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How does the call market method affect price efficiency? Evidence from the Singapore Stock Market ☆

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Abstract

On August 21, 2000, the Singapore Exchange (SGX) adopted the call market method to open and close the market while the remainder of the day's trading continued to rely on the continuous auction method. The call method significantly improved the price discovery process and market quality. A positive spillover effect is observed from the opening and closing calls. Day-end price manipulation also declined after the introduction of the call market method. However, the beneficial impact from the call market method is asymmetric, benefiting liquid stocks more than illiquid stocks.

JEL classification: G14; G15; G18

Keywords: Market mechanism; Call method; Price efficiency; Trading noise; Return reversals; Price manipulation; Singapore Exchange

1. Introduction

Schwartz (2000) correctly predicted that with advances in computer technology the call market trading method, which was less prevalent in the pre-computer age, would increase in its popularity as an electronic trading forum. The recent adoption of a hybrid trading system by two major quote-driven markets, the Nasdaq and the London Stock Exchange (LSE), represents a historic change in the design of securities trading systems. The two exchanges adopted a limit order book-based order-driven trading system in parallel with the traditional quote-driven trading system in February 1997 and October 1997, respectively. In March 2004 the Nasdaq implemented a closing call auction which interacts with the existing quote-driven trading mechanism and subsequently introduced an opening call auction later that same year. The LSE adopted the call market method to open and close its market in 2000. The American Stock Exchange adopted the closing call system in 2003 and the Toronto Stock Exchange adopted it in 2004. In Asia, the Hong Kong Stock Exchange introduced the call method to open the market in March 2002 and the Singapore Exchange (SGX) introduced the call method in August 2000 to determine both opening and closing prices.

As an increasing number of markets have adopted the call method, the method's impact on the price discovery process has become an increasingly important topic. This study examines whether the SGX's adoption of the call market system improved price efficiency, market quality, and reduced day-end price manipulation. Our interest in the SGX is motivated by its unique trading rules relevant to the choice of trading methods. With the adoption of the call system, both the call market method (CMM) and

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the continuous auction method (CAM) are used to determine opening and closing prices. However, unlike the LSE and the Nasdaq markets, traders do not have a choice about which market method to use. Rather, stocks that open or close "on-time" use the CMM, while stocks which open late or close early rely on the CAM. As a result, the opening and/or closing price of a stock may be determined by the CMM one day and by the CAM on the next. The SGX's unique setting and associated trading rules allow us to isolate the opening and closing transactions that are determined by CMM from those determined by CAM and to make a direct comparison of the price discovery processes under the two trading methods.

We find that the CMM unambiguously improves price efficiency. Specifically, return volatility and pricing errors for liquid stocks at the market's open and close decline dramatically when opening or closing prices are determined by the CMM. We confirm the presence of the positive spillover effect documented by Pagano and Schwartz (2003) as (i) return volatility declined even when transactions did not rely on the CMM, and (ii) closing (opening) calls reduce the volatility of the next day's open (same day's close). We also find that the use of the CMM significantly reduces the occurrence of day-end price manipulation. However, the CMM's positive impact on market quality asymmetrically affects liquid and illiquid stocks with liquid stocks benefiting far more from the CMM than illiquid stocks.

The remainder of this paper is organized as follows: Section 2 reviews the literature which motivated this study. Section 3 presents institutional background and the data. Section 4 documents the beneficial impact of the CMM on market quality examining return volatility and trading noise. Section 5 reports how the CMM affects price manipulation at the market's close. Section 6 summarizes the major findings and concludes the paper.

2. Relevant literature and motivation for the study

Previous empirical studies examining the merits and weaknesses of the CMM may be classified into five broad categories. First, a number of studies focus on the impact of opening and closing calls on the hybrid form of trading at the Nasdaq and the LSE where the CMM is found to have improved market quality (Ellul et al. (2005), Pagano and Schwartz (2005), and Smith (2005)).

The second category of studies examines price efficiency and market quality when certain stocks move from one exchange to another or compares stocks jointly-listed on different exchanges that are subject to different trading mechanisms (Bacidore and Lipson (2001) and Barclay et al. (in press)). Evidence from these studies suggests that the CMM is more efficient than the CAM for the opening and closing trades.

The third category of studies relies on experimental comparisons between the call and continuous auction methods or between auction and dealer markets. Schnitzlein (1996) finds that adverse selection costs are significantly lower under the CMM than the CAM. Theissen (2000) reports that the CMM and CAM are more price efficient than dealer markets. Chang et al. (1999) find that trading under the CMM is less volatile and more efficient than under the CAM.

The fourth category of studies relies on the special setting in which some stocks move from the CMM to CAM or vice versa, which differs from the first category because the change of trading method remains within an order-driven trading system. Studies in this category also differ from those in the second category in that the trading systems are compared in a single trading venue as opposed to multiple venues. Amihud et al. (1997) and Lauterbach (2001) demonstrate that continuous trading is superior to call market trading using Tel Aviv Stock Exchange data. Muscarella and Piwowar (2001) report that price discovery in the CMM is inferior to the CAM.

Studies in the fifth category make *indirect* comparisons between the CMM and the CAM within the same order-driven market using open-to-open return volatility (subject to the CMM) and close-to-close return volatility (subject to the CAM) to highlight the differential effects of the two trading methods (Amihud and Mendelson (1987)). Amihud and Mendelson (1991) suggest that the greater volatility at the open is induced by the preceding overnight non-trading period. Gerety and Mulherin (1994) conclude that the CMM is not inherently destabilizing. Ronen (1997) suggests that cross-sectional return correlations lead us to conclude that the variance ratios are not equal to one. George and Hwang (2001) criticize these findings on the basis of the interaction between information flow and trading noise.[1] Empirical evidence from Asian securities markets also indicate that greater variance at the market open than close cannot be attributed to the CMM, because these exchanges rely exclusively on the CAM (Cheung et al. (1994) and Chang et al. (1995)).

Our analysis is most closely related to studies in the last category. However, unlike previous studies, we make a *direct* comparison between the CMM and the CAM rather than an *indirect* comparison. The unique setting afforded by the SGX allows us to isolate opening and closing transactions that are determined by the CMM from those determined by the CAM. Therefore, we are able to *directly* compare the two trading methods within an order-driven system at the *same* exchange. Since all sample stocks are from a single trading venue, the comparison between multiple venues under correspondingly different trading rules, is not an issue. Another important advantage offered by the SGX is that the trading method employed is dictated by the timing of the opening (closing) rather than by traders, listed companies, or the exchange, making sample selection bias a non-issue. As a result, we avoid the potential depen-

[1] Indeed, George and Hwang (1995) do not observe greater volatility at the open for the Tokyo Stock Exchange-listed stocks with the exception of the most actively traded stocks.

dence problem identified by George and Hwang (2001) as we examine the return volatilities within the same trading session. We may assign recent studies by Pagano and Schwartz (2003) and Comerton-Forde et al. (2007) to the last category but they differ from the above cited studies because they conduct a direct comparison between the CMM and CAM after the CMM was introduced on the Paris Bourse and the SGX, respectively.

