

The Effects of Trading Methods on Volatility and Liquidity: Evidence from the Taiwan Stock Exchange

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1. INTRODUCTION

Should stocks be traded in a call market or in a continuous auction market? This question represents an important issue of market design. Under the call market method, orders are batched for execution at a single price to maximize the number of shares traded. In contrast, under the continuous auction method, orders are executed whenever submitted bids and offers cross during a trading session.¹ Presently, organized stock exchanges around the world use different trading methods and there exists a wide range of variation within each type of trading method. As shown in Figure 1, the New York Stock Exchange (NYSE) and the Tokyo Stock Exchange rely on the call market method to determine opening prices and the continuous auction

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method during the remainder of the trading session. In Hong Kong, Jakarta, and Singapore, the continuous auction method is used throughout the entire trading day. In contrast, stock exchanges in Malaysia and Taiwan utilize the call market method as the sole price and order matching method. As trading becomes completely automated with no manual intervention, the call market method is gaining more support (Cohen and Schwartz, 1989; and Amihud and Mendelson, 1989).

Only a limited number of theoretical studies have examined the effects of the call market method on market volatility and liquidity. Garbade and Silber (1979) demonstrate that as a market becomes larger or as securities prices become more volatile, frequent market clearings are preferred. Mendelson (1982) shows that market thinness is an important determinant of the optimal time-interval that must persist between clearings to mitigate price volatility in the call market. Ho, Schwartz, and Whitcomb (1985) demonstrate that the call market method can cause investors to place orders that are too large to be Pareto efficient. Karpoff (1986) demonstrates that the call market improves allocation efficiency, as evidenced by the relatively stable trading volume behavior when compared to the continuous auction market. Using Mendelson's (1982) call

Figure 1

Trading Methods

	<i>Morning Session</i>	<i>Afternoon Session</i>
Indonesia	←C.A.→	←C.A.→
Hong Kong	←C.A.→	←C.A.→
Korea	C.M.←C.A.→	C.M.←C.A.→C.M.
Malaysia	←C.M.→	←C.M.→
Singapore	←C.A.→	←C.A.→
Taiwan	←C.M.→	
Thailand	C.M.←C.A.→	C.M.←C.A.→
Tokyo	C.M.←C.A.→	C.M.←C.A.→
NYSE	C.M. ←—————→	C.A. —————→

Notes:

C.M. = Call Market Method

C.A. = Continuous Auction Method.

market model and their continuous auction model, Domowitz and Wang (1994) conduct simulations to demonstrate that: price volatility is greater, the bid-ask spread is smaller, and trading volume is greater in a continuous auction than in a call market. Schnitzlein (1996) reports that the adverse selection costs incurred by noise traders are significantly lower under the call market method than the continuous auction method, but he observes no significant reduction in price efficiency. Pagano and Roell (1996) find that the greater transparency (in the sense of visibility of the order flow) enhances liquidity more in the call market than the continuous auction market.

Unfortunately, the findings of Schnitzlein (1996) and Pagano and Roell (1996) cannot be directly applicable to this study's empirical analysis of the Taiwan stock market for two reasons: first, the presence of market makers is assumed in their model while they do not exist in Taiwan; and second, their findings are based on the behaviour of market makers under asymmetric information. As discussed later, the issue of asymmetric information in Taiwan may not be as relevant as in other advanced equity markets. Lang and Lee (1999) report empirical evidence which has strong relevance to this study. Using Taiwan equity market data, they report that greater trading frequency in the call market environment induces higher volatility. As trading frequency increases the call market method converges to the continuous auction method. Hence, Lang and Lee's findings imply that the continuous auction method carries greater volatility than the call market method.

Price stability represents the most important advantage of the call market method over the continuous auction method. The call market method experiences superior price stabilization because batching orders over time eliminates price fluctuations caused by transactions bouncing between bid and ask quotes and reduces price volatility induced by a random order arrival sequence. In addition, as trading orders accumulate over a fixed time-interval, the impact of a single large order becomes less severe (Cohen and Schwartz, 1989). The call market also represents an effective mechanism for dealing with asymmetric information problems between informed and uninformed liquidity traders (Stoll, 1985). The call market method, by imposing delays, forces information traders to reveal, through order placements, the existence of

information, which in turn helps to reduce price volatility. However, this reduction in volatility is achieved at the expense of price discontinuity and the imposition of information costs (Madhavan, 1992). Loss of trading continuity and high information costs are reflected by market illiquidity. In contrast, the most frequently cited advantage for the continuous auction method is the supply of immediacy to buyers and sellers. Since it can provide immediate order execution, a higher degree of market liquidity is expected with the continuous auction markets. This study's empirical comparison of the two trading methods, therefore, focuses on the trade-off between volatility and liquidity.

The scope of past empirical work has been limited to an *indirect* comparison of the two trading systems using daily open-to-open returns (subject to the call market method) and close-to-close returns (subject to the continuous auction method), Amihud and Mendelson (1987, 1991a and 1991b), Amihud, Mendelson and Murgia (1990), Stoll and Whaley (1990), Gerety and Mulherin (1994), and George and Hwang (1995). Using the component stocks of the Dow Jones Industrial Average (DJIA), Amihud and Mendelson (1987) report that open-to-open return variance is significantly greater than close-to-close return variance. They attribute this finding to the fact that the NYSE opens with the call market and then switches to the continuous auction method for the remainder of the trading day.

Empirical evidence from foreign securities markets, however, indicates that greater variance at the market open than close cannot be associated with different trading methods. Cheung, Ho, Pope and Draper (1994), for example, observe a greater variance at the market open for the Hong Kong market even though *only* the continuous auction method is employed. Chang, Rhee, and Soedigno (1995) report similar results for the Jakarta Stock Exchange, which also uses the continuous auction method throughout the entire trading session including the market open. Amihud and Mendelson (1991) note that afternoon open-to-afternoon open returns (which are also subject to the call market method) do not exhibit greater volatility than close-to-close returns in the Tokyo market. They suggest, therefore, that the greater volatility at the morning open is induced by the preceding overnight nontrading period.

After comparing interday variances that are computed at every hour of the trading session, Gerety and Mulherin (1994) conclude that the call market method, which is used to open trading on the NYSE, is not inherently destabilizing. Based on their investigation of Milan Stock Exchange-listed securities, Amihud, Mendelson and Murgia (1990) conclude that the call market method provides a more effective price discovery mechanism at the opening of the trading day than the continuous auction method. They find that when the first transaction of a trading day is conducted using the call market method, its return volatility is not consistently greater than that of the subsequent continuous auction-based transactions. However, when the first transaction relies on the continuous auction method, its volatility is higher than that of the subsequent transaction under the call market method.² Based on internationally crosslisted stocks, Forster and George (1992) report that the magnitude of trading volume at the market open is responsible for higher volatility at the open. George and Hwang (1995) observe greater volatility at the open only for the most actively traded stocks. They attribute this phenomenon to the maximum price variation rules designed to slow trade flows on the Tokyo Stock Exchange.

Previous empirical efforts were hampered by the fact that different securities are traded in different markets with different regulatory environments and trading rules (Amihud and Mendelson, 1991). This paper uses a unique data set from the Taiwan Stock Exchange (TSE) which enables us to empirically contrast market volatility and liquidity under the two trading methods.

A number of important results emerge from our analysis. We find significant differences in volatility between the two trading methods. Volatility under the call market method is, on average, one-half of that under the continuous auction method. Surprisingly, under the call market method, heavily traded stocks experience a statistically more significant reduction in volatility than less heavily traded stocks. This contradicts conventional wisdom which suggests that thinly traded stocks are less volatile under the call market method, while heavily traded stocks are more volatile under the continuous auction method (Cohen, Maier, Schwartz and Whitcomb, 1986; Huang and Stoll, 1991;

and Madhavan, 1992). When comparing the price impacts of large order imbalances, we find no appreciable difference between the two trading methods. Furthermore, we find that price discovery appears more efficient in the call market than in the continuous auction market for TSE-listed stocks.

The remainder of this paper is organized as follows: Section 2 presents TSE's institutional background, with special focus on two trading methods and discusses the data; empirical results are contained in Section 3; and the final section concludes the paper.

