

**The Impact of Limit Order Anonymity on Liquidity: Evidence from  
Paris, Tokyo and Korea**

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## **The Impact of Limit Order Anonymity on Bid-Ask Spreads: Evidence from Korea, Tokyo and Paris**

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### **Abstract**

This paper examines the impact of broker anonymity on bid-ask spreads in order driven markets. Previous theoretical research predicts that limit order anonymity results in deeper and more liquid markets. This paper examines this proposition using three natural experiments provided by Euronext Paris, the Tokyo Stock Exchange and the Korea Stock Exchange. Euronext Paris and the Tokyo Stock Exchange removed broker identifiers from limit orders on April 23, 2001 and June 30, 2003, respectively. In contrast, the Korea Stock Exchange introduced broker identifiers for limit order books on October 25, 1999. The results provide evidence that altering limit order anonymity has an impact on liquidity. Consistent with expectations, liquidity is enhanced by increased anonymity and adversely affected by decreased anonymity.

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*JEL Classification:* G10; G14

*Keywords:* anonymity, transparency, limit orders

## 1. INTRODUCTION

This paper examines the impact of the disclosure of broker identifiers in limit order books on market liquidity. While many previous papers have examined the impact of anonymity on bid-ask spreads,<sup>1</sup> only two, Simaan et al. (2003) and Foucault et al. (2003), have examined pre-trade anonymity of quotes and orders placed by liquidity providers (i.e. limit order dealers or traders).

Simaan et al. (2003) argue that anonymity reduces the probability of collusion amongst quote setters. They argue that a transparent market setting enables traders to enforce informal collusive agreements to quote wider spreads. That is, anyone setting narrower spreads can be identified and reprimanded by other quote setters. They consequently argue that spreads will be narrower in an anonymous environment. They provide evidence consistent with their proposition by demonstrating that NASDAQ dealer quotes posted through anonymous Electronic Communication Networks (ECNs) are tighter than dealer quotes posted through the NASDAQ (which is a transparent dealer quotation system).

Foucault et al. (2003) develop a theoretical model which also enables them to argue that anonymity can result in tighter bid-ask spreads. They identify two classes of quote setters: traders who are informed about future price movements and those that are less informed (“uninformed”). They argue that in an environment where broker identity is displayed, informed quote setters who quote competitive bid-ask spreads will give away information about the magnitude of impending price movements. For example, tighter spreads can signal that price risk (expected future price movement) is low. In a non-anonymous environment, uninformed quote setters would learn from observing the quotation behavior of informed traders, and consequently “free ride” on

this information by setting quotes that are slightly more aggressive than those posted by informed quote setters. Presumably, this free riding imposes a cost on informed traders.<sup>2</sup> The authors argue that in an attempt to avoid this problem, quote setters will engage in “bluffing” in which they will sometimes set wider spreads than appropriate. In a non-anonymous market, there is no need for quote setters to engage in bluffing as they are not visible to uninformed quote setters. Hence, they will always quote a competitive spread.

On this basis, Foucault et al. (2003) provide some theoretical rationale that enables them to conclude that anonymous quotes lead to tighter bid-ask spreads. They test this proposition by examining the behavior of bid-ask spreads and depth of CAC-40 and *Continu A* stocks listed on Euronext Paris around April 23, 2001. Prior to this date, the pre-trade transparency of Euronext Paris was high. Brokers trading in the market were able to observe the full limit order book at all times and the identification code of the broker responsible for these orders. However, following April 23, 2001, broker identifiers were no longer displayed. Foucault et al. (2003) document a decline in the bid-ask spread and depth after controlling for the determinants of spreads (trading activity, price volatility and stock prices). This result leads Foucault et al. (2003) to conclude that an increase in pre-trade anonymity has an ambiguous affect on liquidity.

Motivated by the previous research, this paper extends the analysis of Foucault et al. (2003) for Euronext Paris to stocks in the Euronext 100<sup>3,4</sup> index and also examines another measure of liquidity, the effective spreads of orders.<sup>5</sup> This paper also assesses the generalizability of the findings of Foucault et al. (2003) by examining changes in market liquidity in two other markets that altered the level of anonymity: the Tokyo Stock Exchange (TSE) and the Korea Stock Exchange (KSE). Like Euronext Paris,

transparency on the TSE was relatively high before June 30, 2003 with the volume of orders available at the three best prices being displayed to the market along with the corresponding identity of the brokers responsible for each limit order. Following June 30, 2003, the identity of the broker responsible for each limit order was removed from trading screens.<sup>6</sup> In contrast, the KSE introduced broker identifiers on October 25, 1999. Specifically they began to display the identity of the five most active brokers in each stock. This increased the already relatively high level of pre-trade transparency, which included the disclosure of the volume of orders at the best 10 price steps to all investors during continuous trading. This information is displayed to brokers and the general public in real-time.<sup>7</sup> No other changes were made to the market structure on this date.<sup>8</sup>

Using the theoretical rationale outlined in the previous literature, this paper tests whether liquidity increased on Euronext Paris and the TSE following an increase in the level of anonymity. It also examines whether liquidity decreased on the KSE following the elimination of broker anonymity. Our results are consistent with expectations. Relative bid-ask spreads and effective spreads of orders decrease on Euronext Paris and the TSE.<sup>9</sup> Relative bid-ask spreads and effective spreads increase on the KSE. Therefore, these results support the notion that an increase in limit order anonymity improves liquidity. In contrast, a switch to a less anonymous pre-trade environment, where broker identity is disclosed, is detrimental to market liquidity.