In particular, Comerton-Forde et al. (2007) examine the same event as our study. However, our study differs from theirs in scope and methodology while the overall findings complement each other. Specifically, the following major differences are noted. First, unique contributions of Comerton-Forde et al. include the confirmation that: (i) the price discovery process was more synchronized; and (ii) relative volume at the market's open increased without adversely affecting volatility for IPO stocks after the introduction of the CMM, whereas this study demonstrates a dramatic improvement in price efficiency in terms of reduced return volatility and trading noise. Second, we confirm the existence of the "spillover effect" found by Pagano and Schwartz (2003). We believe ours is the first study to confirm the existence of the spillover effect on a market other than the Paris Bourse. Third, both studies examine day-end price manipulation. Comerton-Forde et al. (2007) provide an informative picture of the market's close using the bid-ask spreads of the last trade of the day and the skewness statistics of the absolute values of closing returns, while we provide a useful picture of return reversals surrounding the periods before and after the market close.[2] Both studies draw a similar conclusion that day-end price manipulation declined after the introduction of the CMM. However, for illiquid stocks, our evidence suggests that the overall level of price manipulation activity did not decline. These corroborative conclusions are important because there is no standard definition of price manipulation. Lastly, both studies find smaller improvements for illiquid stocks but Comerton-Forde et al. attribute this to the less frequent usage of CMM for illiquid stocks while our findings, in a multiple regression framework, indicate that the smaller improvement is due to the smaller direct impact of the CMM and a smaller positive spillover effect.

3. Institutional background and data

3.1. The Singapore Stock Exchange

The SGX had a total of 470 listed companies on its main board which had a total market capitalization of S$560 billion (approximately US$325 billion) at the end of September 2000, the midpoint of our study period. The SGX uses a central limit book system in which only limit orders can be placed. The SGX has two trading sessions in each trading day (Monday through Friday): a morning session from 9:00 A.M. to 12:30 P.M. and an afternoon session from 2:00 P.M. to 5:00 P.M. Prior to August 21, 2000, all of the day's securities trading relied on the CAM. From August 21 onward the SGX introduced the CMM to determine opening and closing prices incorporating a 29-min "pre-open" routine and a 5-min "pre-close" routine. If no crossing buy and sell orders are placed during the pre-open or pre-close call routines, no CMM trade takes place. Under such circumstances, the first trade of the day, the "opening" price, or the last trade of the day, the "closing" price, is determined by the CAM.

3.2. Data

We divide the study period into two periods from April 1, 2000 through July 31, 2000 and September 1, 2000 through December 31, 2000. These two periods are referred to as "Period 1" and "Period 2," respectively. Opens and closes are divided into either "on-time" or "not-on-time" categories as illustrated in Panel A of Fig. 1. In Period 1, if the opening trade occurs on or before 9:00:30 A.M., it is classified as "on-time" and all openings occurring after 9:00:30 A.M. are classified as "not-on-time." If the closing trade occurs on or after 4:59:30 P.M., it is considered an "on-time" close while all closes which occur before 4:59:30 P.M. are classified as "not-on-time."[3] In Period 2, an opening is classified as "on-time" if it occurs at 8:59:00 A.M. and all openings which occur after 9:00:00 A.M. are classified as "not-on-time." The close is classified "on-time" only if it occurs at 5:05:00 P.M. while all closes that occur before 5:00:00 P.M. are classified "not-on-time." It should be noted that in Period 1 all opens and closes use the CAM while in Period 2 only "on-time" transactions use the CMM while other transactions use the CAM.

Continuously compounded returns are calculated as shown below in Eqs. (1)–(4) and are illustrated in Panel B of Fig. 1 where p_o refers to the opening price and p_c refers to the closing price. "Trading Day Returns" and "Overnight Returns" are denoted by $r_{D,d}$ and $r_{N,d}$, respectively, while interday returns, $R_{o,d}$ and $R_{c,d}$, denote the "Open-to-Open Returns" and the "Close-to-Close Returns", respectively. The subscript d refers to day d and the subscript $d-1$ refers to the day prior to day d.

$$\text{Open-to-Open Returns}: R_{o,d} = \log(p_{o,d}/p_{o,d-1}) \quad (1)$$

$$\text{Close-to-Close Returns}: R_{c,d} = \log(p_{c,d}/p_{c,d-1}) \quad (2)$$

$$\text{Trading Day Returns}: r_{D,d} = \log(p_{c,d}/p_{o,d}) \quad (3)$$

$$\text{Overnight Returns}: r_{N,d} = \log(p_{o,d}/p_{c,d-1}) \quad (4)$$

We obtained the time-stamped intraday data for all transactions that occurred during Periods 1 and 2 directly from

[2] Comerton-Forde and Putniņš (2007) examine price reversals on the following morning.

[3] Qualitatively similar results are obtained when using a 15 or 45 second rule for the classification of "on-time" and "not-on-time" opens and closes.