2. TAIWAN STOCK EXCHANGE: INSTITUTIONAL BACKGROUND AND DATA

(i) Institutional Background: Call Market vs. Continuous Auction Market

The TSE is the world's busiest stock exchange with an annual turnover ratio amounting to 323% in 1994. Its market capitalization reached US\$247 billion at the end of 1994, which was the 10th largest in the world. The listed number of securities amounted to 354. Of the 354 issues, 240 were classified as category A stocks and the remaining 114 were classified as category B stocks.³ The market capitalization of category A stocks amounted to US\$222 billion, while category B stocks were worth US\$25 billion. At the end of 1994, 246 brokerage firms were in operation. Each broker has multiple sets of order entry terminals directly linked to the TSE computer center.

Like all other organized stock exchanges in Asia, the TSE market is completely order-driven with no market makers.⁴ The TSE has been relying on the call market method since the introduction of its computer-assisted trading system (CATS) in 1985. The CATS, modeled after the Toronto and Tokyo trading systems, was implemented in phases. Initially, only category B stocks were traded on the CATS. Then in January 1987, category A stocks were also placed on the CATS.

On August 2, 1993, the TSE switched from the semi-automated CATS to a fully-automated securities trading system (FASTS).^{5,6} The TSE's call market accepts only limit orders. Market orders are not acceptable. Since 'good-until-canceled' orders are not

permitted, all limit orders expire at the end of each trading day and, hence, no orders are carried over to the next day. One round lot of 1,000 shares represents a trading unit and any trading order exceeding 500 lots is subject to block trading rules.⁷ The TSE begins its trading at 9:00 a.m. and ends at 12:00 noon on weekdays while Saturday trading lasts two hours, 9:00 – 11:00 a.m. Prior to the market open, brokers can enter orders which are batched over a 30-minute period. Before any order is entered into the limit order book, it is first checked to verify that its bid or ask price is within the allowable daily price limit (currently 7% of the closing price on the previous trading day). Orders at the same price are sequenced at random by the computer rather than applying the time-priority rule. However, post-opening trades are subject to usual price and time priority principles. The FASTS matching algorithm chooses the opening price at which the maximum number of shares will be traded. If more than one price generates maximum trading volume, the price nearest to the last traded price is chosen as the matched price.

Unexecuted or partially executed orders at the market open are left on the order book for subsequent call market trading. After the opening prices are determined, subsequent orders are batched over various time intervals ranging from one minute to 90 seconds depending on a security's trading activity. Throughout the trading session, the volume-maximizing algorithm of the call market method is applied to each security's limit order book. Given cumulative buy order quantity from the upper limit price and the cumulative sell order from the lower limit price, this identifies a trade price which maximizes the number of shares to be traded. All matched prices (with the exception of opening prices) are subject to a two-tick limitation.⁸

The most important feature which distinguishes the continuous auction method, from the call market method described above, is that there is no batching period after the market opens, but rather trades occur whenever: (i) newly arrived buy order prices are greater or equal to sell order prices in the queue; or (ii) newly arrived sell order prices are less than buy order prices in the queue. The order matching must satisfy the set of rules governing the price and time priorities of submitted bids and offers. Under the price priority rule, preference is given

to the highest buy orders and the lowest sell orders, while the time priority rule dictates that preference is given to the earliest buy or sell orders when they are quoted at the same price.⁹ An order may be canceled at any time, but at the expense of time priority. If new orders are not tradable because no matches are possible, they are added to the outstanding order queue, waiting for the arrival of matchable orders. Naturally, the trading intensity is greater for the continuous auction method. Thanks to extremely high turnover, the continuous auction method would enjoy trading almost on a continuous basis on the TSE market, whereas trading delays are forced upon the call market method over the batching period, however short it is. This difference provides a valuable empirical setting to contrast the continuous auction method and the call market method in terms of their impact on volatility and liquidity. In the Appendix, numerical illustrations of the call market and the continuous auction method are presented.

Order-placing strategies should vary depending on the trading system in a market with a large number of sophisticated players. An important question is whether or not the use of the call market order flow for the simulation would cause any material distortion in price volatility and liquidity in the continuous auction trading method. Two idiosyncratic features of the TSE market should serve as critically important mitigating factors. First, the time-interval between one trade to another under the call market method is extremely short in the Taiwan market. The average length of time-interval ranges only from 60 to 90 seconds as discussed in the next section. Additionally, our sample contains the mostly heavily traded 30 component stocks of the TSE Composite Stock Price Average (CSPA). Thus, the call market trading on the TSE is virtually continuous, making the order-placing strategies less critical.¹⁰ Second, the individual investor-driven trading pattern in the Taiwan market also minimizes potential biases. In the Taiwan market, over 95% of the trading volume is generated by individual investors. Thus, the role of more sophisticated institutional investors is insignificant. For example, block trading on the TSE accounted for less than 1% of the total trading volume, compared with 54% reported for the NYSE. It is well-known in Taiwan that individuals' trading decisions are triggered by rumors and street talk. This is reflected

by the fact that most brokers frequently place buy orders at day-ceiling price and sell orders at dayfloor price to ensure trading priority for their customers.¹¹ Thus, the trading method utilized by the TSE will have a minimal effect on the order-placing strategies in the TSE market. What really matters for Taiwan individual investors is their drive to trade.

(ii) *The Data*

The study period is from January 5, 1994 to April 30, 1994. This period contains 90 trading days. To maintain an identical number of trading hours across all trading days, we exclude the 15 Saturday trading days from the study period. To avoid post-holiday bias, the five trading days immediately following holidays are also excluded. Finally, we exclude three additional trading days due to missing data. As a result, a total of 67 trading days with complete price and volume data is secured.

Two sets of transaction data from the TSE are used for this study. The first set contains actual transaction data based on the call market method and the second set contains simulated transaction data based on the continuous auction method. The two data sets from the TSE provide a unique opportunity to directly contrast stock price behavior under the call market and the continuous auction methods. The 30 CSPA component stocks are Taiwan 'blue-chips.' During the study period, their combined market value amounted to approximately 27% of the total market capitalization and about one-quarter of total trading volume of the TSE.

Table 1 presents summary statistics of the 30 stocks in our sample. Cross-sectional averages of market capitalization, price per share, and trading-related data are summarized for the whole sample as well as for two 15-stock subgroups sorted by trading volume. Standard deviations are reported in parentheses. A stock's market capitalization is computed by multiplying the stock's closing price by its number of shares outstanding at the beginning of the study period. Average market capitalization of the 30 stocks is NT\$46.48 billion. For the low- and high-volume subgroups, market capitalization is NT\$25.25 billion and NT\$67.82 billion, respectively. The average price per share for the whole sample is NT\$47.92. Between the two subgroups, a

Table 1
Descriptive Statistics

	Whole Sample	Subgroup Sorted by Trading Volume	
		Low-Volume	High-Volume
A. Market Capitalization (NT\$ billion)	46.48 (50.58)	25.25 (19.68)	67.82 (62.74)
B. Price per Share (NT\$)	47.92 (29.69)	43.40 (13.60)	52.44 (39.95)
C. Trading Volume			
<i>a. Average Daily Volume (Lots)</i>			
Call Market Method	8,002.02 (9,174.46)	2,340.07 (1,207.83)	13,663.97 (10,207.82)
Continuous Auction Method	9,741.64 (11,241.64)	2,765.88 (1,439.90)	16,717.40 (12,467.09)
<i>b. Average Number of Trades during 10-Minute Interval</i>			
Call Market Method	11.65 (4.90)	7.70 (2.27)	15.60 (3.32)
Continuous Auction Method	54.30 (44.38)	21.24 (9.92)	87.35 (40.48)

Notes:

Table 1 presents summary statistics of the 30 stocks in the sample during the study period, January 5 – April 30, 1994. Cross-sectional averages of market capitalization, price per share, and trading activity-related data are summarized for the whole sample as well as two 15-stock subgroups sorted by trading volume. Standard deviations are shown in parentheses. Market capitalization is computed by multiplying the closing price by the

relatively small difference is found in the average prices. The low-volume stock group has an average price of NT\$43.40, while the high-volume stock group has a slightly higher average price of NT\$52.44.