The remainder of this paper is organized as follows. Section 2 and 3 describes the data and method, respectively. Section 4 discusses the univariate and multivariate results. The penultimate section discusses robustness tests and the final section concludes.

## **2. DATA**

Details of the stocks included in the major indices are obtained directly from the respective exchanges. For Euronext Paris, stocks included in the Euronext 100 index are considered. These stocks trade in a fully automated order driven market.<sup>10</sup> Of these 100 stocks, 64 are traded on Euronext Paris. For the TSE, Topix 100 index stocks are examined. For the KSE it was not possible to identify the component stocks of the major market indices at the time of the event, consequently the top 250 stocks based on market capitalization are selected.

For each stock, intraday trade and quote data for a period six months before and after the event date is obtained from the *Securities Industry Research Centre of Asia-Pacific (SIRCA)*, sourced from *Reuters International Plc*. For the three markets under consideration, varying levels of limit order book data are available. For Euronext Paris, we have access to the full order book. Due to the change in limit order book transparency on the TSE, the quotes and depth at the best three prices are obtained prior to June 30, 2003. After this date, the quotes and the depth at the best five prices are obtained. Details of all individual trades and changes in the best bid and ask prices are provided for the KSE.

To be included in the final sample, stocks are required to trade continuously for at least 120 days in both the pre and the post periods. This results in a reduction of the number of stocks across the three exchanges. The Euronext Paris sample decreases by 6 firms, Topix 100 by 3 firms, and the KSE top 250 by 50.

## **3. METHOD**

For each market, a number of variables are examined for a 40 day period around the event date. The samples are divided into a pre-period, *Pre*, which covers 20 trading

days prior to the respective event date, and a post-period, *Post1*, which covers 20 trading days immediately after event dates. The events dates are April 23, 2001 for Euronext Paris, June 30, 2003 for the TSE and October 25, 1999 for the KSE. Consistent with previous research such as Goldstein and Kavajecz (2000), the analysis also allows for a period of learning following the changes in market design. As market participants may gradually adjust their behavior in response to the anonymity changes, market behavior is also examined over a second 20-day post-event period, *Post2* commencing 20 trading days after the change in market design (i.e. from day +21 to day +40).

Bid-ask spreads are examined because they are a proxy for liquidity, and because they are also a measure of market quality that has been widely examined in the literature. The determinants of bid-ask spreads, trading activity and price volatility, are also examined (see McNish and Wood, 1992).<sup>11</sup> Following McNish and Wood (1992), this paper calculates time-weighted *relative* bid-ask spreads (*RELSPREADS<sub>it</sub>*) for each day as follows:

$$RELSPREADS_{it} = \frac{\sum_{d=1}^n \frac{(Ask_{id} - Bid_{id})}{(Bid_{id} + Ask_{id})/2} * t_{id} * 100}{\sum_{d=1}^n t_{id}} \quad (1)$$

where  $t_i$  is the amount of time the proportional bid-ask spread  $d$  was alive during the day for firm  $i$ . Volatility is measured as:

$$VOLATILITY_{it} = Ln\left(\frac{High_{it}}{Low_{it}}\right) \quad (2)$$

where High is the highest price during each 30-minute interval of the trading day and Low is the lowest price during each 30-minute interval of the trading day. This is an extreme value estimator, and is used because it is more efficient than estimators based on closing prices (see Wiggins, 1992).<sup>12</sup> Volatility is averaged across each day in

order to produce one observation per stock per day. Price is measured using a daily time-weighted trade price. The proxy for trading activity is the daily volume of shares traded.<sup>13</sup>

## 4. RESULTS

### 4.1 Univariate Analysis

Table 1 reports summary statistics for the pre and post sample periods. Cross-sectional means and medians for relative bid-ask spreads, volume, volatility and price for Euronext Paris, the TSE and the KSE are provided in Panels A, B and C, respectively. Separate figures are reported for the pre-event period *Pre*, and the difference between the *Pre* period and two post event periods. *Difference1* is calculated as *Post1* less *Pre* and *Difference2* is calculated as *Post2* less *Pre*. *T*-tests and Wilcoxon Signed Rank tests are reported to test whether the difference in paired means and medians are statistically different from zero.