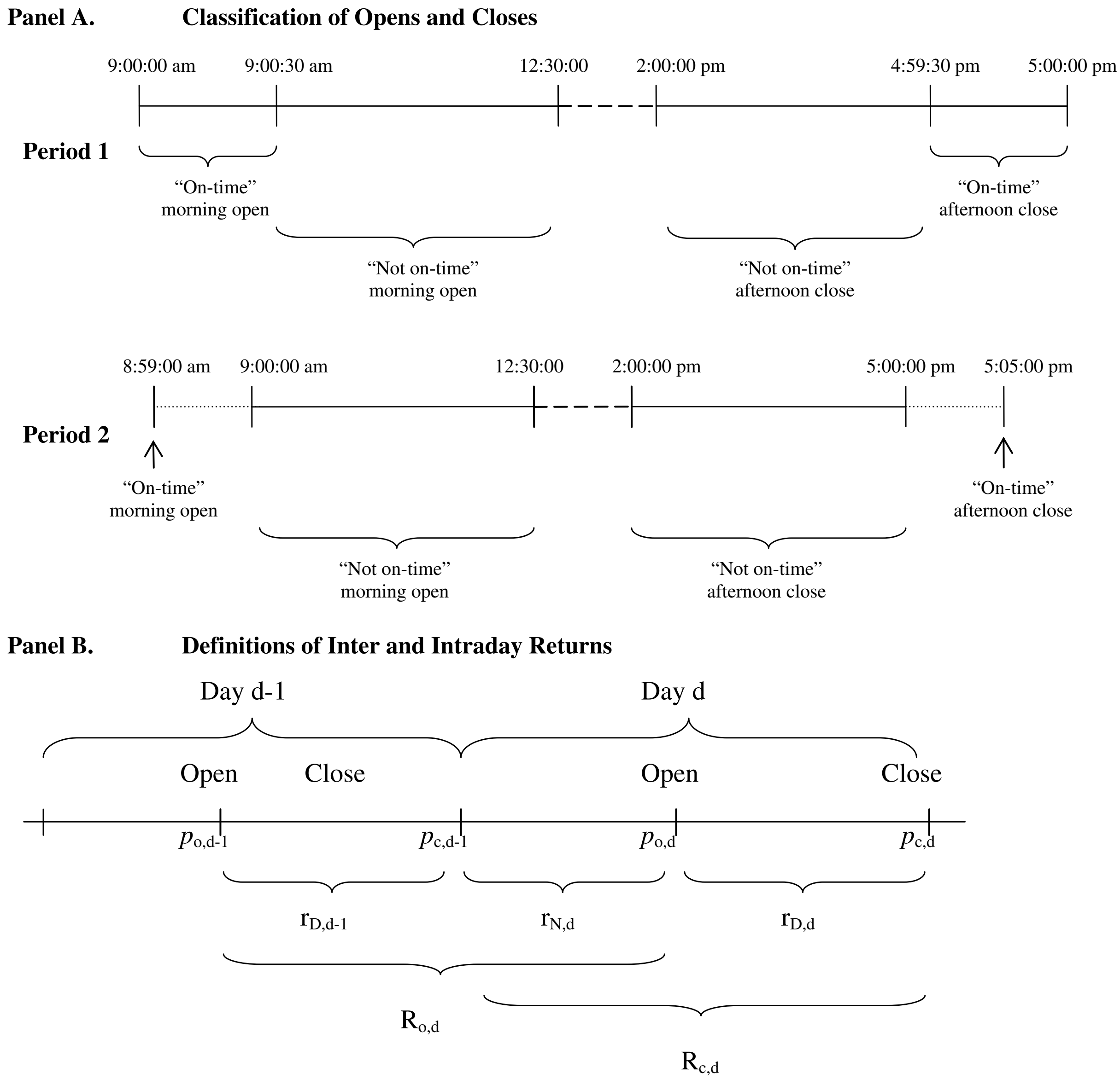

Fig. 1. Classification of opens and closes and definition of returns. Period 1 refers to the period between April 1, 2000 and July 31, 2000. Period 2 refers to the period between September 1, 2000 and December 31, 2000. Open refers to the morning opening transaction and Close refers to afternoon closing transaction. In Panel B, *p* refers to the opening and closing prices; r refers to intraday returns; R refers to interday returns; and the subscripts o, c, d, D, and N denote open, close, day d, day time, and night time, respectively. Panel A: Classification of opens and closes Panel B: Definitions of inter and intraday returns.

the SGX. IPO stocks and those stocks with zero trading volume in any one month during our study period are excluded from the data. The final sample of 352 stocks is sorted into two groups "active" and "inactive." The "active" stock group includes 140 stocks with an average of 50 trades or more per day in Period 1. The "inactive" stock group includes 212 stocks which average less than 50 trades per day in Period 1.[4] Summary statistics for the sample stocks in each of the two periods are presented in Table 1. In the last column, we also present the statistics for the Straits Times Index (STI) component stocks.[5]

There was a significant decline in trading activity among "active" stocks (1.93 million shares in Period 1 vs. 1.34 million shares in Period 2) but not for "inactive" stocks. The trading volume of "on-time" opens (closes) as a percentage of total daily volume increased from 1.67% to 2.06%

[4] Eighty and 100 trades per day were also used as cut-off criteria for classifying stocks as "active" or "inactive" but these alternative criteria do not affect the volatility or price manipulation findings. The 50-trade cut-off point was chosen as it provides a more balanced mix of "active" and "inactive" stocks.

[5] Not all STI component stocks belong to the "active" stock category. Of the 50 STI component stocks, 38 belong to the "active" stock category while the remaining 10 belong to the "inactive" category. Two stocks are excluded from the STI component stocks' set due to their change in status during the study period, but are retained in the full sample.

Table 1
Summary statistics

	Active			Inactive			STI			All		
	Period 1	Period 2	Change	Period 1	Period 2	Change	Period 1	Period 2	Change	Period 1	Period 2	Change
Daily number of trades	284	192	−92***	13	11	−2	305	295	−10	121	83	−38***
Daily trading volume (million shares)	1.932	1.341	−0.590***	0.071	0.078	0.007	1.389	1.445	0.057	0.811	0.580	−0.231***
"On-time" Morning Open Percentage Total Volume	1.67%	2.06%	0.39%*	14.05%	10.90%	−3.15%	1.07%	1.16%	0.09%	2.16%	2.97%	0.81%***
"On-time" Afternoon Close Percentage Total Volume	1.86%	5.52%	3.66%***	11.11%	16.48%	5.37%***	1.89%	4.57%	2.68%***	3.75%	8.31%	4.56%***
% Days Morning Open "On-time"	10.86%	22.18%	11.32%***	0.29%	1.69%	1.40%***	13.01%	33.56%	20.55%***	4.50%	9.84%	5.34%***
% Days Afternoon Close "On-time"	57.07%	54.53%	−2.54%	9.70%	12.30%	2.6%**	55.25%	65.22%	9.97%	28.54%	29.10%	0.56%
Number of Stocks			140			212			48			352

Active stocks have an average of 50 or more trades per day in Period 1. Inactive stocks have an average of fewer than 50 trades per day in Period 1. Period 1 is between April 1, 2000 and July 31, 2000 and Period 2 is between September 1, 2000 and December 31, 2000. "On-time" Morning Open Percentage Total Volume is the morning open volume as the percentage of the entire day's volume for "on-time" days. "On-time" Afternoon Close Percentage Total Volume is afternoon closing volume as percentage of the entire day's volume. "% Days Morning Open (Afternoon Close) On-time" refers to the percentage of days where the individual stock opens (afternoon closes) are on-time.

(1.86% to 5.52%) for "active" stocks. More opens and closes are "on-time" in Period 2 than in Period 1. "Active" stocks open and close "on-time" more frequently than "inactive" stocks. With the introduction of the CMM, the percentage of days with "on-time" opens increases significantly for both "active" and "inactive" stocks, while the percentage of days with "on-time" closes increases significantly for the "inactive" stocks only. The frequency of CMM on-time opens (closes) as a percentage is comparable to what is found by Comerton-Forde et al. (2007). The summary statistics compiled for STI component stocks is similar to that of "active" stocks.

4. Return volatility

4.1. Market-adjusted return volatility at the market open

A market model approach is used to examine market-adjusted return volatility changes that occurred between Periods 1 and 2 and between "on-time" and "not-on-time" opens. As a proxy for the market portfolio, we construct an equally-weighted market index comprising the 140 active stocks in our sample.[6] Following Amihud and Mendelson (1991), we use the daily observations of squared residual returns (multiplied by 1000) from the market model as the proxy for return volatility.[7] Table 2 reports the cross-sectional average of the squared residual returns depending upon whether the day's open (close) is "on-time" or "not-on-time."