To highlight the differential impact of the call and continuous auction methods on trading activity, we report average daily trading volume and average number of trades in a 10-minute interval for both trading methods in Panel C. For the whole sample, trading volume under the continuous auction method is approximately 22% greater than under the call market method (9,742 vs. 8,002 lots). The average number of trades in a 10-minute interval is 11.65 and 54.30 for the call market method and the continuous auction method, respectively. This demonstrates that the continuous matching of one buy-order against a sell-order can

have a positive impact on trading volume. The increased trading volume under the continuous auction method is also observed individually for both low- and high-volume stocks.¹²

Descriptive statistics on the timing of opening and closing transactions are summarized in Table 2. Under the current call market method, it takes, on average, 51 seconds for the 30 stocks to arrive at their opening prices.¹³ Very little time difference is noted between the low- and high-volume stock groups (48 seconds vs. 55 seconds). The time lapse between 9:00 a.m. and the opening trade ranges from a minimum of 1 second to a maximum of 123 seconds. The reported time lapse between the market open and the opening trade is remarkably short. According to Stoll and Whaley (1990), it takes 15.48 minutes for NYSE stocks to open, while Chang, Fukuda, Rhee, and Takano (1993) report an average of 5 minutes for Tokyo stocks.

Under the call market method, the average number of seconds from 12:00 noon to the last trade is 22 seconds for the whole sample. For low- and high-volume subgroups, the average elapsed

Table 2
Timing of Opening and Closing Transactions

	<i>Call Market</i>	<i>Continuous Auction Market</i>
A. Average Number of Seconds from 9:00 a.m. to Opening Trade		
Whole Sample	51.18 seconds	-
Low-Volume Subgroup	47.51 seconds	-
High-Volume Subgroup	54.84 seconds	-
Minimum	1.11 seconds	-
Maximum	123.11 seconds	-
B. Average Number of Seconds from 12:00 Noon to Closing Trade		
Whole Sample	21.78 seconds	-11.72 seconds
Low-Volume Subgroup	19.20 seconds	-18.46 seconds
High-Volume Subgroup	24.35 seconds	-4.98 seconds
Minimum	-11.37 seconds	-34.33 seconds
Maximum	42.79 seconds	-1.70 seconds

Notes:

Table 2 summarizes descriptive statistics on the timing of opening and closing transactions for the 30 stocks in the sample during the study period, January 5–April 30, 1994. The average time lapse between 9:00 a.m. and the opening trade is not reported for the continuous auction method because the simulated data used the call market method to determine opening prices.

time is 19 seconds and 24 seconds, respectively. In contrast, in the continuous auction market, closing transactions take place prior to 12:00 noon. On average, the last trade occurs 12 seconds before the official close of the exchange for the whole sample. The average time lapse is shorter for more active stocks than for less active stocks (5 seconds vs. 18 seconds).

3. EMPIRICAL RESULTS

(i) Price Volatility

We measure price volatility using 10-minute returns as defined by the natural logarithm of price relative, $R_t = \log(P_t/P_{t-1})$, where P_t denotes the prices observed at 10-minute intervals beginning from 9:10 a.m. through 12:00 noon. The first 10-minute return of each trading day is computed using the prices observed at 9:10 a.m. and 9:20 a.m. We do not use opening prices at 9:00 a.m. because they could not be computed for the continuous auction method. Since the last daily trade occurs on or around 12:00 noon, there are seventeen 10-minute intervals during each trading day between 9:10 a.m. and 12:00 noon.

Transaction prices nearest to the 10th minute are identified to calculate intraday 10-minute returns during the three-hour trading period. In identifying the transaction prices at 10-minute intervals, the problem of thin trading is not a serious issue for the TSE stocks. The TSE market is well-known for its heavy trading volume. In 1993, for example, the TSE's market turnover was the highest in the world with 235%, which compares with 72% for the NYSE and 33% for the Tokyo Stock Exchange.¹⁴ As reported in Panel C of Table 1, at least five trades are executed every minute under the continuous auction method, whereas there is at least one trade conducted per minute under the call market method.

For each stock, the 10-minute returns are averaged across the 67 trading days to compute the variance denoted by $\text{Var}(R_t)$. Cross-sectional averages of 10-minute return variances are calculated across the whole sample as well as for two subgroups sorted by trading volume.

A graphical illustration of price volatility plotted against the seventeen 10-minute trading periods within a trading day is

presented in Figure 1. Also plotted in Figure 1 are the differences in variances between the two trading methods. As shown in this figure, the variances of the 10-minute returns exhibit roughly a U-shaped curve, with high volatility at the beginning and at the close of the trading session under both trading methods. The two subgroups also exhibit similar variance patterns. The high-volume stock group consistently has greater volatility than the low-volume stock group. The differences in 10-minute variances under the two trading methods are consistently negative, indicating that price volatility is smaller in the call market than in the continuous auction market.

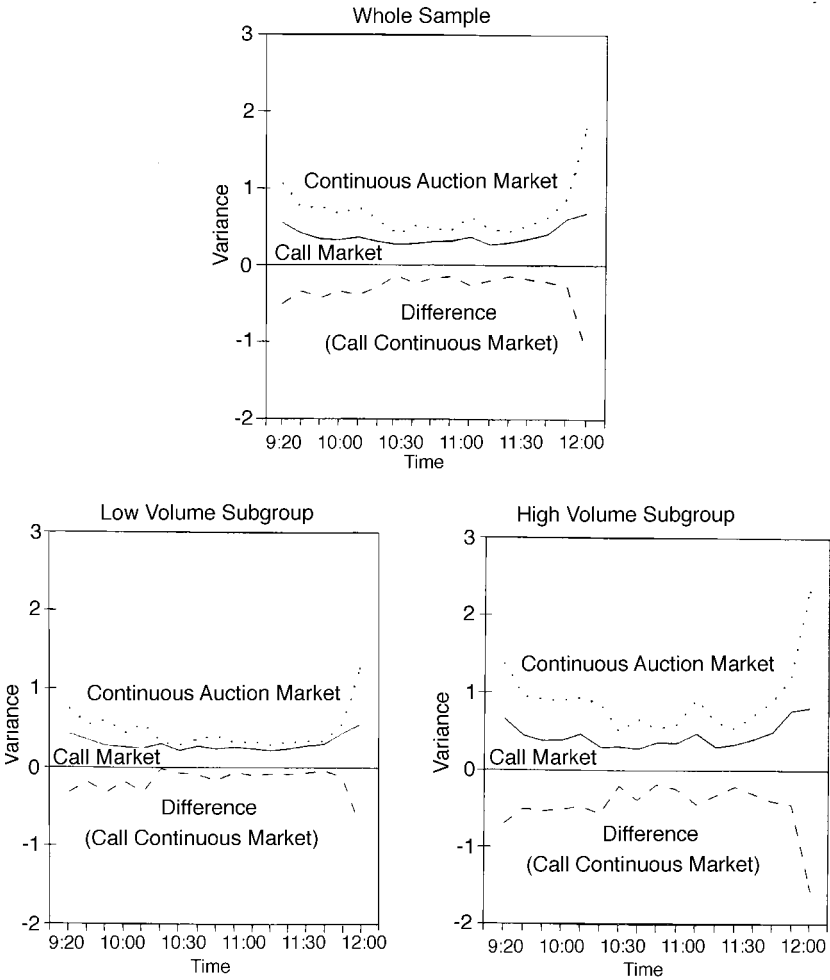
The summary statistics presented in Table 3 suggest that price volatility under the call market method for the whole sample is, on average, one-half of that under the continuous auction method [$0.3792 * 10^{-4}$ vs. $0.6986 * 10^{-4}$]. The significant difference in price volatility observed indicates that the time-interval (one minute to 90 seconds) between periodic clearings in the TSE market is long enough to make its call market trading different from the continuous auction trading.

The smaller volatility observed for the call market method may be due to at least two factors related to the batching of orders over a fixed time-interval: (i) price fluctuations caused by transactions bouncing between bid and ask quotes are eliminated; and (ii) price volatility induced by a random order arrival sequence is reduced. Our results can be considered strong evidence in support of Cohen and Schwartz (1989) and Amihud and Mendelson (1989) who advocate the use of order batching in an electronic call market.¹⁵

A closer examination of the differences reported in the last column of Table 3 yields another interesting finding. The call market method appears to be more effective in reducing volatility in the early and later part of the trading session as illustrated by the variance differences illustrated in Figure 2. For example, in the last 10-minute interval, the difference in variance between the call and continuous auction markets is the largest (in absolute value) with $-1.1226 * 10^{-4}$. For the first 10-minute interval between 9:10 a.m. and 9:20 a.m., the variance difference is $-0.5118 * 10^{-4}$, representing the second largest difference during the day. Given the higher volatility observed in the early part of the trading day and at the market close, a substantial

Figure 2

10-Minute Variances and Differences



reduction in volatility around market open and close reflects the effectiveness of the call market method in price stabilization.

Using Wilcoxon's two-sample test, we examine whether the differences in 10-minute return variances observed for the call and continuous auction methods are significantly different from zero. As shown in the last column of Table 3, two trading methods show significantly different variances for high-volume

Table 3
10-Minute Return Variances

<i>Period</i>	<i>Call Market (I)</i>			<i>Continuous Auction Market (II)</i>			<i>Difference (= I - II)</i>		
	<i>Whole Sample</i>	<i>Low-Volume</i>	<i>High-Volume</i>	<i>Whole Sample</i>	<i>Low-Volume</i>	<i>High-Volume</i>	<i>Whole Sample</i>	<i>Low-Volume</i>	<i>High-Volume</i>
9:11-9:20	0.5598 (0.2545)	0.4401 (0.2087)	0.6796 (0.2447)	1.0716 (0.7495)	0.7657 (0.4002)	1.3775 (0.8960)	-0.5118** (0.7055)	-0.3256* (0.4052)	-0.6979** (0.8903)
9:21-9:30	0.4119 (0.1993)	0.3633 (0.2046)	0.4606 (0.1881)	0.7539 (0.5384)	0.5453 (0.5201)	0.9624 (0.4866)	-0.3419** (0.4214)	-0.1821 (0.3944)	-0.5018** (0.3969)
9:31-9:40	0.3361 (0.1383)	0.2849 (0.1362)	0.3873 (0.1241)	0.7652 (0.6938)	0.6093 (0.7260)	0.9210 (0.6464)	-0.4291** (0.6770)	-0.3245 (0.7026)	-0.5337** (0.6575)
9:41-9:50	0.3280 (0.1845)	0.2642 (0.0888)	0.3918 (0.2322)	0.6733 (0.6145)	0.4435 (0.2705)	0.9031 (0.7718)	-0.3453** (0.6179)	-0.1793* (0.2713)	-0.5113** (0.8113)
9:51-10:00	0.3602 (0.2700)	0.2468 (0.0952)	0.4735 (0.3382)	0.7534 (0.5923)	0.5652 (0.5059)	0.9416 (0.6284)	-0.3932** (0.5953)	-0.3184 (0.4799)	-0.4681** (0.7013)
10:01-10:10	0.3076 (0.1535)	0.3092 (0.1888)	0.3060 (0.1146)	0.5960 (0.5204)	0.3260 (0.2403)	0.8659 (0.5892)	-0.2884* (0.5585)	-0.0168 (0.1891)	-0.5599** (0.6726)
10:11-10:20	0.2663 (0.1152)	0.2211 (0.1027)	0.3115 (0.1122)	0.4025 (0.2632)	0.2930 (0.1848)	0.5119 (0.2892)	-0.1362* (0.2587)	-0.0720 (0.1530)	-0.2005** (0.3262)
10:21-10:30	0.2819 (0.1090)	0.2783 (0.1384)	0.2856 (0.0736)	0.5184 (0.4110)	0.3665 (0.2619)	0.6703 (0.4815)	-0.2365** (0.4281)	-0.0882 (0.2865)	-0.3847** (0.5005)
10:31-10:40	0.3052 (0.1729)	0.2445 (0.1303)	0.3659 (0.1926)	0.4789 (0.3057)	0.4093 (0.2953)	0.5485 (0.3098)	-0.1737* (0.3214)	-0.1648 ⁺ (0.3138)	-0.1826* (0.3396)
10:41-10:50	0.3143 (0.1440)	0.2684 (0.1559)	0.3602 (0.1189)	0.4654 (0.3617)	0.3284 (0.2531)	0.6025 (0.4083)	-0.1511 (0.3663)	-0.0600 (0.2123)	-0.2422* (0.4637)
10:51-11:00	0.3656 (0.1833)	0.2477 (0.1111)	0.4834 (0.1658)	0.6343 (0.5960)	0.3429 (0.2190)	0.9256 (0.7113)	-0.2687* (0.5710)	-0.0952 (0.1787)	-0.4422** (0.7609)

Table 3 (Continued)

Period	Call Market (I)			Continuous Auction Market (II)			Difference (= I - II)		
	Whole Sample	Low-Volume	High-Volume	Whole Sample	Low-Volume	High-Volume	Whole Sample	Low-Volume	High-Volume
11:01-11:10	0.2662 (0.1132)	0.2244 (0.0961)	0.3081 (0.1164)	0.4687 (0.4301)	0.3042 (0.1280)	0.6332 (0.5557)	-0.2024** (0.4131)	-0.0798 (0.0960)	-0.3251** (0.5586)
11:11-11:20	0.2935 (0.1375)	0.2481 (0.1423)	0.3388 (0.1204)	0.4402 (0.3995)	0.3294 (0.2097)	0.5510 (0.5102)	-0.1468* (0.3987)	-0.0813 (0.1860)	-0.2122* (0.5343)
11:21-11:30	0.3473 (0.1599)	0.2824 (0.1456)	0.4123 (0.1506)	0.5317 (0.3493)	0.3463 (0.2335)	0.7171 (0.3529)	-0.1844 ⁺ (0.3169)	-0.0640 (0.2352)	-0.3049** (0.3488)
11:31-11:40	0.4072 (0.1703)	0.3094 (0.1250)	0.5050 (0.1549)	0.6270 (0.4815)	0.3466 (0.1836)	0.9073 (0.5274)	-0.2198 (0.4256)	-0.0372 (0.1360)	-0.4023* (0.5341)
11:41-11:50	0.6094 (0.3094)	0.4430 (0.2783)	0.7759 (0.2375)	0.8877 (0.7268)	0.5577 (0.5097)	1.2176 (0.7754)	-0.2783 (0.6424)	-0.1148 (0.3447)	-0.4418* (0.8239)
11:51-12:00	0.6851 (0.2699)	0.5544 (0.2674)	0.8158 (0.2068)	1.8077 (1.2305)	1.2780 (0.9114)	2.3373 (1.3057)	-1.1226** (1.1019)	-0.7236** (0.7989)	-1.5215** (1.2393)
Average Across Time	0.3792 (0.1392)	0.3077 (0.1289)	0.4507 (0.1121)	0.6986 (0.3543)	0.4799 (0.2063)	0.9173 (0.3391)	-0.3194** (0.3261)	-0.1722** (0.1499)	-0.4666** (0.3890)

Table 3 summarizes cross-sectional averages of 10-minute return variances with standard deviations shown in parentheses for the whole sample and two subgroups sorted by trading volume in the call and continuous auction market. The variances are multiplied by 10^4 . The study period is from January 5 to April 30, 1994. We measure 10-minute returns as the natural logarithm of price relative, $R_t = \log(P_t/P_{t-1})$, where P_t signifies the price observed at time t and $t = 9:20$ a.m., 9:30 a.m., ..., 12:00 noon. For example, the first 10-minute return of the day, $R_{9:20}$, is calculated using prices observed at 9:10 a.m. and 9:20 a.m., while $R_{12:00}$ is a 10-minute return between 11:50 a.m. and the market close. The returns at 9:10 a.m. are not included because the prices at 9:00 a.m. are determined by the periodic calls under both trading methods. For each stock, the 10-minute returns are averaged across the 67 trading days to compute $\text{Var}(R_t)$, the variance of these 10-minute returns. Using Wilcoxon's two-sample test, we examine whether the differences in 10-minute return variances observed for the call and continuous auction methods are different from zero. Statistical significance is denoted by: ** at the 0.01 level; * at the 0.05 level; and + at the 0.10 level.

stocks, but not for low-volume stocks. Apparently, the call market method is more effective than the continuous auction method in reducing price volatility of high-volume stocks. This contradicts conventional wisdom which suggests that call markets are more appropriate for thinly traded stocks than heavily traded stocks (Cohen, Maier, Schwartz and Whitcomb, 1986; Huang and Stoll, 1992; and Madhavan, 1992). This unusual conclusion may be in part attributed to two unique features of the TSE market: (i) the dominance of individual investors who are not usually well-informed and rational in their investment decision-making; and (ii) a lack of transparency and adequate financial disclosure by TSE-listed companies. As a result, the TSE market exhibits its own empirical regularities: First, high-volume stocks tend to have greater volatility than low-volume stocks. The volatility difference between the two groups of stocks is a lot more pronounced in Taiwan than other advanced capital markets. Second, high-volume stocks tend to suffer from more trading noise and pricing errors than low-volume stocks, which is not the case for other advanced capital markets. Thus, price stabilization of the call market method becomes more effective for high-volume stocks than low-volume stocks.

(ii) Market Liquidity

As Kyle (1985) suggests, market liquidity is an 'elusive' and 'slippery' concept which is not easy to define because it is composed of multiple dimensions. At least two dimensions are considered in this study: one dimension is associated with the 'price impact' of large order imbalances, while the other dimension is characterized by the 'immediacy' of transacting at a minimum cost (Hasbrouck, 1991).¹⁶

(a) Price impact of large order imbalances: For each stock, we calculate a liquidity ratio which is defined as the sum of the 10-minute trading volume, $V_{t,t-1}$ (in the number of lots) between $t-1$ and t , to the sum of squared price changes during the same interval $(P_t - P_{t-1})^2$, over 67 trading days. This ratio has a natural appeal as a liquidity measure since it measures volatility-adjusted trading volume. The previous section suggests that each trading method causes significantly different levels of volatility. After adjusting for volatility, a comparison of trading volume of the two

Table 4
Liquidity Ratios

<i>Period</i>	<i>Call Market (I)</i>			<i>Continuous Auction Market (II)</i>			<i>Difference (= I - II)</i>		
	<i>Whole Sample</i>	<i>Low-Volume</i>	<i>High-Volume</i>	<i>Whole Sample</i>	<i>Low-Volume</i>	<i>High-Volume</i>	<i>Whole Sample</i>	<i>Low-Volume</i>	<i>High-Volume</i>
9:11-9:20	0.9005 (1.8341)	0.2207 (0.2705)	1.5803 (2.4299)	0.6972 (1.7414)	0.1627 (0.2827)	1.2316 (2.3642)	0.2033 (0.6714)	0.0579 (0.1139)	0.3488 (0.9357)
9:21-9:30	1.4297 (3.1814)	0.2748 (0.2801)	2.5846 (4.2461)	1.0090 (2.4094)	0.2772 (0.3245)	1.7407 (3.2821)	0.4207 (1.2497)	-0.0024 (0.0916)	0.8438 (1.6861)
9:31-9:40	1.3267 (2.7882)	0.3282 (0.2909)	2.3252 (3.7259)	0.8030 (1.5977)	0.2954 (0.3846)	1.3105 (2.1419)	0.5238 (1.3096)	0.0328 (0.1774)	1.0147 (1.7334)
9:41-9:50	1.6432 (3.8230)	0.3063 (0.3450)	2.9801 (5.1308)	0.8171 (1.7961)	0.2405 (0.3612)	1.3938 (2.4164)	0.8261 (2.3854)	0.0658 (0.1717)	1.5864 (3.2433)
9:51-10:00	1.2692 (2.4951)	0.3279 (0.3167)	2.2105 (3.3010)	0.5688 (1.3407)	0.2122 (0.1735)	0.9254 (1.8496)	0.7004 (1.6233)	0.1157 (0.3282)	1.2851 (2.1490)
10:01-10:10	1.6644 (3.3012)	0.3723 (0.4275)	2.9565 (4.3375)	0.7978 (2.0057)	0.3858 (0.3787)	1.2097 (2.7974)	0.8666 (2.3254)	-0.0135 (0.1679)	1.7468 (3.0843)
10:11-10:20	1.5406 (3.2641)	0.3945 (0.4356)	2.6866 (4.3665)	1.0675 (2.5451)	0.3563 (0.3709)	1.7787 (3.4923)	0.4731 (1.3727)	0.0382 (0.1369)	0.9079 (1.8652)
10:21-10:30	1.7165 (4.0159)	0.3104 (0.3576)	3.1225 (5.3891)	1.2109 (4.0212)	0.2654 (0.2882)	2.1565 (5.6121)	0.5055 (1.8669)	0.0450 (0.1860)	0.9661 (2.5943)
10:31-10:40	1.3087 (2.5762)	0.3317 (0.2630)	2.2856 (3.4107)	0.9397 (1.9875)	0.2837 (0.4160)	1.5957 (2.6623)	0.3690 (1.4167)	0.0480 (0.3642)	0.6899 (1.9503)
10:41-10:50	1.4923 (3.3261)	0.3492 (0.3783)	2.6354 (4.4691)	0.8520 (1.3210)	0.4409 (0.4873)	1.2630 (1.7365)	0.6403 (2.2581)	-0.0918 (0.2133)	1.3724 (3.0608)
10:51-11:00	1.4397 (3.3914)	0.3276 (0.2767)	2.5517 (4.5933)	1.0758 (2.7284)	0.3082 (0.2609)	1.8434 (3.7536)	0.3638 (0.8510)	0.0194 (0.1720)	0.7083 (1.1029)

11:01–11:10	1.6817 (3.4299)	0.4139 (0.4405)	2.9495 (4.5531)	1.1216 (2.6745)	0.2804 (0.2149)	1.9627 (3.6407)	0.5601 (1.6930)	0.1334 (0.2768)	0.9868 (2.3389)
11:11–11:20	1.6445 (3.3761)	0.3804 (0.3363)	2.9087 (4.4802)	1.3204 (3.2512)	0.2951 (0.2223)	2.3457 (4.4266)	0.3241 (1.4664)	0.0852 (0.2764)	0.5630 (2.0629)
11:21–11:30	1.5373 (3.0613)	0.4505 (0.5467)	2.6241 (4.0721)	0.9656 (1.7008)	0.3515 (0.2476)	1.5798 (2.2632)	0.5717 (1.5089)	0.0990 (0.4557)	1.0443 (2.0075)
11:31–11:40	1.3221 (2.7621)	0.3360 (0.3404)	2.3083 (3.6882)	1.1246 (2.4124)	0.3572 (0.3317)	1.8920 (3.2685)	0.1975 (0.6452)	-0.0213 (0.1205)	0.4163 (0.8632)
11:41–11:50	1.3407 (3.0913)	0.3545 (0.3902)	2.3268 (4.1903)	1.0047 (2.1026)	0.3340 (0.2683)	1.6753 (2.8499)	0.3360 (1.2708)	0.0205 (0.3647)	0.6515 (1.7318)
11:51–12:00	1.6573 (3.6766)	0.4938 (0.6349)	2.8207 (4.9696)	0.8108 (2.1553)	0.2315 (0.1983)	1.3901 (2.9773)	0.8465* (1.7120)	0.2623 (0.4535)	1.4306 (2.2659)
Average Across Time	1.4656 (3.0755)	0.3513 (0.3590)	2.5798 (4.0993)	0.9521 (2.0889)	0.2987 (0.2532)	1.6056 (2.8389)	0.5134 (1.1458)	0.0526 (0.1204)	0.9743 (1.5000)

Notes:

Table 4 summarizes cross-sectional averages of liquidity ratios at the 10-minute time-intervals for the whole sample and two subgroups sorted by trading volume in the call market and continuous auction markets. The study period is from January 5 to April 30, 1994. Figures in parentheses represent standard deviations. For each stock, the liquidity ratio is measured by the sum of 10-minute trading volume, $V_{t,t-1}$ (in the number of lots), between $t-1$ and t over 67 trading days to the sum of squared price changes during the same interval $(P_t - P_{t-1})^2$, over 67 trading days. The estimated ratios are deflated by 10,000. This liquidity ratio measures the price impact of large order imbalances. This liquidity ratio measures the price impact of large orders. A high ratio indicates that a large order can be accommodated with a small price movement, while a low ratio suggests the inability of absorbing a large order without a large price movement. Wilcoxon's two-sample test suggests that none of the differences in liquidity ratios observed for the call and continuous auction methods are statistically different from zero except at the closing for the whole sample, which is significant at the 0.05 level.

trading methods will be more meaningful. At the same time, this ratio measures the market's ability to absorb large order flows without significant changes in price, which is closely linked to market resiliency (Kyle, 1985; Naidu and Rozeff, 1994; and Massimb and Phelps, 1994). Thus, a liquid market is characterized by a small impact on market prices by the execution of large orders. Therefore, a high ratio indicates that a large order can be executed with only a small price movement resulting, while a low ratio suggests the inability to absorb a large order without a large price movement.

Table 4 presents the liquidity ratios for the whole sample and two subgroups at 10-minute intervals within a trading day. The volatility-adjusted volume does not exhibit any particular pattern. Interestingly, the market appears most liquid around the middle of the trading session. Although market liquidity increases towards the close of the trading day, the liquidity ratio at the market close is not always the highest of the day. Not surprisingly, high-volume stocks show greater liquidity than low-volume stocks. As shown in the last column of Table 4, in general, no differences are noted between the call and continuous auction markets. This conclusion is drawn for the whole sample as well as both subgroups. This finding reflects positively on the call market method since it is able to achieve greater reduction in volatility, without sacrificing an important dimension of market liquidity. The next sub-section examines the other dimension of market liquidity: the cost of market immediacy.

(b) *Implicit cost of market immediacy*: The immediacy service is provided by market makers and the cost of this service is measured by the bid/ask spread.¹⁷ The bid/ask spread is explicitly defined in a quote-driven market, but it can be defined only implicitly in an order-driven market such as the TSE market. The implicit cost of the immediacy service is measured by the ratio of long- to short-term return variances. This variance ratio is inversely related to the implicit cost of immediacy service (Roll, 1984; Grossman and Miller, 1988; and Hasbrouck and Schwartz, 1988).¹⁸ Additionally, the variance ratio indicates the noisiness of a market, which is a useful property for investigating the TSE market. If the variance ratio is different from unity, then there exists trading noise. A noisier market is reflected by a smaller variance ratio. A smaller variance ratio also implies a greater

amount of friction in the market or market illiquidity, which is reflected by a higher implicit bid/ask spread or higher cost of immediacy. For each stock, two sets of variance ratios are estimated: the 10- and 30-minute variance ratios. The 10-minute variance ratio is measured by: $\text{Var}(R_{oc})/[17*\text{Var}(R_{10})]$, where $\text{Var}(R_{oc})$ is the variance of open-to-close returns and $\text{Var}(R_{10})$ is the variance of 10-minute returns. The 30-minute variance ratio is measured by $\text{Var}(R_{oc})/[6*\text{Var}(R_{30})]$, where the variance in the denominator is replaced by the 30-minute return variance. The prices observed at 9:10 a.m. are used as a proxy for opening prices since opening prices are determined exclusively by the call market method (see the Appendix).

Table 5 summarizes the variance ratios estimated for the whole sample and for both subgroups under the two different trading structures. The variance ratios under the call market method are consistently greater than those estimated for the continuous auction method. For the whole sample, the average variance ratio is about 50% greater for the call market method than for the continuous auction method (0.6033 vs. 0.4112). The differences in the variance ratios under the two trading methods are statistically significant. Similar results are obtained for the 30-minute variance ratios. As expected, the 30-minute variance ratios are greater than the 10-minute return variance ratios, indicating less friction in the market.¹⁹ Trading volume makes little difference in the overall pattern of variance ratios as summarized in Panels B and C.

Overall, these results are interesting as well as surprising. They are interesting because the amount of trading noise is smaller in the call market than the continuous auction market. They are surprising because the continuous auction market is usually considered a more efficient trading environment in providing market immediacy and efficient price discovery. Thus, one would expect higher variance ratios for the continuous auction market. Despite the continuous auctions that occur both on the buying side and on the selling side, a greater amount of friction and a higher cost of immediacy are found under the continuous auction market. Our results render empirical evidence in support of Goldman and Sosin (1979) who prove that continuous trading does not necessarily minimize pricing errors in the presence of uncertainty concerning the number of informed speculators.

Table 5
Variance Ratios

	<i>Call Market (I)</i>		<i>Continuous Auction Market (II)</i>		<i>Difference (= I – II)</i>	
	<i>10-Minute</i>	<i>30-Minute</i>	<i>10-Minute</i>	<i>30-Minute</i>	<i>10-Minute</i>	<i>30-Minute</i>
A. Whole Sample						
Mean Variance Ratio	0.6033	0.8429	0.4112	0.5955	0.1921**	0.2474**
(Standard Deviation)	(0.1365)	(0.1605)	(0.1542)	(0.2435)	(0.1322)	(0.1981)
Median	0.6431	0.8330	0.3914	0.5638	–	–
Minimum	0.3343	0.5427	0.1885	0.2423	–	–
Maximum	0.8617	1.1946	0.8168	1.1274	–	–
B. Low-Volume Subgroup						
Mean Variance Ratio	0.6164	0.8678	0.4589	0.6547	0.1576*	0.2131*
(Standard Deviation)	(0.1526)	(0.1744)	(0.1969)	(0.2795)	(0.1407)	(0.1937)
Median	0.6590	0.8749	0.4523	0.5848	–	–
Minimum	0.3343	0.5427	0.1885	0.2423	–	–
Maximum	0.8520	1.1194	0.8168	1.1274	–	–
C. High-Volume Subgroup						
Mean Variance Ratio	0.5902	0.8180	0.3635	0.5363	0.2267**	0.2817**
(Standard Deviation)	(0.1222)	(0.1471)	(0.0749)	(0.1927)	(0.1175)	(0.2031)
Median	0.5920	0.8267	0.3552	0.5631	–	–
Minimum	0.4266	0.5877	0.2056	0.2617	–	–
Maximum	0.8617	1.1946	0.5255	0.8726	–	–

Table 5 presents cross-sectional averages of the variance ratios estimated for the whole sample and two subgroups under the two different trading methods. The study period is from January 5 to April 30, 1994. For each stock, two sets of variance ratios are estimated: the 10- and 30-minute variance ratios. The 10-minute variance ratio is measured by: $\text{Var}(R_{oc})/[17*\text{Var}(R_t)]$, where $\text{Var}(R_{oc})$ is the variance of open-to-close returns and $\text{Var}(R_t)$ is the variance of 10-minute returns. The 30-minute variance ratio is measured by $\text{Var}(R_{oc})/[6*\text{Var}(R_t)]$, where the variance in the denominator is the 30-minute return variance. If the variance ratio is different from unity, then there exists trading noise. The noisier the market is, the smaller the variance ratio. A smaller variance ratio also implies a greater amount of frictions in the market or market illiquidity, which is reflected in a higher implicit bid/ask spread or higher cost of immediacy. Wilcoxon's two-sample test is used to examine whether the differences in French-Roll variance ratios estimated for the call and continuous auction methods are different from zero. Statistical significance is denoted by: ** at the 0.01 level; and * at the 0.05 level.

Goldman and Sosin's proof is very pertinent to the TSE trading in which a large number of uninformed individual investors are active market participants. Block trading in the TSE, for example, accounted for less than one-hundredth of 1% of the total trading volume in 1993, compared with 53.7% reported for the NYSE. Apparently, the call market method reduces trading noise caused by pricing errors more effectively than the continuous auction method in the TSE market. As a result, we observe significantly greater variance ratios in the call market. Our results are corroborated by the findings by Lang and Lee (1999) who examine the impact of trading frequency on price volatility using TSE market data. They find that frequent trading results in higher price volatility.

To corroborate our conjecture, we investigate correlations between adjacent 10-minute return series. If the continuous auction market suffers from more trading noise and pricing errors, we would expect the continuous auction method to exhibit a higher degree of price reversals than the call market method. This should be manifested in larger negative correlations for the continuous auction market than the call market. Table 6 summarizes estimated correlations between the return series of the neighboring 10-minute intervals. Three findings are noted: first, the continuous auction method shows larger, negative correlations than the call market method as predicted; second, statistically significant differences are observed in the early part of the trading day and again during the mid-trading session between 10:30 a.m. and 11:20 a.m.; and third, subgroups sorted by trading volume show similar patterns in price reversals.

For TSE-listed stocks, a lower implicit cost of immediacy is achieved in the call market than in the continuous auction market. Additionally, no difference in the price impact of large order imbalances is found between the two trading methods. The fact that lower price volatility is associated with the call market without impairing its market liquidity represents valuable insight on market design for other volatile emerging markets. The benefits of the call market are gained at the expense of a smaller trading volume. As noted earlier, trading volume in the call market is approximately 20%–25% smaller than in the continuous auction market for the TSE. At the same time,

Table 6
Correlation

Correlation	Call Market (I)			Continuous Auction Market (II)			Difference (= I - II)		
	Whole Sample	Low-Volume	High-Volume	Whole Sample	Low-Volume	High-Volume	Whole Sample	Low-Volume	High-Volume
$r(\tau_{9:21}, \tau_{9:30})$	-0.0920 (0.1779)	-0.0817 (0.1125)	-0.1024 (0.2294)	-0.3612 (0.1844)	-0.2817 (0.1747)	-0.4407 (0.1623)	0.2692** (0.2359)	0.2001** (0.1719)	0.3383** (0.2748)
$r(\tau_{9:31}, \tau_{9:40})$	-0.3366 (0.1481)	-0.3564 (0.1320)	-0.3167 (0.1648)	-0.4222 (0.1932)	-0.4597 (0.1570)	-0.3848 (0.2229)	0.0857 ⁺ (0.2379)	0.1033 (0.2189)	0.0681 (0.2620)
$r(\tau_{9:41}, \tau_{9:50})$	-0.2313 (0.1710)	-0.2629 (0.1460)	-0.2000 (0.1926)	-0.2695 (0.2718)	-0.2440 (0.2506)	-0.2950 (0.2980)	0.0382 (0.2992)	-0.0189 (0.2386)	0.0954 (0.3487)
$r(\tau_{9:51}, \tau_{10:00})$	-0.1268 (0.1736)	-0.1495 (0.1829)	-0.1041 (0.1670)	-0.1531 (0.2655)	-0.1352 (0.2969)	-0.1711 (0.2392)	0.0263 (0.3006)	-0.0143 (0.3689)	0.0670 (0.2182)
$r(\tau_{10:01}, \tau_{10:10})$	-0.2060 (0.1547)	-0.1135 (0.0980)	-0.2984 (0.1472)	-0.4059 (0.2586)	-0.3473 (0.2094)	-0.4646 (0.2954)	0.2000** (0.2757)	0.2337** (0.1955)	0.1662 (0.3417)
$r(\tau_{10:11}, \tau_{10:20})$	-0.3806 (0.1171)	-0.3772 (0.1520)	-0.3841 (0.0727)	-0.3489 (0.2238)	-0.3348 (0.1558)	-0.3630 (0.2811)	0.0317 (0.2380)	-0.0423 (0.1917)	-0.0211 (0.2834)
$r(\tau_{10:21}, \tau_{10:30})$	-0.3718 (0.1630)	-0.3739 (0.1798)	-0.3696 (0.1506)	-0.3270 (0.2362)	-0.3178 (0.2460)	-0.3362 (0.2343)	-0.0448 (0.1981)	-0.0561 (0.1850)	-0.0334 (0.2162)
$r(\tau_{10:31}, \tau_{10:40})$	-0.0819 (0.2537)	-0.1351 (0.2660)	-0.0286 (0.2378)	-0.2072 (0.2463)	-0.2031 (0.2548)	-0.2112 (0.2463)	0.1253 (0.3855)	0.0680 (0.4190)	0.1826 ⁺ (0.3539)
$r(\tau_{10:41}, \tau_{10:50})$	-0.1585 (0.2387)	-0.1629 (0.1771)	-0.1541 (0.2942)	-0.3053 (0.2500)	-0.2867 (0.2858)	-0.3239 (0.2169)	0.1468* (0.2478)	0.1238* (0.2394)	0.1697 (0.2622)
$r(\tau_{10:51}, \tau_{11:00})$	-0.3640 (0.1688)	-0.3942 (0.1408)	-0.3337 (0.1929)	-0.2701 (0.2263)	-0.2896 (0.2039)	-0.2505 (0.2524)	-0.0939 ⁺ (0.3039)	-0.1045* (0.2773)	-0.0832 (0.3379)
$r(\tau_{11:01}, \tau_{11:10})$	-0.2618 (0.1783)	-0.2823 (0.1619)	-0.2413 (0.1968)	-0.4422 (0.2401)	-0.3758 (0.2906)	-0.5087 (0.1597)	0.1804** (0.2999)	0.0935 (0.2590)	0.2674** (0.3209)

$r(r_{11:11}, r_{11:20})$	-0.2196 (0.1898)	-0.2719 (0.1780)	-0.1674 (0.1925)	-0.3263 (0.2146)	-0.4032 (0.1617)	-0.2494 (0.2378)	0.1067 ⁺ (0.2691)	0.1313* (0.2345)	0.0820 (0.3062)
$r(r_{11:21}, r_{11:30})$	-0.2569 (0.1499)	-0.2558 (0.1637)	-0.2580 (0.1404)	-0.3183 (0.1944)	-0.2736 (0.2442)	-0.3631 (0.1200)	0.0614 (0.2378)	0.0177 (0.3116)	0.1050* (0.1266)
$r(r_{11:31}, r_{11:40})$	-0.2941 (0.1616)	-0.2750 (0.1571)	-0.3132 (0.1692)	-0.3339 (0.1980)	-0.2905 (0.1529)	-0.3773 (0.2320)	0.0398 (0.1887)	0.0155 (0.1578)	0.0641 (0.2181)
$r(r_{11:41}, r_{11:50})$	-0.2128 (0.1610)	-0.2636 (0.1481)	-0.1619 (0.1619)	-0.2158 (0.1745)	-0.2308 (0.1865)	-0.2008 (0.1667)	0.0031 (0.2221)	-0.0328 (0.2513)	0.0389 (0.1904)
$r(r_{11:51}, r_{close})$	-0.1715 (0.1672)	-0.1898 (0.1476)	-0.1531 (0.1882)	-0.2407 (0.2054)	-0.2600 (0.2249)	-0.2214 (0.1896)	0.0692 (0.2658)	-0.0702 (0.2440)	0.0683 (0.2946)
Average Across Time	-0.2354 (0.0700)	-0.2466 (0.0587)	-0.2241 (0.0802)	-0.3092 (0.0680)	-0.2959 (0.0766)	-0.3226 (0.0577)	0.0739** (0.0892)	0.0493 ⁺ (0.0669)	0.0985** (0.1035)

Table 6 presents cross-sectional averages of correlations between the adjacent 10-minute return series for the whole sample and two subgroups sorted by trading volume. Standard deviations are shown in parentheses. The study period is from January 5 to April 30, 1994. If the continuous auction market suffers from more trading noise and pricing errors, we would expect the continuous auction method to exhibit a higher degree of price reversals than the call market method. This should be manifested in large negative correlations. Wilcoxon's two-sample test is used to examine whether the differences in 10-minute correlations observed for the call and continuous auction methods are different from zero. Statistical significance is denoted by: ** at the 0.01 level; * at the 0.05 level; and + at the 0.10 level.

however, it should be recognized that the call market method exhibits a more effective price discovery process than the continuous auction method.

4. CONCLUSIONS

This study empirically contrasts volatility and liquidity under the call and continuous auction markets using unique data sets from the TSE. The first data set is the actual transaction data under the current call market method and the second set is simulated data generated under the continuous auction method.

A number of important results emerge from our analysis. First, significant differences in volatility exist between the two trading methods. Price volatility under the call market method for the whole sample is, on average, one-half of that under the continuous auction method. Second, the call market method is more effective in reducing volatility in the early and later part of the trading session. Given the higher volatility observed in the early part of the trading day and at the market close, a substantial reduction in volatility around market open and close demonstrates the effectiveness of the call market method in price stabilization. Our results provide empirical support to Cohen and Schwartz (1989) and Amihud and Mendelson (1989) who advocate the advantage of order batching in an electronic call market. Third, the call market method works more effectively in reducing price volatility of high-volume stocks than low-volume stocks. This contradicts conventional wisdom which suggests that the call market is better for thinly traded stocks, while the continuous auction market is preferred for heavily traded stocks. Fourth, the call market method is able to reduce volatility without sacrificing liquidity. No difference in the price impact of large order imbalances is found between the two trading methods. An analysis of the variance ratios indicates that price discovery is more efficient in the call market than in the continuous auction market. Our results render empirical evidence in support of Goldman and Sosin (1979) who prove that continuous trading does not necessarily minimize pricing errors in the presence of uncertainty concerning the number of speculators informed.

APPENDIX

TSE Call Market and Continuous Auction Market Algorithms*A. Order Matching Principles*

Two principles are applicable to both call market (CM) and continuous auction market (CA): first, preference is given to the highest buy orders and lowest sell orders (price priority); and second, when buy/sell orders are quoted at the same price, preference is given to the earliest buy/sell orders (time priority). In the CM, orders are batched intermittently for execution when there is a cross. In the CA, the execution is carried out on a first-come-first-serve basis.

B. Rules to Determine Trade Price under the Call Market Method

Trade price of a stock is the price at which the greatest number of shares can be executed. It is denoted by $p(i)$ where $i (= 0, 1, 2, 3, \dots, N)$ represents the trading round. $p(0)$ is the opening price at 9:00 a.m. after a 30-minute batching period and $p(N)$ is the closing price of the day. The length of the time interval between each trade is on average 60 to 90 seconds on the TSE. All buy orders quoted above $p(i)$ and all sell orders quoted below $p(i)$ at round i are executed.

C. Rules to Determine Trade Price under the Continuous Auction Method

If the i th arriving buy order is priced higher than or equal to the lowest selling price in the queue, then a new trade price, $p(i)$, is determined at the price of the counter-party. The traded sell orders or a portion thereof are removed from the queue and the remaining portion of the sell orders is added to the queue. Likewise, if the i th arriving sell order priced lower than or equal to the buy orders in the queue, then a new trade price, $p(i)$, is determined. Matching price is always at or closest to the last trade price.

In the CA simulation, opening prices, $p(0)$, are determined by the CM method rather than the CA method because the cumulated orders during the pre-opening period are randomized at the TSE without a time stamp, making the

application of the CA simulation impossible. Beginning at 9:00 a.m., the CA algorithms apply. At the end of each execution, there should be no crosses in the queue.

D. Numerical Example

The following is an illustration of the CM matching at the beginning of a session:

<i>Buy</i>			<i>Sell</i>	
<i>Cumulative Quantity</i>	<i>Order Quantity</i>	<i>Price</i>	<i>Order Quantity</i>	<i>Cumulative Quantity</i>
180	180	\$54.00		
		53.50	15	260
		53.00	20	245
<u>190</u>	<u>10</u>	<u>52.50</u>	<u>60</u>	<u>225</u>
	60	52.00	55	165
	150	51.50	60	110
	90	51.00	10	50
	100	50.50	40	40

a. At price \$52.50, the most number of lots can be executed. Thus, at $p(0) = 52.50$, a total of 190 lots in the buy column are matched, but 35 lots are left unmatched in the sell column.

b. After the 190 lots are executed, the following orders are carried over:

<i>Buy</i>			<i>Sell</i>	
<i>Cumulative Quantity</i>	<i>Order Quantity</i>	<i>Price</i>	<i>Order Quantity</i>	<i>Cumulative Quantity</i>
		\$54.00		
		53.50	15	
		53.00	20	
		52.50	35	
	60	52.00		
	150	51.50		
	90	51.00		
	100	50.50		

c. After new orders arrive, the order book now looks as shown below:

<i>Buy</i>			<i>Sell</i>	
<i>Cumulative Quantity</i>	<i>Order Quantity</i>	<i>Price</i>	<i>Order Quantity</i>	<i>Cumulative Quantity</i>
		\$54.00		
		53.50	15	
10	10	53.00	20	
15	5	52.50	35	65
<u>75</u>	<u>60</u>	<u>52.00</u>	<u>10</u>	<u>30</u>
	150	51.50	20	20
	90	51.00		
	100	50.50		

d. Under the CM method, the most number of lots (30) can be executed at \$52.00.

e. Under the CA method, we assume the following sequence of newly arrived orders:

- (1) Buy order of 10 lots at \$53.00;
- (2) Sell order of 20 lots at \$51.50;
- (3) Sell order of 10 lots at \$52.00; and
- (4) Buy order of 5 lots at \$52.00.

The following series of matching is determined:

First, the 10 lots of buy order at \$53.00 will be matched with 10 lots of the sell orders at \$52.50. The matching price is \$52.50, the price of the counterparty. Second, 20 lots of sell order at \$51.50 will be matched with 20 lots from buy order of 60 at \$52.00. The matching price is \$52.00. Third, sell order of 10 lots at \$52.00 will be matched with 10 lots of buy order at \$52.00, leaving 30 lots unmatched of the original buy order of 60 lots. The last buy order does not cross and it will be added to the queue.

f. The order book now looks as shown below:

<i>Buy</i>			<i>Sell</i>	
<i>Cumulative Quantity</i>	<i>Order Quantity</i>	<i>Price</i>	<i>Order Quantity</i>	<i>Cumulative Quantity</i>
		\$54.00		
		53.50	15	
		53.00	20	
		52.50	25	
	<u>40</u>	<u>52.00</u>		
	150	51.50		
	90	51.00		
	100	50.50		

g. The CM matching algorithm provides two matching prices, \$52.50 and \$52.00, while the CA matching algorithm provides three consecutive prices, \$52.50, \$52.00, and \$52.00.

NOTES

- 1 Two trading methods are usually found in an order-driven market where traders submit orders before prices are determined. In contrast, in a quote-driven market, dealers or market makers post prices before order submissions (Madhavan, 1992).
- 2 The Milan Stock Exchange's trading system is unusual in that: trading in high-volume stocks usually starts with the continuous auction method, then proceeds to the call market method, and returns back to the continuous auction method. On some days, the first transaction of the day may start with the call market method (see Amihud et al., 1990).
- 3 More rigid listing requirements are imposed on category A stocks in terms of: size, profitability, ownership structure, years of operation, etc.
- 4 Rhee and Chang (1992) list the following reasons why order-driven systems are dominant in the Asian capital markets: (i) the significant role of individual investors; (ii) distrust of deal-making; (iii) less complicated regulatory considerations; and (iv) relatively low trading cost.
- 5 Chen, Chow, Liu and Liu (1994) have examined the intraday risk and return behavior of TSE-listed stocks during the pre-automation period.
- 6 For a review of automated trade execution systems adopted by various stock and futures exchanges, see Domowitz (1990) and Rhee and Chang (1992).
- 7 Block trading orders are submitted after the market is closed, between 2:00 p.m. and 3:30 p.m., on Monday through Friday to have them matched at the closing price of the day.

- 8 The tick size varies in proportion to share price level:

<i>Price (P)</i>	<i>Tick Size</i>
$P < \text{NT\$}5$	NT\$0.01
$\text{NT\$}5 \leq P < \text{NT\$}15$	NT\$0.05
$\text{NT\$}15 \leq P < \text{NT\$}50$	NT\$0.10
$\text{NT\$}50 \leq P < \text{NT\$}150$	NT\$0.50
$\text{NT\$}150 \leq P < \text{NT\$}1,000$	NT\$1.00
$\text{NT\$}1,000 \leq P$	NT\$5.00

- 9 One exception is when the orders are received prior to the market open. A random number is generated for each of those orders to replace the time stamp.
- 10 As reported in the empirical section of this study, however, the short time-interval between trades does not prevent from obtaining a meaningful difference between the two trading methods.
- 11 Given the daily price limit of $\pm 7\%$, it is a highly costly order-placing behavior. These observations are, however, confirmed through a number of interviews we conducted with leading brokerage houses.
- 12 Karpoff (1986) simulates the continuous and call markets to compare their trading volume behavior. He reports a higher volume in the call market than in the continuous market, which contradicts the results reported here. However, his results are not directly comparable with our results since a continuous market with significant frictions (information and transaction costs) and a costless Walrasian call market are compared in his simulations. Karpoff demonstrates, however, that the call market shows an improvement in allocation efficiency, as evidenced by a relatively stable trading volume behavior, over the continuous market.
- 13 No counterpart figures are reported for the continuous auction method because all orders cumulated during the 30-minute pre-opening period are randomized at the TSE. Therefore, each order loses a time stamp to make it impossible to determine opening prices under the continuous auction method.
- 14 See *Emerging Stock Markets Factbook 1994* of the International Finance Corporation.
- 15 Another important reason for a lower volatility under the call market method is related to asymmetric information. Cohen and Schwartz (1989) suggest that the asymmetric information problem between informed and uninformed liquidity traders is mitigated by order batching in the call market environment. However, this explanation may not be readily applicable to the Taiwan stock market because of the dominance of uninformed individual investors.
- 16 Another dimension is the time it takes to exchange an asset for money as defined by Lippman and McCall (1986).
- 17 Market width and depth are frequently cited concepts which affect the cost of this immediacy service. Width refers to the bid/ask spread (and to brokerage commissions and other fees per share) for a given number of shares and depth refers to the number of shares that can be traded at given bid and ask quotes (Harris, 1990). Both width and depth are inversely related to the magnitude of the explicit or implied bid/ask spread.
- 18 Recent application of this variance ratio is found in French and Roll (1986), Lo and MacKinlay (1988), Skinner (1989), Fama and French (1988), Kaul

and Nimalendran (1990), Hamon, Handa, Jacquillat and Schwartz (1993), and Grünbichler, Longstaff and Schwartz (1994).

- 19 Unlike the 10-minute variance ratios, a few stocks have 30-minute variance ratios greater than unity. This is not surprising because additional intervening factors associated with longer time-interval returns are introduced, thereby inducing positive autocorrelations. These factors include an increasing number of: (i) stale limit orders; (ii) mean-reverting cases; (iii) price undershooting, etc.

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