The summary statistics reveal several important points. First, Panel A of the Table 1 documents a reduction in relative bid-ask spreads from 0.2833 percent in the *Pre* period to 0.2290 percent in *Post1*. These results are comparable to Foucault et al. (2003) who report relative bid-ask spreads fell approximately 5 basis points for CAC-40 stocks. Panel A of Table 1 also reports that bid-ask spreads declined even further in *Post-Period2*, by approximately 6 basis points. A *t*-test and Wilcoxon Sign Rank test for the paired difference between means and medians confirms that these changes are significant at the 0.01 level. This result suggests that liquidity increases significantly following the removal of broker identifiers.

The determinants of bid-ask spreads are also examined in the post-event periods. Volatility fell by at least 20 percent from the *pre* to the *post* trading periods. These

results are comparable to those reported in Foucault et al. (2003). Mean daily volume on the other hand decreased significantly from *Pre* to *Post1*, falling from 1,014,153 to 914,760 shares. No significant concomitant change is observed in the second post-event period. The average share price increased significantly in the first post-event period and decreased in the second post-event period.

Panel B of Table 1 reports descriptive statistics for the TSE. Consistent with Euronext Paris, the removal of broker identifiers resulted in a decrease in mean relative bid-ask spreads, although this change is not significant. The median relative bid-ask spreads however declined significantly over the two post-event periods; falling 0.0028 percent in *Post1*, and 0.0081 in *Post2*. Panel B, of Table 1 also documents that average daily traded volume increased in *Post1* by 517,477. Unlike Euronext Paris, mean and median volatility is significantly greater on the TSE in the two post-event periods, and prices are also higher irrespective of the event window.

The descriptive statistics for the KSE are reported in Panel C of Table 1. The results suggest that reducing anonymity, by providing details of the identity of the five most active brokers in each stock, does not have a clear effect on relative bid-ask spreads. Mean and median relative spreads decrease in *Post1*, but increase in *Post2*. Moreover the reduction in limit order anonymity is associated with a significant increase in the daily volume of trade. This is true for means and medians. Results for volatility closely resemble those for relative bid-ask spreads on the KSE, with average volatility decreasing in *Post1*, and increasing in *Post2*. The only variable which exhibits no significant change is the average price level.

## 4.2 Regression Analysis

In each of the three markets, a significant change is observed in relative bid-ask spreads from the pre to post periods. However, as documented in section 4.1, the results also suggest that there were significant changes in the determinants of bid-ask spreads. McInish and Wood (1992) report that trading volume, stock price and volatility influence bid-ask spreads. Specifically they document that bid-ask spreads are negatively related to volume and positively related to price volatility. Given these well documented relationships, changes in these variables driven by broad market conditions may have contributed to the changes in spreads documented in Table 1.

In order to isolate the impact of the change in anonymity on liquidity we control for changes in the determinants of bid-ask spreads, which are likely to be driven by broad market conditions. The following model is estimated for time-weighted relative bid-ask spreads:

$$Y_{it} = \alpha + \varphi PeriodDummy_{it} + \beta_1 Volatility_{it} + \beta_2 LnVolume_{it} + \beta_3 InvsPrice_{it} + \varepsilon_{it} \quad (3)$$

where  $Y_{it}$  is the time-weighted relative bid-ask spread;  $PeriodDummy_{it}$  is a dummy variable taking on the value of 0 prior to event date and 1 otherwise;  $Volatility_{it}$  is defined as the daily average volatility;  $LnVolume_{it}$  is the logarithm of daily traded volume and  $InvPrice_{it}$  is the inverse of the daily time-weighted trade price of firm  $i$ . The inverse price is included in the regression to identify effects related to the minimum price variations as suggested by Harris (1994). We estimate the model for two separate periods: (1)  $Period1$ , measured over  $Pre$  and  $Post1$ ; and; (2)  $Period2$ , measured over  $Pre$  and  $Post2$ . All  $t$ -statistics in the analysis are adjusted in accordance with the procedure outlined by Newey and West (1987). The Newey-

West estimator provides a way to adjust  $t$ -statistics for autocorrelation and heteroscedasticity.

Table 2 reports the estimates of the regression parameters in equation (3). Panel A of Table 2 presents the results for Euronext Paris. The independent variables explain approximately 60 percent of the variation in relative bid-asks spreads. In general, the coefficients are of the expected signs and are significantly different from zero. Irrespective of the post-event period examined, bid-asks spreads are directly related to volatility, and inversely related to volume. Consistent with Foucault et al. (2003) our first testable hypothesis that the change in pre-trade anonymity should affect the size of the bid-ask spread on Euronext Paris is accepted as evidenced by the significant and negative event dummy coefficients, for all post-event periods. This implies that after controlling for changes in the determinants of bid-ask spreads, there is a significant decrease in relative bid-ask spreads following the removal of broker identifiers on April 23, 2001.

Results for the TSE, reported in Panel B of Table 2, document a positive mean coefficient on volatility (significant at the 0.01 level), and a negative mean coefficient on volume (significant at the 0.01 level). As is the case for Euronext Paris, these results are consistent with the previous literature, and confirm that spreads are positively related to volatility and negatively related to volume. Similarly, we do not reject the hypothesis that the removal of broker identifiers results in a decrease in bid-ask spreads. The event dummy coefficient is significant and negative, irrespective of whether the anonymous event period is measured over 20 days following June 30, 2003, or from 20 to 40 days post the event date.