4.1.1. Period 1 vs. Period 2 "on-time" return volatilities

Among the underlying sources of volatility, information flow and trading method are the most important. Fig. 2 schematically illustrates return volatilities for "on-time" and "not-on-time" opens (closes) in Periods 1 and 2 with the underlying sources of the volatility changes specified. Return volatility in Period 1, when opens (closes) are "on-time" and "not-on-time" are denoted $V1_{ot}$ and $V1_{not}$, respectively. Likewise, $V2_{ot}$ and $V2_{not}$ denote the return volatilities in Period 2 for "on-time" and "not-on-time" opens (closes).

The difference between $V1_{ot}$ and $V2_{ot}$ is attributable to both trading method and information flow. Trading method is critical because "on-time" opens in Period 2 rely on the CMM while those in Period 1 rely on the CAM. We expect trading volume at the market open to be larger under the CMM than the CAM because of the

[6] PACAP Singapore Data, and hence information on the number of shares outstanding, was unavailable for 2000. Consequently, an equally-weighted market portfolio return, rather than a market weighted portfolio return, was calculated. Daily market value information is available from Datastream but only for a subset of our "active" stocks. The number of stocks in the subset is 101 and the use of value-weighted market index returns based on this subset yields results that are qualitatively similar to what we report in this study.

[7] Returns greater than 50% or less than −50% are removed to eliminate the influence of extreme outliers from the sample.

Table 2
Impact of opening and closing calls on return volatility

		Today's morning open		Today's afternoon close	
		On-time	Not-on-time	On-time	Not-on-time
Active	Period 1	2.9749 $^{+++}$	1.0863	1.4319 $^{+++}$	0.6643
	Period 2	1.2587 $^{+++}$	0.8676	1.0449 $^{+++}$	0.8432
	Δ	−1.6710***	−0.2186***	−0.3870***	0.1789***
Inactive	Period 1	7.1572 $^{+++}$	1.2737	1.3543 $^{+++}$	0.9690
	Period 2	3.5693 $^{+++}$	1.7816	1.8461	1.6809
	Δ	−3.5879**	0.5079***	0.4919***	0.7119***
STI	Period 1	1.5751 $^{+++}$	0.7247	1.0227 $^{+++}$	0.4150
	Period 2	0.8948 $^{+++}$	0.5366	0.7227 $^{+++}$	0.4682
	Δ	−0.6803***	−0.1881***	−0.3000***	0.0532

Active stocks have an average of 50 or more trades per day during Period 1. Inactive stocks average of less than 50 trades per day during Period 1. Period 1 is from April 1, 2000 to July 31, 2000. Period 2 is from September 1, 2000 to December 31, 2000. The market model is used to estimate market-adjusted return volatility which is reported as the squared residual returns multiplied by 1000. Asterisks are used to indicate the significance level when examining changes between the two periods. The plus symbol refers to the significance of testing whether "on-time" return volatility is significantly different than "not-on-time" return volatility in the same period. *** and $^{+++}$ indicate significance at the 1% level; ** indicates significance at the 5% level.

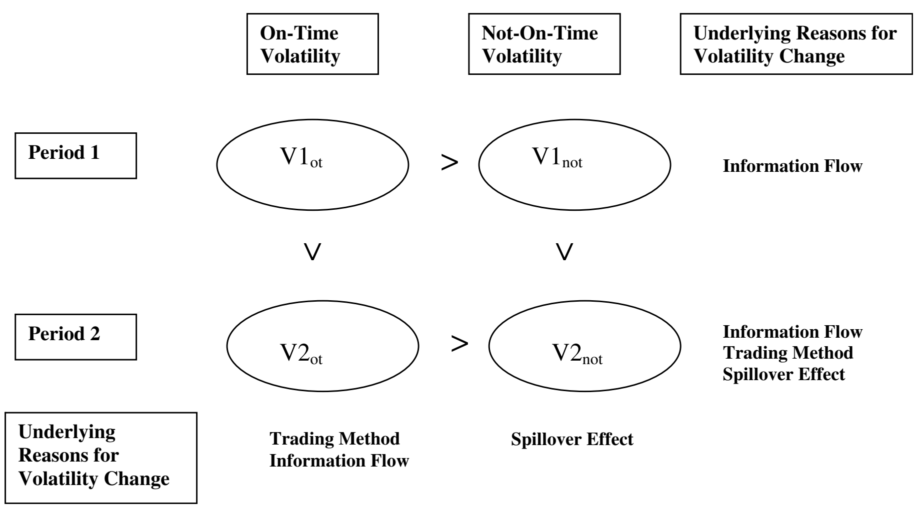

Fig. 2. Schematic illustration of return volatility. Fig. 2 depicts the relative return volatilities for "on-time" and "not-on-time" opens (closes) in periods 1 and 2 with the potential sources of the differences in volatilities. $V1_{ot}$ and $V1_{not}$ denote return volatilities in Period 1 when opens (closes) are "on-time" and "not-on-time," respectively. Likewise, $V2_{ot}$ and $V2_{not}$ are return volatilities in Period 2 for "on-time" and "not-on-time" opens (closes).

inherent nature of the CMM. Under the CMM, orders are batched for execution at a single price in order to maximize the number of shares executed while, under the CAM, orders are executed whenever submitted bids and offers cross. With the greater trading volume of the CMM comes greater information flow, as compared to the CAM. As a result, $V2_{ot}$ should be greater than $V1_{ot}$ if only information flow is considered. If $V2_{ot}$ turns out to be less than $V1_{ot}$, then the information flow effect is subsumed by the CMM or "trading method effect." Indeed, the overall results indicate that this is the case. When opens are "on-time," market-adjusted morning open-to-open return volatility for "active" stocks declines from 2.97 in Period 1 to 1.26 in Period 2, a decline of 58%. The large decline in "on-time" volatility observed for "inactive" stocks confirms the impact of the trading method effect. The STI component stocks exhibit results similar to those of the "active" stocks and also suggest that the CMM reduces volatility.

4.1.2. "On-time" vs. "not-on-time" return volatilities in Period 1

The difference between $V1_{ot}$ and $V1_{not}$ (2.97 vs. 1.09) for "active" stocks can be attributed to information flow as the CAM is the only trading method used in Period 1. "On-time" opens must be associated with larger information flow than "not-on-time" opens because the latter indicate a lack of trading interest due to the absence of significant information flow. Hence, we expect that $V1_{ot}$ will be greater than $V1_{not}$. Consistent with this prediction, significant differences do exist between "on-time" and "not-on-time" opening volatilities for "inactive" stocks (7.16 vs. 1.27).

4.1.3. Period 1 vs. Period 2 "not-on-time" return volatilities

The significant difference between $V1_{not}$ and $V2_{not}$ (1.09 vs. 0.87) for "active" stocks is of interest as the same trading method, the CAM, is used and there is no reason why information flow should not remain approximately equal in both periods. As Pagano and Schwartz (2003) report, when the Paris Bourse adopted the closing call system, the call generates a positive spillover effect on the next morning's opening trades. They suggest that the cause of the volatility change is the result of a "spillover" effect; hence, $V2_{not}$ is smaller than $V1_{not}$. The results shown in Table 2 indicate that only "active" stocks enjoy the spillover effect while "inactive" stocks do not. Interestingly, "inactive" stocks experience an increase in volatility in the second period (1.27 vs. 1.78). The question of why "active" stocks experience a spillover effect while "inactive" stocks do not is addressed in Section 5 using a multiple regression analysis.

4.1.4. "On-time" vs. "not-on-time" return volatilities in Period 2

In Period 2, the "on-time" and "not-on-time" volatilities are subject to at least three underlying sources of volatility. First, to the extent that "on-time" opens are associated with higher information flow than their "not-on-time" counterparts, $V2_{ot}$ should be greater than $V2_{not}$. However, since "not-on-time" opens rely on CAM while "on-time" opens rely on CMM, and as shown previously the CMM reduces volatility, $V2_{ot}$ may be less than $V2_{not}$. Additionally, the positive spillover effect may reduce the return volatility for "not-on-time" opens. Therefore, if $V2_{ot}$ is greater than $V2_{not}$, we may conclude that the information effect dominates both the trading method effect and the spillover effect. The return volatility for "on-time" opens is greater than for "not-on-time" opens for both "active" and "inactive" stocks. The "on-time" volatility of "active" stocks is 1.26 which can be compared to the "not-on-time" volatility of 0.87. "Inactive" stocks exhibit "on-time" volatility of 3.57 and "not-on-time" volatility of 1.78. Hence, the information effect dominates both the trading method effect and the spillover effect.

4.2. Market-adjusted return volatility at the market's close

Close-to-close return volatilities are reported in the last two columns of Table 2. The results are similar to those of the open-to-open return volatility. For the sake of brevity and to avoid a repetitive discussion, a concise summary of the major findings is presented. First, "active" stocks exhibit a significant decline in return volatility when the close is "on-time" ($V1_{ot}$ is 1.43 vs. $V2_{ot}$ of 1.04), indicating that the information flow effect is subsumed by the trading method effect. However, the opposite result occurs for "inactive" stocks even when their close is "on-time" (1.35 in Period 1 vs. 1.85 in Period 2) suggesting that inactive stocks do not benefit from the CMM and that the information effect dominates the trading method effect. Second, for both "active" and "inactive" stocks $V1_{ot}$ is greater than $V1_{not}$ highlighting the importance of information flow. Third, "not-on-time" volatility at market close increases from 0.66 in Period 1 to 0.84 in Period 2 for "active" stocks and from 0.97 in Period 1 to 1.68 in Period 2 for "inactive" stocks. After the CMM is introduced, both "active" and "inactive" stocks show increases in volatility when the close is "not-on-time." This suggests an increase in return volatility in Period 2 and that the spillover effect is not large enough to override the structural shift in volatility. Fourth, $V2_{ot}$ is greater than $V2_{not}$ for both "active" (1.04 vs. 0.84) and "inactive" stocks (1.84 vs. 1.68), indicating that the information flow effect dominates both the trading method effect and the positive spillover effect.

4.3. Multiple regression analysis of market-adjusted return volatility

The following two models are used to highlight the impact of the CMM on return volatility while controlling for trading volume and the shift in volatility levels between the two periods:

$$\begin{aligned}V^{\mathrm{o}}_{id} = {} & \alpha_0 + \alpha_1 T_{id} + \alpha_2 T_{id-1} + \alpha_3 M_{id} \\ & + \alpha_4 M_{id-1} + \alpha_5 A_{id-1} + \alpha_6 \mathrm{ACT}_{id} + \alpha_7 D_{\mathrm{d}} + \alpha_8 (M_{id} * D_d) \\ & + \alpha_9 (M_{id-1} * D_d) + \alpha_{10} (A_{id-1} * D_d) \\ & + \alpha_{11} (\mathrm{ACT}_{\mathrm{id}} * D_d) + \varepsilon_{id} \end{aligned} \tag{5}$$

$$\begin{aligned}V^{\mathrm{c}}_{id} = {} & \beta_0 + \beta_1 T_{id} + \beta_2 T_{id-1} + \beta_3 A_{id} + \beta_4 A_{id-1} + \beta_5 M_{id} \\ & + \beta_6 \mathrm{ACT}_{id} + \beta_7 D_d + \beta_8 (A_{id} * D_d) \\ & + \beta_9 (A_{id-1} * D_d) + \beta_{10} (M_{id} * D_d) + \beta_{11} (\mathrm{ACT}_{id} * D_d) + \varepsilon_{id} \end{aligned} \tag{6}$$

where, i refers to stock i and d refers to day d; V^{o} and V^{c} are market-adjusted open-to-open and close-to-close return volatilities, respectively; T is log of daily trading volume; M is a dummy variable equal to 1 if the day's open is "on-time," 0 otherwise; A is a dummy variable equal to 1 if the day's close is "on-time," 0 otherwise; ACT is a dummy variable equal to 1 for "active" stocks, 0 otherwise; and D is a dummy variable equal to 1 for Period 2, 0 otherwise.[8]

Because return volatilities are affected by trading volume, we introduce two trading volume variables. Since V^{o}, in regression model (5) incorporates two opening transactions straddling a closing transaction, we introduce M_{id}, M_{id-1}, and A_{id-1} to account for the impact of the CMM. Likewise, since V^{c} in regression model (6), involves two closing transactions straddling an opening transaction, we introduce A_{id}, A_{id-1}, and M_{id} to control for the impact of the CMM with two closing transactions and one opening transaction. If the CMM significantly reduces volatility, the estimated coefficients of $M_d{}^* D_d$ and $M_{d-1}{}^* D_d$ in regression model (5) and $A_d{}^* D_d$ and $A_{d-1}{}^* D_d$ in regression model (6) should be negative. Since the calcula-

[8] An STI dummy variable and the interaction term, STI * D were also examined. The estimated coefficients are similar to those of ACT and ACT * D but are not reported for the sake of brevity.

Table 3
Multiple regression analyses: interday return volatility

	Open-to-open return volatility			Close-to-close return volatility		
	All	Inactive	Active	All	Inactive	Active
T_d	0.0083	−0.0258	0.0415	0.1967	0.0435	0.3542
	(0.4105)	(0.0151)	(0.0003)	(<.0001)	(<.0001)	(<.0001)
T_{d-1}	0.0853	0.0183	0.1199	−0.1266	−0.0611	−0.1959
	(<.0001)	(0.0929)	(<.0001)	(<.0001)	(<.0001)	(<.0001)
M_d	0.1151	0.1637	0.1373	0.0521	0.0422	0.0489
	(<.0001)	(<.0001)	(<.0001)	(<.0001)	(0.0137)	(<.0001)
M_{d-1}	0.0623	0.2525	0.0423			
	(<.0001)	(<.0001)	(0.0004)			
A_d				0.0518	0.0327	0.0439
				(<.0001)	(0.0012)	(<.0001)
A_{d-1}	0.0233	0.0265	0.0105	−0.0053	0.0074	−0.0271
	(0.0054)	(0.0243)	(0.2921)	(0.5053)	(0.4619)	(0.0072)
ACT_d	−0.1049			−0.0698		
	(<.0001)			(<.0001)		
D_d	0.0762	0.0555	0.0445	0.1067	0.0888	0.0731
	(<.0001)	(<.0001)	(<.0001)	(<.0001)	(<.0001)	(<.0001)
$M_d{}^* D_d$	−0.0743	−0.1054	−0.1113	−0.0360	−0.0309	−0.0517
	(<.0001)	(<.0001)	(<.0001)	(<.0001)	(0.0726)	(<.0001)
$M_{d-1}{}^* D_d$	−0.0587	−0.2178	−0.0599			
	(<.0001)	(<.0001)	(<.0001)			
$A_d{}^* D_d$				−0.0392	−0.0115	−0.0655
				(<.0001)	(0.2801)	(<.0001)
$A_{d-1}{}^* D_d$	−0.0322	−0.0102	−0.0486	−0.0190	−0.0159	−0.0209
	(0.0008)	(0.4131)	(0.0002)	(0.0313)	(0.1384)	(0.1001)
$ACT^* D_d$	−0.0513			−0.0581		
	(<.0001)			(<.0001)		
Adj – R^2	0.0210	0.0199	0.0395	0.0207	0.0101	0.0534

This table reports the regression results from regression models (5) and (6) which examine market-adjusted morning open-to-open return volatility before and after the introduction of the call market method:

$$V^o_{id} = \alpha + \beta_1 T_{id} + \beta_2 T_{id-1} + \beta_3 M_{id} + \beta_4 M_{id-1} + \beta_5 A_{id-1} + \beta_6 \mathrm{ACT}_{id} + \beta_7 D_d + \beta_8 (M_{id} * D_d) + \beta_9 (M_{id-1} * D_d) + \beta_{10}(A_{id-1} * D_d) + \beta_{11}(\mathrm{ACT}_{id} * D_d) + \varepsilon_{id} \tag{5}$$

$$V^c_{id} = \alpha + \beta_1 T_{id} + \beta_2 T_{id-1} + \beta_3 A_{id} + \beta_4 A_{id-1} + \beta_5 M_{id} + \beta_6 \mathrm{ACT}_{id} + \beta_7 D_d + \beta_8 (A_{id} * D_d) + \beta_9 (A_{id-1} * D_d) + \beta_{10}(M_{id} * D_d) + \beta_{11}(\mathrm{ACT}_{id} * D_d) + \varepsilon_{id} \tag{6}$$

where, the subscript i and d refer to stock i and day d, respectively; T is the log of the current day's trading volume; M is a dummy variable equal to 1 if the day's open is "on-time," 0 otherwise; A is a dummy variable equal to 1 if the day's close is "on-time," 0 otherwise; ACT is an "active" stock group dummy variable equal to 1 if a stock is classified as actively traded, 0 otherwise; and D is a dummy variable equal to 1 in Period 2, 0 otherwise. The reported coefficients are standardized coefficients. P-values are reported in parentheses.

tion of V^o does not involve an afternoon closing price and V^c does not involve a morning opening price, a negative coefficient $A_{d-1}{}^* D_d$ in regression model (5) and $M_d{}^* D_d$ in regression model (6) imply a positive spillover effect from the CMM. Regression results are reported in Table 3. All coefficients are standardized so that they can be compared across variables and equations.[9]

In the first three regressions, which examine open-to-open return volatility, the estimated coefficient ACT is significant and negative indicating that "active" stocks are less volatile than "inactive" stocks. The coefficient D_d is significant and positive in all three regressions, suggesting that after controlling for trading volume, return volatility increased in the second period. The estimated coefficients $M_d{}^* D_d$ and $M_{d-1}{}^* D_d$ are negative and significant in the first three regressions indicating that volatility significantly declines when opens are "on-time," hence, the CMM reduces volatility at the open. The coefficient $A_{d-1}{}^* D_d$ is significant and negative for "active" stocks but not for "inactive" stocks, indicating that there is a positive spillover effect from the CMM but this spillover effect is limited to actively traded stocks.

The last three regressions in Table 3 report the results of regression model (6), close-to-close return volatility. Consistent with the first three regressions, the ACT dummy has a significant and negative coefficient while the D_d dummy has a significant and positive coefficient. The estimated coefficients $A_d{}^* D_d$ and $A_{d-1}{}^* D_d$ are significant and negative for all sample stocks and "active" stocks but not for "inactive" stocks. The interpretation of this result is that the CMM reduces volatility at afternoon close

[9] A standardized coefficient is computed by dividing the parameter estimate by the ratio of the sample standard deviation of the dependent variable to the sample standard deviation of the regressor.

for "active" stocks but does not benefit "inactive" stocks. The estimated coefficient $M_d{}^* D_d$ is significant and negative in each of the three regressions, indicating a positive spillover effect from the morning opening call for both "active" and "inactive" stocks.

To summarize, an examination of the interday return volatility reveals that the CMM significantly reduces return volatility at the open for both "active" and "inactive" stocks and at the close for "active" stocks. Moreover, the opening and closing CMM transactions produce a positive spillover effect but this effect is limited to "active" stocks.

4.4. Trading noise

To provide further insight into how the CMM affects the price discovery process, we employ two additional tests to detect changes in trading noise before and after the implementation of the CMM. The first evaluates intraday return correlations while the second examines changes in the deviations of stock prices from a proxy of intrinsic value.

4.4.1. Correlations between trading day and overnight returns

Trading noise is the temporary deviation of the stock price from its intrinsic value. This temporary departure is corrected quickly if the market is efficient. Such a departure and quick correction induces a negative return correlation. If the CMM improves the price discovery process, we should observe a less negative or more positive return correlation. Table 4 reports the regression results of the changes in correlations between trading day ($r_{\mathrm{D,d}}$) and overnight ($r_{\mathrm{N,d}}$) returns based on regression model (7):

$$r_{Did} = \alpha + \beta_1 T_{id} + \beta_2 T_{id-1} + \beta_3 \mathrm{ACT}_{id} + \beta_4 D_d + \beta_5 A_{id} + \beta_6 A_{id-1} + \beta_7 M_{id} + \beta_8 r_{Nid} + \beta_9 r_{Nid} * D_d + \beta_{10}(r_{Nid} * D_d) + \varepsilon_{id} \tag{7}$$

where subscript i and d refer to stock i and day d, respectively; r_{D} is the trading day return; r_{N} is the overnight return; all other variables have previously been defined in regression models (5) and (6).

Table 4 presents the regression results. The coefficient for r_{N} is significant and negative, indicating a significantly negative return correlation, whereas "active" stocks exhibit a less negative coefficient than "inactive" stocks after controlling for all confounding effects. The coefficient of the interaction term, $r_{Nid}{}^* D_d$, is significant and positive, suggesting that the return correlations became significantly less negative in Period 2 or more intuitively, trading noise subsided after the introduction of the CMM.

Table 4
Correlations between trading day returns and overnight returns

	All	Inactive	Active
T_{d}	0.1071 (<.0001)	0.0054 (0.3741)	0.1256 (<.0001)
$T_{\mathrm{d-1}}$	−0.0667 (<.0001)	−0.0055 (0.3582)	−0.0764 (<.0001)
$\mathrm{ACT_d}$	0.0037 (0.4433)		
D_{d}	−0.0253 (<.0001)	−0.0133 (0.0278)	−0.0370 (<.0001)
A_{d}	0.0150 (0.0021)	0.0260 (<.0001)	0.0066 (0.2960)
$A_{\mathrm{d-1}}$	−0.0252 (<.0001)	−0.0215 (0.0005)	−0.0244 (0.0001)
M_{d}	−0.0054 (0.2533)	−0.0090 (0.1361)	0.0073 (0.2637)
r_{Nd}	−0.6379 (<.0001)	−0.7044 (<.0001)	−0.5855 (<.0001)
$r_{\mathrm{Nd}}{}^* D_{\mathrm{d}}$	0.0946 (<.0001)	0.0631 (<.0001)	0.1714 (<.0001)
Adjusted R^2	0.3388	0.4415	0.2588

Table 4 reports the regression results from regression model (7) which examines the correlation between day-time and night-time returns:

$$r_{Did} = \alpha + \beta_1 T_{id} + \beta_2 T_{id-1} + \beta_3 \mathrm{ACT}_{id} + \beta_4 D_d + \beta_5 A_{id} + \beta_6 A_{id-1} + \beta_7 M_{id} + \beta_8 r_{Nid} * D_d + \beta_9 (r_{Nid} * D_d) + \varepsilon_{id} \tag{7}$$

where, the subscript i and d refer to stock i and day d, respectively; r_{D} is the day-time return; T is the log of the current day's trading volume; ACT is an "active" stock group dummy variable which equals 1 if the stock is classified as actively traded, 0 otherwise; D is a dummy variable equal to 1 in Period 2, 0 otherwise. A is a dummy variable equal to 1 if the day's afternoon close is "on-time," 0 otherwise; M is a dummy variable equal to 1 if the day's morning open is "on-time," 0 otherwise; r_{N} is the night-time return. The reported coefficients are standardized coefficients. P-values are reported in parentheses.

4.4.2. Change in pricing errors

Next, we conduct a test of the change in pricing errors caused by trading noise. In this analysis trading prices are compared to the two-day volume-weighted average price, a proxy for the intrinsic value of the stock.[10] The pricing error of a stock at time t on day d is defined as the weighted squared difference as shown in Eq. (8):

$$\mathrm{PE_{i,d,t}} = [100 * (P_{\mathrm{i,d,t}} - \mathrm{VWAP_{i,d-1,d}})/P_{\mathrm{i,d,t}}]^2 \tag{8}$$

where, the subscripts refer to stock i at time t on day d; PE is the pricing error; P is the trading price; and VWAP is volume-weighted average price. Representative trades are chosen to examine pricing errors at different points during the trading day. The representative trades chosen are the opening trade, closing trade, and the first trade in each one-hour period during the day's trading.

If the CMM effectively reduces trading noise, we should expect the changes in pricing errors to be negative for the opening trade and the closing trade when opens (closes) are "on-time." We should also expect the changes in pricing errors to be negative for other trades throughout the day if a positive spillover effect exists. Table 5 reports the change in pricing errors over the two periods.

Panel A of Table 5 presents the results of the morning session. The change in pricing errors for morning trades for "active" stocks is significant and negative regardless of whether the open is "on-time" or not indicating a decline

[10] We also examined the one-day and three-day volume weighted prices using them as proxies for intrinsic value. The results remain qualitatively similar.

Table 5
Changes in pricing errors

	Active		Inactive		STI	
	On-time	Not-on-time	On-time	Not-on-time	On-time	Not-on-time
Panel A: morning session						
Opening trade	−2.2592***	−1.9877***	−10.0892***	0.4163***	−5.7762***	−2.6180***
First trade between 9:00 and 10:00 A.M.	−2.0106***	−1.0073***	−8.1524	0.3690	−0.8427**	−0.9099***
First trade between 10:00 and 11:00 A.M.	−2.4724***	−0.6968***	−10.7172**	0.1845	−1.4302***	−0.5209***
First trade between 11:00 and 12:00 A.M.	−1.9981***	−0.5905***	−1.4844**	0.2202	−1.3670***	−0.3762***
Panel B: afternoon session						
Closing trade	−0.6007**	−1.3143***	0.5719	0.4091***	−2.5440***	−1.3460***
First trade between 4:00 and 5:00 P.M.	−1.1917***	0.0932	0.7713**	0.6694***	−1.0119***	0.0529
First trade between 3:00 and 4:00 P.M.	−1.4918***	0.0650	0.8104**	0.4230**	−1.1965***	−0.0286
First trade between 2:00 and 3:00 P.M.	−1.2829***	0.3717**	0.6055	0.3906**	−0.8812***	0.0199

Table 5 reports the change in pricing errors for representative trades between Period 1 and Period 2. Pricing error is defined as follows:

$$\mathrm{PE}_{i,d,t} = [100 * (P_{i,d,t} - \mathrm{VWMP}_{i,d-1,d})/P_{i,d,t}]^2 \tag{8}$$

where, $\mathrm{PE}_{i,d,t}$ is the pricing error for stock i at time t on day d; $P_{i,d,t}$ is the trading price for stock i at time t on day d; and $\mathrm{VWMP}_{i,d-1,d}$ is the volume-weighted average price across all trades from the beginning of day $d-1$ to the end of day d. Representative trades are chosen to examine pricing errors at different points of time during the day. Panel A displays the results of the morning session. The change in pricing error is based on whether the open is "on-time" or "not-on-time." Panel B displays the results of the afternoon session and the change in pricing errors is based on whether the close is "on-time" or not. Active stocks are stocks with an average of 50 or more trades per day during Period 1. Inactive stocks are stocks with an average of less than 50 trades per day during Period 1. Asterisks indicate the significance levels of t-tests of whether the change in pricing errors are different from zero. *** indicates significance at the 1% level; ** indicates significance at the 5% level; and * indicates significance at the 10% level.

in pricing errors after the CMM is introduced. The magnitude of the change in pricing error, when the open is "on-time," is much larger than when the open is "not-on-time." For "inactive" stocks, pricing errors are reduced on days with "on-time" opens and increase on days with "not-on-time" opens. This pattern of pricing errors is consistent with the CMM reducing trading noise and the existence of a positive spillover effect. "Inactive" stocks seem to benefit less from the introduction of the CMM. Not surprisingly, STI component stocks exhibit a pattern similar to that of the "active" stocks. The same conclusions can be reached from the results summarized in Panel B in the afternoon session indicating this result is robust.

5. Day-end price manipulation

One of the primary objectives of the SGX's introduction of the closing call was to reduce day-end price manipulation. Day-end price manipulation, or closing price manipulation, is one of the most common forms of trade-based manipulation. Various incentives exist for market participants to manipulate closing prices. Brokers can improve their performance on various measures of execution quality (Felixson and Pelli (1999) and McSherry and Sofianos (1998)), investment managers can improve the appearance of their fund's performance (Carhart et al. (2002), Bernhardt et al. (2005), Bernhardt and Davies (2005)), and arbitrage traders have incentives to manipulate closing prices on index expiration days.

When manipulating a closing price, the manipulator is attempting to create a temporary divergence between the market price and intrinsic value of a stock in such a way that the manipulator benefits from the inflated or deflated closing price. To do this, the manipulator attempts to create a short-term liquidity imbalance. In many cases the manipulator needs to create this imbalance for only a matter of minutes. While partaking in this activity, the manipulator is prepared to accept a loss on the manipulative transactions (Comerton-Forde and Putniņš, 2007). Creating a short term liquidity imbalance can be done either by placing several orders during the last moments before the market's close or a single order at the close. To create a departure from intrinsic value, the manipulator submits an order with either an inflated price or a deflated price as near to the end of the trading day as possible, or submits multiple orders with inflated or deflated prices during the last moments of trading. Such a strategy reduces the opportunity for other traders to take advantage of the disparity between market and intrinsic values before the day's closing price is determined. At least three recurrent price patterns can be observed if the closing price is manipulated. First, when the closing price deviates from the intrinsic value in the last moments of the trading day, creating a price reversal at the close, the market will quickly correct the discrepancy at next morning's open. Hence, overnight return reversals are likely to be observed following a manipulated close. This pattern may be described as a "double price reversal." This double price reversal is characterized by a sudden day-end price reversal followed by an offsetting reversal the following morning as the security's price returns to its intrinsic value.[11]

Second, manipulating the closing price higher (lower) than the intrinsic value leads to a higher (lower) than normal return for the security. Third, because a manipulator needs to create a liquidity imbalance to successfully manipulate the closing price, day-end trading volume will likely be greater than normal volume. Comerton-Forde and Putniņš (2007) find that when closing prices are manipulated upward, day-end returns are higher, trading volume is larger, bid and ask spreads are wider, and returns are likely to reverse the following morning.

In an effort to identify potential day-end price manipulation, we use two of the three patterns described above. First, double price reversals are identified. If a stock trades no higher (lower) than the day's morning open for 80% of the day, but closes higher (lower) than the morning opening price and this day-end reversal is followed by another reversal at the next morning's open, this stock satisfies the double price reversal criterion.[12] Next, we examine whether the same stock satisfies either the return test or the volume test. Under the return test, we confirm that the square of the last hour's return during the day is greater than the stock's average squared last hour return for the period. Under the volume test, we confirm that the last hour's trading volume during the day is larger than the stock's average last hour trading volume for the period. If a stock passes the double price reversal test and either the return or volume test, its closing price is considered to be non-normal (with indication of been manipulated). If not, we consider it as a normal close. After non-normal closes are identified, they are categorized into upward and downward closes depending upon whether the closing price is higher (lower) than the opening price on the same day.

5.1. The frequency distribution of potential manipulations at the market's close

Since Aggarwal and Wu (2006) find that illiquid stocks are more likely to be manipulated, both active and inactive stocks are examined. Also, to enhance the contrast between STI component stocks, upon which equity index futures are written and other active stocks, we exclude STI component stocks from the "active" and "inactive" stock categories. Thus, we compare three subsets of stocks: "active" stocks excluding STI stocks; "inactive" stocks excluding STI stocks; and STI component stocks. After we identify market closes that display indications of manipulation, the frequency distributions of seemingly manipulated closes are compared to normal closes on "on-time" and "not-on-time" days. Because of the tendency for manipulated closes to be "on-time," the frequency distribution of the two types of market closes should be significantly different if there were significant manipulation activities.

Table 6 reports the frequency distribution for upward price reversal at the market's close.[13] Fifty-seven percent of all normal closes for "active" stocks in Period 1 are "on-time." In contrast, 85% of non-normal closes (those with indications of manipulation) are "on-time." The difference between the distributions is significant, as indicated by a chi-square statistic of 6.34. The statistically significant difference suggests the existence of day-end price manipulation in Period 1. In Period 2, however, 52% of normal "active" stock closes are "on-time" while 65% of non-normal closes for the same group are "on-time." The difference is not statistically significant indicating an increasing similarity between the two frequency distributions and that active stocks experienced a reduction in manipulation after the CMM was introduced.

In Periods 1 and 2, the frequency distribution for "inactive" stocks is significantly different but with a smaller and less significant chi-square statistic in Period 2, suggesting the existence of manipulation in both periods but lower levels of manipulation in Period 2. For STI stocks, the overall results are identical to those of the active stocks: The frequency distributions are significantly different in Period 1 but not in Period 2, again suggesting that the introduction of the CMM reduced price manipulation. The frequency distributions in Table 6 also suggest that inactive stocks are more vulnerable to manipulation than active stocks in both periods. This result is consistent with the findings of Aggarwal and Wu (2006) who show that illiquid stocks are more likely to be manipulated.

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[11] A price reversal at the close is reported in an article in *The Straits Times*, Singapore's leading daily newspaper. The article entitled "SGX Measures Failed to Curb Manipulation" describes the following incident of market manipulation:

"How else is one to explain Tuesday's activity on the SGX, when the Straits Times Index opened at 9 a.m. at 1684.90, stayed in negative territory throughout the day to end at 1673.65 at 5 p.m., only to put on over 12 points in the 'post-trading' five-min session to finish at 1686.14?" The description of this incident suggests that closing price manipulation can be associated with a sudden day-end price reversal.

[12] Our results remain robust when increasing the cut-off point from 75% to 80% and 85%.

[13] We have also examined the frequency distribution of downward price reversals at the market's close. We find that the distribution of closes with downward price reversals on "on-time" and "not-on-time" days is insignificantly different from non-manipulated closes in both periods. We are grateful to an anonymous referee for pointing out that the intentional manipulation of closing prices downward is more complicated and quite different from upward manipulation and the occurrence of downward manipulation is rare. