002 sample period (see Fig. 1), since an increase in stock price usually results in an increase in spread. Thus, we also conduct tests based on the daily relative spread.

For daily relative spread, Null Hypothesis H1B is negatively rejected at both events at the 1% level in the unstratified sample of all stocks, indicating an increase in market quality. The decrease in the daily relative spread is 13.4% for the 2000 event in the midst of a declining market, whereas it is 5.6% at the 2002 event in the midst of a rising market.[23] However, we cannot determine whether this decrease results from an improvement in market quality or simply from the increase in stock prices.[24]

5.1.2. Liquidity: market depth

The daily market depth is defined as the time-average of the market depth over the course of a day. Next, we average the daily averages over each before- and after-the-event sample period. Null Hypothesis H2 is negatively rejected for the 2000 event,[25] using the Wilcoxon signed-rank test, but it is not rejected using the paired *t*-test.[26] This indicates that the 2000 event probably improved market quality somewhat. Our test statistic for Null Hypothesis H2 is statistically significantly positive in the 2002 event in the group of all firms using the Wilcoxon singed-rank test, suggesting that market quality may have declined somewhat.[27]

As noted above, at the suggestion of a referee, we measured market depth by computing the size of the order book within a fixed spread from the market price. We also analyzed market depth defined in the conventional way, as the sum of the order size at the best bid price and the order size at the best ask price; the results are qualitatively similar, and exhibit greater statistical significance.

5.1.3. Transient volatility

We report conditional transient volatility (with transaction time 20), averaged over all transactions during each of our two sample periods. Since the average trading duration before the 2000 event is 32.1 seconds (see section 4), the transient volatility is equivalent to the volatility over the 11 minute period before the transaction.[28] The volatility in the declining market (the 2000 sample period) is higher than that in the rising market (the 2002 sample period).

For all the firms in the sample, the transient volatility decreases by 5.3% after the 2000 event, leading to a negative rejection of our Null Hypothesis H3. In contrast, while it decreases by 1.9% at the 2002 event, the decrease is not statistically significant. This indicates that the 2000 event improved market quality, as measured by transient volatility, while it is unclear whether or not the 2002 event did so.[29]

5.1.4. Market-to-limit order ratio

The daily market-to-limit order ratio is the time-average of the market-to-limit order ratio during a given day. The ratio is calculated two ways: using the number of shares and the number of orders. Null Hypothesis H4A (number of shares) and Null Hypothesis H4B (number of orders) are negatively rejected in the group of all firms for the 2000 sample: the average daily market-to-limit order ratio decreases statistically significantly. By contrast, Null Hypothesis H4A and H4B are *positively* rejected in the group of all firms in the 2002 sample, indicating a decline in market quality.

Recall that the market-to-limit order ratio reflects market quality in a complicated way, and one cannot draw firm inferences about changes in market quality from the direction of changes in the ratio. Our results suggest that the 2000 event improved market quality whereas the 2002 event reduced it, but are not definitive.

5.1.5. Trade execution cost: full-information transaction cost

The FITC is based on the return between successive transactions, using a bandwidth parameter k (see equation (2)), based on the number of significant lags in the return autocorrelation. We tested

the number of significant lags for each firm in our data sample; since the largest significant lag of any firm was of order at most 6, we take $k = 6$ as our bandwidth parameter.

Null Hypothesis H5 is negatively rejected for the group of all firms in both sample 2000 and 2002; the FITC decreases by 10.3% following the 2000 event, while it decreases by 5.5% following the 2002 event. This indicates that the 2000 event improved market quality, as measured by FITC, more than did the 2002 event. FITC is notably higher in 2000 than in 2002, indicating that market quality was markedly higher in the rising market of 2002 than in the declining market of 2000. For individual groups stratified by trading volume, the FITC of the small-firm group is larger than that of the large-firm group, presumably reflecting the greater liquidity of large firms. The difference in the FITC between the small- and large-firm groups is substantially greater in the 2000 sample than in the 2002 sample. This supports the conclusion that market quality was higher in 2002 than in 2000, as it is natural to suppose that quality of the market for small stocks suffers more than that for large stocks in a period of poor overall market quality.[30]

5.1.6. Implied spread, and its adverse selection and transitory cost components

The implied spread consists of the adverse selection cost (or extent of informational asymmetry) θ and the transitory cost ϕ. The implied spread is much greater among small firms than among large firms in both sample periods; for example, the implied spread in the small-firm group is 3.8 and 6.1 times greater than that in the large-firm group before the 2000 and 2002 events, respectively.

For the group of all sample firms, Null Hypotheses H6A, H6B, and H6C are negatively rejected in the 2000 sample period; the implied spread and its two components θ and ϕ show a statistically significant decrease, indicating an improvement in market quality. The decreases in θ and ϕ (8.7% and 8.4% respectively) are quite similar, indicating that the 2000 event reduced adverse selection and transitory costs about equally; the decrease in θ indicates that the price discovery function improved, while the decrease in ϕ indicates that the operational efficiency improved.

In contrast, Null Hypothesis H6B is *positively* rejected groups in the 2002 sample; θ increases by 11.9% in the sample of all stocks. The test statistic for H6A is positive and significant in the Wilcoxon signed-rank test, but not significant in the paired *t*-test, while the test statistic for H6C is mostly negative but not significant. These results suggest that, after the 2002 event, the operational efficiency improves but the price discovery function deteriorates.

<Insert Table 2>

5.2. Panel-data analysis, controlling for volume and price

Using standard event-study methodology without controlling for volume or price, market quality clearly improved in all of our tests following the 2000 event. The picture is more mixed after the 2002 event: only two of the tests, using relative spread and FITC, show improvement in market quality, while the other test statistics are mostly positive, indicating a decline in market quality, with some statistically significant and others not. Thus, the standard event-study methodology indicates the market quality did not increase, and arguably decreased, following the 2002 event.

However, when we use the panel-data analysis to control for volume and price, we find that market quality increased following both events; thus, using the panel-data analysis to correctly control for the endogenous variables volume and price reverses our finding for the 2002 event.

Table 3 reports our panel data estimates, with standard errors computed using OLS. In order to obtain statistical power, Panel A analyzes daily observations; since MRR cannot be readily computed on a daily basis for infrequently-traded firms, it is calculated using weekly observations and reported in Panel B. The important coefficient is β_1, the coefficient of the after-the-event dummy variable. The Table shows that following the 2002 event, controlling in a panel-data setting for volume and price, relative spread, transient volatility, the BR FITC, MRR implied spread and MRR transitory cost component are all statistically significantly decreased, indicating an improvement in market quality; spread, market-to-limit order ratio (measured by number of orders) and the adverse selection cost component of MRR implied spread all decrease, indicating an improvement in market quality, but are

not statistically significant. Only the market-to-limit order ratio (measured by number of shares) shows a statistically significant deterioration in market quality. The connection between market-to-limit order ratio and market quality is quite indirect, and the sign of the coefficient depends on whether the ratio is measured by orders or shares, so we do not put much weight on this one finding of deterioration of market quality. Thus, the conclusion of our panel-data analysis, with standard errors computed by OLS, is that the 2002 event improved market quality.

<Insert Table 3>

Table 4 reports the same panel-data analysis, but with standard errors computed using Rogers (1993) clustering by time. The coefficient estimates are the same as in Table 3, but the standard errors are higher and thus the statistical significance is reduced. The results clearly confirm that the 2000 event resulted in an improvement in market quality: all the coefficients are negative, and all but three are statistically significant. As in Table 3, the signs of 8 of the 10 coefficients for the 2002 event are negative. Only one coefficient (MRR transitory cost) is statistically significant and negative; there are no statistically significant positive components. The one-sided *p*-value for the MRR transitory cost is 0.00297. When one does 10 tests, the probability that one or more tests have a *p*-value smaller than α is at most 10α,[31] so taking all 10 tests into account, we reject (with a *p*-value of $10\times0.00297= 0.0297$) the hypothesis that market quality declined or stayed constant. Thus, using the Rogers standard errors with time clustering, we find that the 2002 event improved market quality. However, the small magnitude of the coefficients, and the fact that only one of the individual tests is significant, indicates that the improvement in market quality following the 2002 event was quite small.

In comparing the panel-data results from the two events, we find strong evidence that the 2000 event improved market quality, and weaker evidence that the 2002 event improved market quality. We conclude that market quality is increasing and concave in pre-trade transparency, with significantly diminishing returns to pre-trade transparency above the level of disclosure established at the 2000 event.

<Insert Table 4>

6. Concluding remarks

We examined the effect of pre-trade transparency on market quality. For this, we analyzed two real-world events undertaken by the KRX, which increased the number of publicly disclosed quotes from 3 to 5 on March 6, 2000 and from 5 to 10 on January 2, 2002. We measured market quality using spread, relative spread, market depth, transient volatility, market-to-limit order ratio, BR FITC, MRR implied spread and its adverse selection and transitory cost components.

We compared measures of market quality before and after the events using standard event-study methodology, which indicated an improvement in market quality following the 2000 event, but a deterioration in market quality following the 2002 event. Because the standard event-study methodology does not control for the relevant variables volume or price, and because these variables are endogenous, we conducted a panel-data analysis. This analysis indicated that both events improved market quality, confirming the finding of the standard event-study methodology for the 2000 event, but reversing the finding for the 2002 event. We conclude that market microstructure event studies should use panel-data analyses to control for relevant endogenous variables to ensure the reliability of their results.

The panel-data study indicated that the improvement in market quality was much smaller following the 2002 event, indicating that market quality is a concave function of pre-trade transparency.

We attempted to analyze the relationship between pre-trade transparency and market quality in a comprehensive way. We did not have access to information on each trader's type (individual versus institutional, domestic versus foreign) which might have provided more detailed results about the relationship of informational efficiency and pre-trade transparency on the KRX; we will pursue this in future research.

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Footnotes

[1] The *post-trade* transparency is defined as a measure of the public release of information concerning participants' buy and sell orders after these orders are executed. We distinguish in this paper between pre-trade and post-trade transparency. However, when we refer to previous studies that did not differentiate them or analyzed them together, we use the term "transparency".

[2] The theoretical studies regarding post-trade transparency are Naik, Neuerberger, and Viswanathan (1999) and Madhavan (1995), while Gemmill (1996) is empirical. Gemmill (1996) examines a change in reporting block trades on the London Stock Exchange (LSE) and argues that less post-trade transparency does not affect spread and the speed of price adjustment. The theoretical studies regarding transparency include Madhavan (1995), Pagano and Roëll (1996), Lyons (1996), Rindi (2002), and so on, while the related laboratory experiment studies are Bloomfield and O'Hara (1999, 2000) and Flood, Huisman, Koedijk, and Mahieu (1999).

[3] The KRX was formed in 2005 from the consolidation of the Korea Stock Exchange (KSE), a new market (KOSDAQ), and the Korea Futures Exchange (KOFEX).

[4] Thus, on its face, the 2002 event involves a simultaneous increase and decrease of disclosure. Since the motivation for the decrease in disclosure was to shut off a mechanism by which traders could post misleading information, we see this reduction in disclosure as an increase in the quality of disclosure, and hence an increase in transparency. In addition, further analysis shows that the information which was no longer disclosed was very highly correlated with information that continued to be disclosed; see section 2, especially footnote 10.

[5] On November 10, 2001, the KRX issued a press release in Korean announcing the 2002 event and providing its rationale for the change in disclosure. Here is our translation of the portion of the release giving the rationale for stopping the disclosure of the sum of the numbers of shares offered or sought at all prices on each side of the order book: "Under the current system, we have frequently witnessed spoofing orders submitted without any intention of execution, only for the purpose of hooking other traders. 92% of the spoofing orders were submitted during the continuous-trading session, rather than in the call auctions at the open and close of the market; 92.84% of the spoofing orders were submitted outside the 5 best bid and ask prices," so traders could not see the prices at which these orders were placed. "As a consequence, small traders face losses and relative appropriation of their profits, which may lead them to leave the market. In addition, these spoofing

orders have resulted in abrupt changes in the market price and caused investors to doubt the integrity of the market. Therefore, it is necessary to change the rule."

[6] Petersen (2006) argues that many panel-data studies in Finance have calculated standard errors incorrectly. Petersen considers two forms of dependence among the regression residuals. The first, which he calls the unobserved firm effect, is that the residual of a given firm may be correlated across times. The second form of dependence, which he calls a time effect, is that residuals for a given period may be correlated across firms. Assuming that there is no time effect, and the firm effect is fixed, including firm fixed effects eliminates the bias in the standard errors. Since we consider relatively short data periods before and after the two events, it is unlikely that the firm effect varies enough over time to substantially affect the standard errors. However, the residuals may well be correlated across firms, so Petersen's analysis argues for using Rogers (1993) clustered standard errors, clustering by time.

[7] The following studies exemplify the difficulty in defining market quality as a single word: for market quality, Porter and Weaver (1997) use spread, market depth, preferencing and internalization, and profit of exchange member firms; whereas Hendershott and Jones (2005b) mostly use some variants of bid-ask spread. Krishnamurti, Sequeira, and Fangjian (2003) use the standard deviation of pricing error defined by Hasbrouck (1993).

[8] Transitory cost is a component of trade execution cost arising from liquidity provision, contrasting with the permanent effect of adverse selection cost. Transitory cost includes most of the market microstructure frictions except the cost arising from price discreteness. See section 3.2.2 for details.

[9] See footnote 5, which translates the relevant portion of the KRX press release announcing the 2002 event.

[10] We used two months' data for all firms listed on KRX: December 2001 to January 2002, a month right before and after the event. For December 2001, 93.8% (94.0%) of the variation in the total number of shares sought (offered) at all prices on the bid (ask) side of the order book was explained by the change in the sum of the sizes at the 5 best bid (ask) quote, indicating that the incremental information contained in the total size of the order book, over and above that contained in the sizes of the 5 best bid and ask quotes, was very small. As we have noted, the December 2001 disclosure policy permitted traders to manipulate the disclosed statistics by placing orders very far from the best prices, so the small informational increment bears a dubious relationship to the true value of the securities. For January 2002, 95.3% (95.4%) of the variation of the total number of shares

included in the 10 best bid (ask) prices was explained by the variation in the total number of shares included in the 5 best bid (ask) prices. In interpreting this latter fact, it is important to note that the January disclosure included the number of shares sought (offered) at *each* of the 10 best bid (ask) prices, not just the sum of the total number of shares included in the 10 best bid (ask) prices. Thus, this additional disclosure might well be informationally significant, with a systematic relationship to the true prices of the securities. As we have noted, disclosure of additional significant information plays a complex role, whose sign cannot be determined theoretically, on the equilibrium level of market quality, the focus of this paper. In addition, we found that the sum of the number of shares included in the 5 best bid (ask) quotes increased slightly after the 2002 event. This suggests that after the event, traders were more willing to place limit orders at one of the 5 best bid (ask) prices because the event made it much harder to avoid disclosure and still enter an order with a reasonable chance of execution. We also found that the sum of the 10 best bid (ask) quotes after the event was essentially double the sum of the 5 best bid (ask) quotes. The detailed results are available from the authors on request.

[11] We find that the number of trades, transient volatility, and market-to-limit order ratio (based on number of shares) are highly correlated with volume, so to avoid the multicollinearity problem, we do not use them as control variables. We also considered controlling for the market-to-limit order ratio (based on number of orders), but decided against on the grounds that, as a measure of market quality, should really be viewed as a dependent variable. If the market-to-limit order ratio is included as a control variable, the results are qualitatively very similar to those in Table 3.

[12] We are grateful to a referee for pointing this out.

[13] We use the mid-price rather than the market price because the KRX does not have a market maker, and thus we cannot obtain the market price if a new market order arrives on the sell (buy) side when there is no quote on the buy (sell) side of the order book. In the event that there are no sell orders, we take the midpoint to be the best bid price; in the event there are no buy orders, we take the midpoint to be the best sell price. If there are no orders at all, the market depth is zero.

[14] This procedure in effect assumes that the stock price is an Itô process with stochastic volatility. The sample standard deviation of *continuously-compounded* returns is an unbiased estimate of return volatility *per unit time*; the choice of a transaction time of 20 represents a compromise between longer transaction times (which give a more accurate estimate, but an estimate of *average* return volatility over a longer period rather than an estimate

of *instantaneous* return volatility) and shorter transaction times (which give a less accurate estimate, but an estimate of *instantaneous* return volatility, the desired variable). Perold (1988) insists that the ideal measurement of trade execution cost is the difference between the trader's transaction price and the efficient price at the moment of his/her decision making. This provides the main basis for most of literature that develop various versions of trade execution cost (see Hasbrouck (1993), Bandi and Russell (2006), among many others). Given a lag between the decision and the resulting transaction, instantaneous volatility is a component of the gap between the trader's transaction price and the efficient price at the time of the decision.

[15] For a survey of the recent discussion on trade execution cost, see the special issue of *the Journal of Financial Markets* 6 (2003).

[16] BR allow autocorrelation in the full-information price, cross-correlation between the full-information price and the market microstructure effect, and autocorrelation (above the second order) of the market microstructure effect.

[17] Equation (2) is as given in the 2006 version of BR. The original (2003) version of BR had a different denominator. In a subsequent revision (2004), BR added a correction for finite sample bias and changed the denominator. However, they removed this finite-sample correction and again changed the denominator, arriving at the form given in Equation (2), saying "Our consistent estimates promise to be roughly unbiased if the number of trades within a day is large, but are potentially biased for less frequently-traded assets (p. 15)." Since the average number of trades per day among the stocks in our sample was 542.9 before and 452.3 after the 2000 event, 559.7 before and 726.6 after the 2002 event, we feel confident in using Equation (2).

[18] MRR set $x_t = 0$ if it is not clear whether the order is a buy or a sell. In contrast, the KRX data set clearly indicates whether each trade is buyer- or seller-initiated. Thus, we do not use $x_t = 0$.

[19] On May 22, 2000, the "no-trading rule during the lunch hour (12:00 pm to 1:00 pm)" was abolished. We were concerned that including this date in the sample period would contaminate our findings. Using a 50-day sample period, we include the days up to May 19, 2000, so we avoid the May 22 event.

[20] We form three different groups of firms stratified by trading volume (in number of shares) occurring during the regular continuous trading session for the 50 before-the-event sample days. We analyzed the data using these three groups of firms, and also in the group of all firms. Table 1 describes the data for each group. For brevity, our main Tables (Tables 2, 3, and 4) report only the results for the group of all firms. The results for

the individual firm groups are available from the corresponding author, and are discussed where appropriate in the text. We also tried forming the three groups using total trading volume, including both the opening and closing call auctions and the continuous trading session. The resulting portfolios are almost identical.

[21] The minimum and maximum of the firm's market values for the 2000 (2002), not reported in Table 1, are 3.1 (5.4) billion won and 39.9 (42.2) trillion won, respectively.

[22] The hypotheses are rejected, in the indicated direction, for each of the three firm-size groups as well.

[23] Results in the three firm-size groups show mixed statistical significance.

[24] It seems reasonable to suppose that spread is, for the most part, a concave function of stock price. In that case, in a period of decreasing (increasing) prices, both price and spread decrease (increase), but the rate of price decrease (increase) is generally greater than the decrease (increase) in relative spread. Accordingly, the daily relative spread should be expected to increase after the 2000 event and decrease after the 2002 event as a result of changing prices. However, the results in Table 2 show that the relative spread decreases after the 2000 event, indicating that market quality improves. The relative spread decreases after the 2002 event, but we cannot determine whether this reflects an improvement in market quality or simply the rise in stock prices.

[25] For the group of all firms, Null Hypothesis H2 is negatively rejected using the Wilcoxon signed-rank test even though the mean value decreases after the event. The decrease in the all-firm mean results from the decrease in the mean among large firms; since the order book for large firms is much larger than the order book for small and medium firms, the small percentage decrease among large firms overwhelms the large percentage increase among small and medium firms. In the Wilcoxon signed-rank test, for the group of all firms, the rank-sum decrease is 3,598, while the rank-sum increase is 6,987.

[26] It is negatively rejected in the small- and medium-size firm groups.

[27] Again, the statistical significance among the individual firm-size groups is mixed.

[28] The results for the individual firm-size groups, available from the corresponding author, show two stylized empirical findings from market microstructure studies; the (transient) volatility of small firms, which are typically infrequently traded, is higher than that of large firms, regardless of the sample period. Table 1 shows that the average daily trading volume of the large firms before and after the 2000 (2002) event is larger than that of the small firms by factors of 72 (257) and 32 (162).

[29] We use the paired *t*-test and the Wilcoxon signed-rank test together for all tests in this paper. In general, the results of the Wilcoxon signed-rank test show more statistical significance than those of the paired *t*-test. For individual firm-size groups, transient volatility decreases after both events but the statistical significance is weak.

[30] The FITC decreases in all firm-size groups with statistical significance at the 1% level, using both the paired *t*- and Wilcoxon signed-rank tests, following the 2000 event; they all decline following the 2002 event, but the statistical significance is mixed.

[31] Note that this does not require independence of the tests.

Table 1
Descriptive statistics

This Table reports descriptive statistics of the sample firms stratified into each of three groups (small, medium, and large firms) listed on the KRX. We form the groups based on trading volume during the continuous trading session for each of the before-the-event sample periods. The Table reports the number of sample firms, the firms' average market capitalizations (in billions of won), average daily trading volume (in thousands of shares), average daily number of trades, and average daily closing price. We analyze only the trading occurring during the regular continuous trading session. For the 2000 sample period, the duration of the continuous trading session is 290 minutes (9:00~12:00 and 13:00~14:50); for the 2002 sample period, it is 350 minutes (9:00~14:50).

Group (based on volume)	No. of firms	Market cap. (billion won) Mean	Average volume (1,000 shares) Mean		Average number of trades Mean		Average closing price (won) Mean	
			before	after	before	after	before	after
<Panel A> 2000								
All	145	740.0	451.0	419.6	542.9	452.3	13,126.5	12,705.8
Small-firm	35	43.2	13.9	28.2	44.3	72.7	13,850.5	13,781.4
Medium-firm	49	85.8	73.8	95.0	159.3	187.5	11,697.6	11,060.7
Large-firm	61	1,665.4	1,004.9	904.9	1,137.1	882.9	13,859.0	13,410.2
<Panel B> 2002								
All	245	540.6	1,599.1	1,458.4	559.7	726.6	12,564.0	14,401.4
Small-firm	81	44.7	17.5	24.7	82.5	102.4	16,969.9	18,859.8
Medium-firm	79	426.0	108.5	180.9	257.5	345.8	13,626.1	14,931.3
Large-firm	85	1,119.7	4,491.6	4,011.8	1,295.4	1,675.3	7,378.4	9,660.2

Table 2
Results from standard event-study

This Table shows the results of the standard event-study, without controlling for other relevant variables, using the (parametric) paired *t*-test and the (nonparametric) Wilcoxon signed-rank test. Each hypothesis has the following basic structure: market quality is unchanged after the event compared to before the event. The market quality measures are as follows: spread and relative spread, market depth, transient volatility, market-to-limit order ratio (measured by number of shares and number of orders), BR FITC, and MRR implied spread and its adverse selection and transitory cost components. Negative rejections (market quality after the event minus market quality before the event, except in the case of market depth in which we use before minus after) indicate a statistically significant improvement in market quality, while positive rejections indicate a statistically significant deterioration. Parentheses denote standard errors. * and ** (+ and ++) denote statistical significance at the 5% and 1% level, respectively, using the paired *t*-test (the Wilcoxon signed-rank test). †† denotes a statistically significant *increase* at the 1% level using the paired *t*-test (the Wilcoxon signed-rank test), even though the mean decreases.

	2000		2002	
	Before	After	Before	After
No. of firms	145		245	
sp (spread)	129.05 (160.93)	108.40$^{**,++}$ (142.34)	84.63 (159.94)	90.16$^{**,++}$ (173.61)
spr (relative spread)	1.42 (1.13)	1.23$^{**,++}$ (0.88)	0.72 (0.40)	0.68$^{**,++}$ (0.37)
md (market depth)	25,328.70 (104,929.06)	24,158.50†† (98,582.82)	53,513.20 (410,214.31)	37,093.40^{++} (177,529.39)
σ (transient volatility) (%)	0.94 (0.51)	0.89$^{*,+}$ (0.45)	0.52 (0.23)	0.51 (0.22)
MLRS (market-to-limit order ratio: number of shares)	8.59 (2.32)	7.64$^{*,++}$ (2.26)	3.71 (1.25)	4.01**,$^{++}$ (1.34)
MLRN (market-to-limit order ratio: number of orders)	11.22 (4.25)	9.43$^{**,++}$ (3.65)	4.23 (1.81)	4.38^{++} (1.61)
FITC (BR full-information trade cost) (%)	1.17 (0.85)	1.05$^{**,++}$ (0.67)	0.55 (0.32)	0.52$^{**,++}$ (0.29)
IS (MRR implied spread)	46.15 (51.73)	42.24$^{*,++}$ (50.84)	31.03 (63.80)	31.91^{+} (61.00)
θ (MRR adverse selection cost of implied spread)	20.32 (1.53)	18.56$^{*,++}$ (1.17)	13.81 (1.04)	15.45$^{**,++}$ (1.05)
ϕ (MRR transitory cost of implied spread)	25.83 (1.85)	23.67$^{*,++}$ (1.46)	17.22 (1.27)	16.46 (1.19)

Table 3
Results from panel-data analysis, controlling for the endogenous variables volume and price: OLS

Since the Hausman test rejects the random effects specification, indicating that endogeneity is an issue, this Table reports the coefficients and *t*-values from a panel-data analysis, using fixed effects estimation, which is robust to endogeneity problems. For each measure of market quality, we estimate the following regression:

$$y_{it} = \beta_0 + \beta_1 D_{it} + \beta_2 \log(Vol_{it}) + \beta_3 \log(P_{it}) + \alpha_i + \varepsilon_{it}$$

where the subscript *i* indexes individual firms, *t* indexes the period, *y* is the following our market quality measures: spread and relative spread, market depth, transient volatility, market-to-limit order ratio (measured by number of shares and number of orders), BR FITC, MRR implied spread and its adverse selection and transitory cost components. *D*, *Vol*, and *P* are a dummy variable (if after-the-event, then *D*=1), average daily volume, and average daily price, respectively. α_i is individual firm-specific effects and ε_{it} is independently and identically distributed with zero mean and σ_ε^2. In order to obtain statistical power for the panel-data analyses, we use daily observations in Panel A; since MRR cannot be readily computed on a daily basis for infrequently-traded firms, it is calculated using weekly observations and reported in Panel B. Parentheses denote *t*-values, with standard errors computed using OLS. * and ** denote statistical significance at the 5% and 1% level, respectively.

	2000				2002			
	β_0	β_1	β_2	β_3	β_0	β_1	β_2	β_3
<Panel A>								
No. of firms (observations per firm)	145 (100)				245 (100)			
sp (spread)	-449.59 (-12.91)**	-10.29 (-7.72)**	-25.71 (-29.47)**	100.30 (23.35)**	-525.58 (-20.88)**	-1.34 (-1.71)	-11.66 (-24.32)**	85.45 (27.79)**
spr (relative spread)	7.22 (22.78)**	-0.19 (-15.56)**	-0.24 (-30.00)**	-0.36 (-9.09)**	1.93 (17.15)**	-0.01 (-3.69)**	-0.10 (-45.33)**	-0.01 (-0.98)
md (market depth)	92,802.91 (3.26)**	-2,245.15 (-2.06)*	6,673.53 (9.36)**	-16,561.08 (-4.72)**	1,777,491.00 (21.27)**	4,587.01 (1.76)	19,903.22 (12.50)**	-224,463.10 (-21.98)**
σ (transient volatility) (%)	2.50 (10.96)**	-0.09 (-9.62)**	0.02 (3.10)**	-0.22 (-7.68)**	0.03 (0.24)	-0.02 (-4.89)**	-0.01 (-5.39)**	0.07 (4.62)**
MLRS (market-to-limit order ratio: number of shares)	-4.52 (-1.48)	-0.71 (-6.09)**	-0.55 (-7.32)**	2.23 (5.95)**	-8.90 (-4.36)**	0.17 (2.60)**	-0.27 (-6.89)**	1.80 (7.22)**
MLRN (market-to-limit order ratio: number of orders)	-9.76 (-4.18)**	-1.52 (-16.93)**	-0.44 (-7.55)**	2.99 (10.41)**	-12.87 (-7.99)**	-0.08 (-1.51)	-0.14 (-4.62)**	2.15 (10.96)**
FITC (BR full-information trade cost) (%)	4.55 (18.37)**	-0.12 (-12.12)**	-0.03 (-4.19)**	-0.36 (-11.89)**	0.77 (7.81)**	-0.02 (-5.36)**	-0.02 (-10.17)**	-0.00 (-0.21)
<Panel B>								
No. of firms (observations per firm)	145 (20)				245 (20)			
IS (MRR implied spread)	2.03 (9.65)**	-0.04 (-5.18)**	-0.07 (-11.41)**	-0.07 (-2.76)**	0.61 (7.56)**	-0.01 (-4.24)**	-0.04 (-19.11)**	0.01 (0.90)
θ (MRR adverse selection cost of implied spread)	1.31 (9.70)**	-0.03 (-5.18)**	-0.04 (-8.95)**	-0.07 (-4.20)**	0.19 (3.82)**	-0.00 (-1.13)	-0.01 (-11.59)**	0.01 (1.62)
ϕ (MRR transitory cost of implied spread)	0.70 (4.20)**	-0.014 (-2.33)*	-0.04 (-7.37)**	0.00 (0.11)	0.41 (5.95)**	-0.01 (-4.09)**	-0.02 (-13.64)**	-0.00 (-0.15)

Table 4
Results from panel-data analysis, controlling for the endogenous variables volume and price: Rogers standard errors with clustering by time

Since the Hausman test rejects the random effects specification, indicating that endogeneity is an issue, this Table reports the coefficients and *t*-values from a panel-data analysis, using fixed effects estimation, which is robust to endogeneity problems. For each measure of market quality, we estimate the following regression:

$$y_{it} = \beta_0 + \beta_1 D_{it} + \beta_2 \log(Vol_{it}) + \beta_3 \log(P_{it}) + \alpha_i + \varepsilon_{it}$$

where the subscript i indexes individual firms, t indexes the period, y is the following our market quality measures: spread and relative spread, market depth, transient volatility, market-to-limit order ratio (measured by number of shares and number of orders), BR FITC, MRR implied spread and its adverse selection and transitory cost components. D, Vol, and P are a dummy variable (if after-the-event, then D=1), average daily volume, and average daily price, respectively. α_i is individual firm-specific effects and ε_{it} is independently and identically distributed with zero mean and σ_ε^2. In order to obtain statistical power for the panel-data analyses, we use daily observations in Panel A; since MRR cannot be readily computed on a daily basis for infrequently-traded firms, it is calculated using weekly observations and reported in Panel B. Parentheses denote *t*-values, with Rogers (1993) standard errors with clustering by time. * and ** denote statistical significance at the 5% and 1% level, respectively.

	2000				2002			
	β_0	β_1	β_2	β_3	β_0	β_1	β_2	β_3
<Panel A>								
No. of firms (observations per firm)	145 (100)				245 (100)			
sp (spread)	-449.59 (-6.00)**	-10.29 (-2.47)*	-25.71 (-13.14)**	100.30 (11.01)**	-525.58 (-15.81)**	-1.34 (-0.81)	-11.66 (-17.66)**	85.45 (21.08)**
spr (relative spread)	7.22 (6.92)**	-0.19 (-3.50)**	-0.24 (-11.24)**	-0.36 (-3.21)**	1.93 (9.74)**	-0.01 (-0.95)	-0.10 (-22.87)**	-0.01 (-0.57)
md (market depth)	92,802.91 (2.49)*	-2,245.15 (-1.53)	6,673.53 (8.91)**	-16,561.08 (-4.11)**	1,777,491.00 (4.61)**	4,587.01 (1.21)	19,903.22 (7.30)**	-224,463.10 (-4.73)**
σ (transient volatility) (%)	2.50 (3.48)**	-0.09 (-2.33)*	0.02 (1.47)	-0.22 (-2.38)*	0.03 (0.16)	-0.02 (-1.85)	-0.01 (-3.83)**	0.07 (3.02)**
MLRS (market-to-limit order ratio: number of shares)	-4.52 (-0.93)	-0.71 (-3.27)**	-0.55 (-4.24)**	2.23 (3.75)**	-8.90 (-4.11)**	0.17 (1.31)	-0.27 (-5.60)**	1.80 (6.86)**
MLRN (market-to-limit order ratio: number of orders)	-9.76 (-1.92)	-1.52 (-5.38)**	-0.44 (-3.35)**	2.99 (5.27)**	-12.87 (-4.73)**	-0.08 (-0.51)	-0.14 (-3.29)**	2.15 (6.86)**
FITC (BR full-information trade cost) (%)	4.55 (5.54)**	-0.12 (-2.82)**	-0.03 (-1.97)	-0.36 (-3.89)**	0.77 (4.97)**	-0.02 (-1.39)	-0.02 (-5.63)**	-0.00 (-0.14)
<Panel B>								
No. of firms (observations per firm)	145 (20)				245 (20)			
IS (MRR implied spread)	2.03 (3.29)**	-0.04 (-1.59)	-0.07 (-9.10)**	-0.07 (-1.02)	0.61 (5.72)**	-0.01 (-1.75)	-0.04 (-11.08)**	0.01 (0.75)
θ (MRR adverse selection cost of implied spread)	1.31 (4.25)**	-0.03 (-2.25)*	-0.04 (-6.83)**	-0.07 (-1.96)	0.19 (2.49)*	-0.00 (-0.53)	-0.01 (-8.74)**	0.01 (1.07)
ϕ (MRR transitory cost of implied spread)	0.70 (2.05)	-0.014 (-0.98)	-0.04 (-5.90)**	0.00 (0.06)	0.41 (8.19)**	-0.01 (-2.75)*	-0.02 (-8.60)**	-0.00 (-0.22)

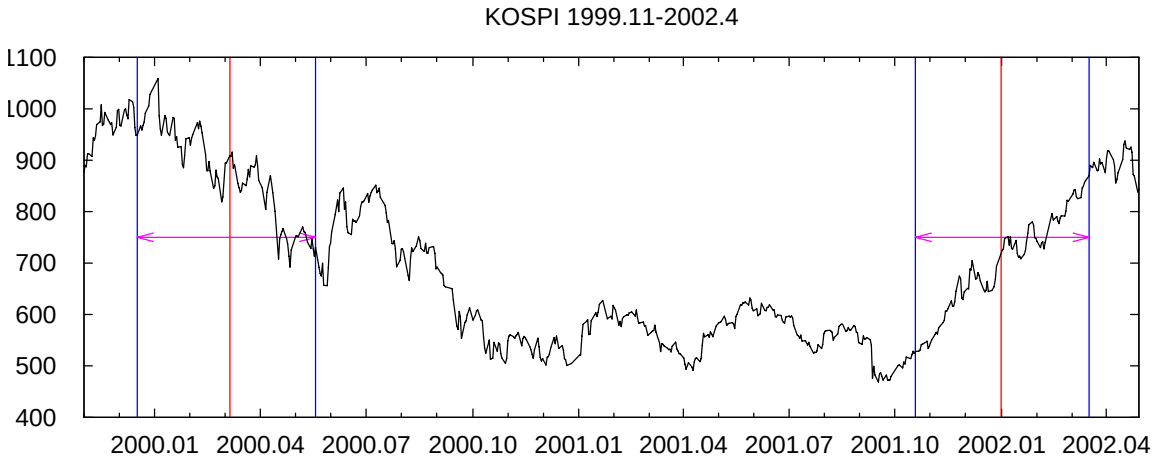

Fig. 1. The Korea Stock Price Index (KOSPI) from November 1999 to April 2002.