The results for the KSE reported in Panel C of Table 2, indicate that disclosure of the top five brokers in each stock also has a statistically significant impact on spreads.

After controlling for its determinants, bid-ask spreads on the KSE increase significantly. The increase in spreads is persistent, with the event dummy variable being statistically significant in the two post event periods. This result supports our second hypothesis that a decrease in the level of anonymity in the order book will result in decreased liquidity.

In order to further test the impact of the change in pre-trade transparency on Euronext Paris, the TSE and the KSE, following Boehmer et al. (2005) we examine the effective spreads of orders. This measure of liquidity is estimated by calculating the price impact associated with the immediate execution of orders of different values. The advantage of using the effective spreads of orders as a measure of liquidity is that it accounts for orders that walk up (or down) the limit order book or gain price improvement. This enables one to better gauge the essence of liquidity; the ability of market participants to trade immediately and the associated market impact. The effective spreads of orders are calculated based on the depth in the order book at the end of each 30-minute interval. This cost is estimated for *simulated* market orders of €1000, €10,000, €100,000 and €1,000,000 for Euronext Paris; and for ¥100,000, ¥1,000,000, ¥10,000,000 and ¥100,000,000 for the TSE, as follows:

$$ORDERSPREAD_i = \delta \frac{VWAP_i - Quote\ Midpoint_i}{Quote\ Midpoint_i} \quad (4)$$

where  $\delta$  is equal to 1 (-1) for orders that walk up (down) the ask (bid) side of the order book i.e. buy-orders (sell-orders),  $VWAP_i$  is the volume-weighted bid (ask) price that completes an order for firm  $i$ , and  $Quote\ Midpoint_i$  is average of the best bid and ask at the time of the *simulated* order for firm  $i$ .

Table 3 presents the results of the econometric specification in (3) where the effective spreads of orders are regressed on an intercept and control variables, for buy market orders which execute against the ask quotes, and sell market orders which execute

against the bid quotes, for *Period1* and *Period2*.<sup>14</sup> Panel A of Table 3 presents the results for buy orders for Euronext Paris. Results indicate that the effective spreads of orders for all order values decrease significantly. Similarly for sell orders presented in Panel B of Table 3, the effective spreads of orders decrease significantly for orders of €1000, €10,000, €100,000 and €1,000,000.

The results for purchases executed on the TSE are presented in Panel C of Table 3. For *Period1*, the event dummy is significantly negative for trades of ¥100,000, ¥1,000,000 and ¥100,000,000, but insignificant for orders of ¥10,000,000. Results for *Period2* are comparable, with only orders of ¥10,000,000 and ¥100,000,000 not exhibiting a significant decrease. Comparable results for sell orders are presented in Panel D of Table 3; all event dummy coefficients are negative and statistically significant, except for orders of ¥100,000,000 in *Period1*, and orders of ¥10,000,000 and ¥100,000,000 in *Period2*. Together these results provide further support for our first hypothesis that an increase in anonymity for Euronext Paris and TSE stocks is associated with an increase in liquidity.<sup>15</sup>

## 5. ROBUSTNESS TESTS

In addition to the two measures of liquidity discussed in section 4, we employ different econometric specifications to test the validity of our results. As Boehmer et al. (2005) point out for OLS analysis it is possible that the error terms are correlated across stocks since the event date is common to all stocks. They overcome this problem by estimating a pooled regression which tests for a structural break in the dummy coefficients. Consistent with Boehmer et al. (2005) we estimate equation (3) for relative bid-ask spreads and the effective spreads of orders, however instead of one event-dummy, 20 post-event dummy variables are estimated, such that they take the value of one for the  $n^{th}$  day in the 20-day post event period and zero otherwise.

We estimate the model using *Period1* and *Period2*, and test whether the median dummy variable is significantly different from zero using a Wilcoxon Sign Rank test. We use a non-parametric test, as the event dummy variables may not fit the normality assumption required for a *t*-test. The results provide further support for an increase in liquidity on Euronext Paris and the TSE, as evidenced by a decline in bid-ask spreads and the effective spreads of orders.<sup>16</sup>

Previous research (see Harris, 1994) suggests that market capitalization may also explain bid-ask spreads. To account for this, the natural logarithm of a firm's market capitalization is included in equation (3); the inclusion of this control variable does not alter conclusions drawn in previous sections. All event dummy coefficients are significantly negative for Euronext Paris and the TSE, and significantly positive for the KSE, consistent with expectations.<sup>17</sup> The addition of market capitalization however does increase the overall explanatory power of the current tests as evidenced by a small increase in the adjusted  $R^2$ .

The fact that the results are qualitatively similar using different econometric specifications and measures of liquidity indicates that our results are robust.

## **6. CONCLUSIONS**

This paper examines the impact of changes in the anonymity of limit orders on Euronext Paris, TSE and KSE on April 23, 2001, June 30, 2003 and October 25, 1999, respectively. The results demonstrate that the removal of broker identifiers attached to limit orders on Euronext Paris and TSE had a significant impact on liquidity. The increase in anonymity gave rise to a decrease in relative bid-ask spreads and effective spreads of orders. These results suggest that the introduction of anonymous limit orders improves market quality. Correspondingly, the reduction in anonymity on the

KSE is associated with a decline in liquidity. An important implication of these findings is that information pertaining to broker identification provides information to market participants about the nature of the order flow displayed in the order book.

An interesting extension of the paper would be to test if results differ across stocks and to test whether other attributes of market quality other than bid-ask spreads (see Pagano and Schwartz, 2003) experienced any adjustment following a change in the anonymity of limit orders.

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**Table 1. Summary Statistics**

Table 1 reports cross-sectional means and medians for relative bid-ask spreads, volume, volatility and price. Figures are reported for 20 trading days prior to the event date (*Pre*) and its difference from two post event periods; *Difference1* (*Post1* less *Pre*, measured 20 trading days following the event date) and *Difference2* (*Post2* less *Pre*, 20 to 40 trading days following the event date). *T*-tests and Wilcoxon Sign Rank tests examine whether the difference in the paired means and medians are equal zero. Panel A provides the results for Euronext 100 stocks traded on Euronext Paris, around April 23, 2001. Panel B reports results TOPIX 100 stocks traded on the TSE, around June 30, 2003. Panel C reports the results for top 250 stocks based on market capitalization on the KSE, around October 25, 1999.

<i>Panel A: Euronext Paris</i>						
	Event Period	Mean	Std. Dev.	Median	t-statistic	Wilcoxon
Relative Spread	Pre	0.2833	0.1514	0.2328		
	Difference	-0.0544	0.0527	-0.0402	-7.87***	-852***
	Difference 2	-0.0637	0.0604	-0.0454	-8.03***	-855***
Volume	Pre	1,014,153	1,593,123	496,221		
	Difference	-99,393	396,263	-10,081	-1.91*	-203*
	Difference 2	28,110	615,320	-1,837	0.35	37.5
Volatility	Pre	0.0086	0.0022	0.0084		
	Difference	-0.0019	0.0010	-0.0012	-14.79***	-854***
	Difference 2	-0.0023	0.0010	0.0022	-16.95***	-855***
Price	Pre	78.3232	63.2175	57.8914		
	Difference 1	3.7333	7.2751	3.0016	3.91***	692***
	Difference 2	-0.3670	22.6041	3.1534	-0.12	445***
<i>Panel B: Tokyo Stock Exchange</i>						
	Event Period	Mean	Std. Dev.	Median	t-statistic	Wilcoxon
Relative Spread	Pre	0.2135	0.1042	0.2026		
	Difference	-0.0007	0.0798	-0.0028	-0.09	-703***
	Difference 2	-0.0057	0.0896	-0.0081	-0.63	-1,115***
Volume	Pre	3,451,131	5,528,632	1,67,710		
	Difference	517,477	2,499,825	25,886	2.04**	894***
	Difference 2	-85,579	2,279,520	-18,340	-0.37	-682***
Volatility	Pre	0.0068	0.0019	0.0067		
	Difference	0.0012	0.0012	0.0010	10.05***	2,184***
	Difference 2	0.0002	0.0010	0.0002	1.90**	457*
Price	Pre	63,051	171,194	1,928		
	Difference 1	7,097	24,184	119	2.89***	2,009***
	Difference 2	9,189	36,232	98	2.50***	1,640***
<i>Panel C: Korea Stock Exchange</i>						
	Event Period	Mean	Std. Dev.	Median	t-statistic	Wilcoxon
Relative Spread	Pre	0.5777	0.3938	0.4630		
	Difference	-0.0569	0.1326	-0.280	-6.01***	-5,318***
	Difference 2	0.0220	0.1899	0.0220	1.65*	2,210***
Volume	Pre	602,245	1,294,025	330,332		
	Difference	285,046	591,348	69,616	6.82***	7,434**
	Difference 2	100,610	652,615	28,546	2.18**	2,528***
Volatility	Pre	0.0151	0.0042	0.0156		
	Difference	-0.0003	0.0020	-0.0003	-1.76*	-1569***
	Difference 2	0.0024	0.0029	0.0020	11.85***	7,651***
Price	Pre	28,206	88,473	12,680		
	Difference 1	3,289	27,542	229	1.68	3,618***
	Difference 2	8,531	93,756	-463	1.29	-1,122***

\* Significant at the 0.10 level

\*\* Significant at the 0.05 level

\*\*\* Significant at the 0.01 level

**Table 2. Analysis of Relative Bid-Ask Spreads**

Table 2 provides descriptive statistics for parameter estimates of the following equation:  $Y_{it} = \alpha + \phi \text{PeriodDummy}_{it} + \beta_1 \text{Volatility}_{it} + \beta_2 \text{LnVolume}_{it} + \beta_3 \text{InvPrice}_{it} + \varepsilon_{it}$  where  $Y_{it}$  is the time-weighted daily relative bid-ask spread;  $\text{PeriodDummy}_{it}$  is a dummy variable taking on the value of 0 prior to event date and 1 otherwise;  $\text{Volatility}_{it}$  is defined as daily average of  $\text{Ln}(\text{High}/\text{Low})$ , where High (Low) is the highest (lowest) price during each 30-minute interval of the trading day;  $\text{LnVolume}_{it}$  is the natural logarithm of daily traded volume and  $\text{InvPrice}_{it}$  is the inverse of the daily time-weighted trade price of firm  $i$ . The model is estimated for two separate periods: (1) *Period1*, measured over *Pre* (20 trading days prior to the respective event date) and *Post1* (20 trading days following the respective event date) and; (2) *Period2*, measured over the *Pre* and *Post* (20 to 40 trading days following the respective event date). Panel A provides the results for Euronext 100 stocks traded on Euronext Paris, around April 23, 2001. Panel B reports results TOPIX 100 stocks traded on the TSE, around June 30, 2003. Panel C reports the results for top 250 stocks based on market capitalization on the KSE, around October 25, 1999. All  $t$  statistics in the analysis are adjusted in accordance with a procedure outlined by Newey and West (1987).

<i>Panel A: Euronext Paris</i>						
	Constant	Period Dummy	Volatility	Volume	Price	Adj- R <sup>2</sup>
<i>Period1 Coefficients</i>	1.0903	-0.0241	19.2664	-0.0782	1.4427	60.46
<i>t-statistic</i>	26.92***	-3.68***	10.57***	-21.72***	7.84***	
<i>Period2 Coefficients</i>	1.0543	-0.0210	19.6263	-0.0757	1.4751	59.70
<i>t-statistic</i>	26.86***	-2.75***	9.79***	-21.19***	7.61***	
<i>Panel B: Tokyo Stock Exchange</i>						
	Constant	Period Dummy	Volatility	Volume	Price	Adj- R <sup>2</sup>
<i>Period1 Coefficients</i>	0.3660	-0.0118	15.7165	-0.0231	57.5656	37.93
<i>t-statistic</i>	20.19***	-2.98***	15.02***	-14.47***	20.22***	
<i>Period2 Coefficients</i>	0.3397	-0.0054	18.1126	-0.0222	54.9203	38.92
<i>t-statistic</i>	27.46***	-2.06**	9.72***	-20.36***	26.80***	
<i>Panel C: Korea Stock Exchange</i>						
	Constant	Period Dummy	Volatility	Volume	Price	Adj- R <sup>2</sup>
<i>Period1 Coefficients</i>	2.6212	0.0150	10.6337	-0.1868	638.1877	57.43
<i>t-statistic</i>	59.88***	2.60***	16.16***	-57.03***	19.40***	
<i>Period2 Coefficients</i>	2.8668	0.0536	10.5441	-0.0207	828.6835	57.87
<i>t-statistic</i>	46.05***	2.58***	12.10***	-46.00***	15.66***	

\* Significant at the 0.10 level

\*\* Significant at the 0.05 level

\*\*\* Significant at the 0.01 level

**Table 3. Analysis of Effective Spreads of Orders**

Table 3 provides descriptive statistics for parameter estimates of the following equation:  $Y_{it} = \alpha + \phi PeriodDummy_{it} + \beta_1 Volatility_{it} + \beta_2 LnVolume_{it} + \beta_3 InvPrice_{it} + \varepsilon_{it}$  where  $Y_{it}$  is the effective spreads of orders;  $PeriodDummy_{it}$  is a dummy variable taking on the value of 0 prior to event date and 1 otherwise;  $Volatility_{it}$  is defined as daily average of  $\ln(High/Low)$ , where High (Low) is the highest (lowest) price during each 30-minute interval of the trading day;  $LnVolume_{it}$  is the natural logarithm of daily traded volume and  $InvPrice_{it}$  is the inverse of the daily time-weighted trade price of firm  $i$ . The model is estimated for two separate periods: (1) *Period1*, measured over *Pre* (20 trading days prior to the respective event date) and *Post1* (20 trading days following the respective event date) and; (2) *Period2*, measured over the *Pre* and *Post* (20 to 40 trading days following the respective event date). Panel A (B) provides the results for buy (sell) orders of €1,000, €10,000, €100,000 and €1,000,000 on Euronext Paris. Panel C (D) provides the results for buy (sell) orders of ¥100,000, ¥1,000,000, ¥10,000,000 and ¥100,000,000 on the TSE. All  $t$  statistics in the analysis are adjusted in accordance with a procedure outlined by Newey and West (1987).

<i>Panel A: Euronext Paris Buy Order</i>						
Effective Spreads of Orders	<i>Period1</i> Dummy	<i>t</i> -statistic	Adj- $R^2$	<i>Period2</i> Dummy	<i>t</i> -statistic	Adj- $R^2$
€1,000	-0.013	-5.79***	57.51	-0.012	-5.45***	56.47
€10,000	-0.012	-3.73***	57.30	-0.011	-3.60***	56.39
€100,000	-0.040	-8.40***	51.09	-0.038	-7.66***	48.36
€1,000,000	-0.069	-6.57***	11.60	-0.072	-7.05***	7.26
<i>Panel B: Euronext Paris Sell Order</i>						
Effective Spreads of Orders	<i>Period1</i> Dummy	<i>t</i> -statistic	Adj- $R^2$	<i>Period2</i> Dummy	<i>t</i> -statistic	Adj- $R^2$
€1,000	-0.012	-5.62***	56.85	-0.012	-5.33***	55.95
€10,000	-0.013	-4.18***	55.79	-0.013	-4.13***	55.05
€100,000	-0.036	-8.29***	55.36	-0.037	-8.54***	52.07
€1,000,000	-0.065	-6.78***	10.12	-0.059	-8.65***	9.76
<i>Panel C: Tokyo Stock Exchange Buy Order</i>						
Effective Spreads of Orders	<i>Period1</i> Dummy	<i>t</i> -statistic	Adj- $R^2$	<i>Period2</i> Dummy	<i>t</i> -statistic	Adj- $R^2$
¥100,000	-0.003	-2.72***	40.06	-0.002	-2.05**	38.88
¥1,000,000	-0.009	-6.35***	39.04	-0.005	-4.30***	39.60
¥10,000,000	-0.001	-0.86	40.71	0.000	0.55	41.81
¥100,000,000	-0.009	-2.81***	32.42	-0.003	-1.17	33.53
<i>Panel D: Tokyo Stock Exchange Sell Order</i>						
Effective Spreads of Orders	<i>Period1</i> Dummy	<i>t</i> -statistic	Adj- $R^2$	<i>Period2</i> Dummy	<i>t</i> -statistic	Adj- $R^2$
¥100,000	-0.003	-2.71***	40.06	-0.002	-2.06***	38.88
¥1,000,000	-0.008	-6.12***	39.54	-0.006	-4.72***	39.48
¥10,000,000	-0.002	-1.19	41.56	0.000	0.21	42.27
¥100,000,000	-0.008	-2.24***	29.27	-0.004	-1.27	33.48

\* Significant at the 0.10 level

\*\* Significant at the 0.05 level

\*\*\* Significant at the 0.01 level

## **APPENDIX: INSTITUTIONAL DETAIL**

### **A.1 Euronext Paris**

Euronext Paris is best described as a hybrid market. The market is segmented into a number of different groups of stocks based on size and liquidity. The mechanism used for trading varies depending on the segment. Stocks included in the Euronext 100 index, the Next 150 index, the CAC 40 index or stocks which have more than 2,500 order book transactions per year, are traded continuously. Stocks outside these groups are traded using a call auction twice each day. Unlike stocks in the Euronext 100 index, those outside the index may choose to engage a Liquidity Provider to make a market (see the Euronext Cash Markets Trading Manual, 2003 for further details about the role and responsibilities of Liquidity Providers).

The analysis in this paper focuses on stocks which are continuously traded. Continuous trading takes place on an automated trading system known as NCS between 9:00 and 17:25. Note that the use of NCS began on 23 April 2001. Prior to this time another automated trading system was used. Other than the change in the display of broker identifiers described below, the switch to NCS did not change the market structure.

The opening and closing prices are determined by a call auction. Limit orders are queued for execution against incoming market orders using price then time priority rules. The minimum tick varies with the price of the stock.

### **A.2 Tokyo Stock Exchange**

The Tokyo Stock Exchange (TSE) operates a fully automated order driven trading system known as the Computer-assisted Order Routing and Execution System (CORES). Trading takes place in two trading sessions from 9:00 to 11:00 and 12:30 to 15:00 (see Lehmann and Modest (1994) and Hamao and Hasbrouck (1995) for a

detailed description of the trading process on the TSE). Each trading session opens with a call auction (*itayose*) followed by continuous trading (*zaraba*) until the end of the trading session. In principle, each session closes with another call auction. However, in practice this seldom occurs.

During the *itayose* period the order book is closed and only an indicative auction price and indicative equilibrium volume are disclosed to the market. Market-on-open and market-on-close orders may also be used. There is no time priority for orders entered during the *itayose* period. All orders are treated as being entered simultaneously.

During *zaraba* trading, both limit and market orders are permitted. The minimum tick on the TSE varies with the price of the stock. The TSE imposes a number of price variation limits based on the stock's previous closing price. There are also limits on the trade-to-trade price changes. Market and limit orders are not allowed in violation of these limits. To ensure that these price change limits are not violated "special quotes" are disseminated in order to solicit additional orders from the market to offset order imbalances.

### **A.3 Korea Stock Exchange**

The Korea Stock Exchange (KSE) operates a fully automated order driven trading system known as the Korea Automated Trading System (KATS). Trading takes place between 9:00 and 15:00. After-hours trading is also permitted between 15:10 and 16:00, however, trades must be executed at the closing price set during the main trading session. The opening and closing price are set using a call auction. Prior to the opening call auction only the best bid and ask prices and an indicative auction price and equilibrium volume are displayed. Traders may enter market and limit orders with limit orders queued for execution against incoming market orders according to price then time precedence rules. Note there is an exception to this rule

at the opening call if the indicative auction price exceeds the price variation limit of  $\pm 15\%$  from the previous day's closing price. In these circumstances time is replaced by order size (i.e. large orders are given priority).

## Footnotes

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<sup>1</sup> Examples of work examining the impact of anonymity on spreads include Theissen (2003) and Waisburd (2003). Theissen (2003) provides evidence which suggests that specialists are able to infer the motivations of traders in non-anonymous markets. Waisburd (2003) provides evidence which suggests that post-trade anonymity results in wider bid-ask spreads. While the first paper is concerned with pre-trade anonymity of incoming market orders (not limit orders), the second is concerned with post trade anonymity of both limit and market order traders.

<sup>2</sup> An example of such a cost is that the uninformed quote setters may learn that there is little price risk impending (if they observe the informed trader quoting tight spreads) and consequently may improve on the quoted price of the informed trader causing their order to wait longer in the limit order queue and face price risk for a longer time period.

<sup>3</sup> At the time of the study, Euronext Paris divided continuously traded stocks into two categories “*Continu A*” and “*Continu B*” stocks. Foucault et al. (2003) notes a change in the level of post-trade anonymity which occurred in the “*Continu B*” stocks on 23 April 2001. However, our sample does not include any “*Continu B*” stocks. Therefore, the only change in market structure experienced by the sample stocks examined here is the change in pre-trade anonymity.

<sup>4</sup> The Euronext 100 comprises the largest and most actively traded stocks, and represents approximately 80 percent of the total market capitalization of Euronext.

<sup>5</sup> This measure is used in Boehmer et al. (2005) to examine the impact of an increase in pre-trade transparency on the NYSE.

<sup>6</sup> On the same date, the TSE increased the level of pre-trade transparency to include the price and volume of orders at the best five price steps, previously only the first three steps were displayed. This may cause the TSE to be a “weaker experiment” due to extraneous factors, however our results are consistent with the other markets analyzed. Further, Madhavan et al (2005) construct a theoretical model to address the question of how revealing the content of the limit order book to all traders in a market affects elements of market quality. Their results indicate that an increase in limit order book exposure gives rise to an increase in bid-ask spreads. Therefore, the simultaneous change in market structure on the TSE is likely to bias against a finding of improved liquidity following an increase in anonymity.

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<sup>7</sup> Revealing the presence of the top five brokers and not necessarily their association with particular limit orders is different to identifying the identity of brokers attached to each order in the order book. Nonetheless the “bluffing” explanation is still relevant in this market, as these brokers whose identities are disclosed are the most active in the market, and will set a wider spread in order to avoid being undercut by other traders.

<sup>8</sup> Refer to the appendix for further institutional detail about the trading arrangements in place on Euronext Paris, the TSE and the KSE.

<sup>9</sup> These results contrast with Boehmer et al. (2005) who reports that increased pre-trade transparency following the introduction of OpenBook on the NYSE resulted in a decrease in the effective spread of trades. The difference in these results is explained by the fact that Boehmer et al. (2005) considers a change in order exposure while this paper examines a change in the exposure of trader identity. This suggests that not all aspects of pre-trade transparency have the same impact on spreads.

<sup>10</sup> In addition to Euronext 100 stocks, stocks in the CAC 40 and Euronext Next 150 index are also examined. Note Next 150 stocks may have a Liquidity Provider making a market in the stock. The results for these stocks are generally consistent and therefore are not reported.

<sup>11</sup> Papers such as McNish and Wood (1992) which seek to describe factors which influence spreads typically use OLS regression. This approach may produce biased parameter estimates because the bid ask spread is bounded by the minimum tick. These models may be more appropriately modeled using censored regression techniques (see Maddala (1992)). However, this paper examines relative rather than absolute spreads. Relative spreads are not censored by the minimum tick size and therefore parameter estimates are less likely to be influenced by this issue. However, relative spreads are bounded between 0 and 1, which may also create a bias in the parameter estimates.

<sup>12</sup> Volatility is also measured as the standard deviation of 30-minute mid-quote returns. The results are generally consistent with those reported in this paper and are therefore not presented.

<sup>13</sup> Trading activity is also measured using the value of shares traded, number of transactions and average trade size.

<sup>14</sup> Only the event dummy is reported in order to conserve space, coefficient estimates for all the control variables and model intercept are significant and of the expected sign, for Euronext Paris and the TSE.

<sup>15</sup> It is not possible to examine the effective spreads of orders for Korean stocks, due to data limitations. In light of this effective bid-ask spreads are examined. Results show that effective bid-ask spreads increase significantly for Korean stocks, consistent with hypothesis two.

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<sup>16</sup> Details of these results are available from the authors on request.

<sup>17</sup> Details of these results are available from the authors on request.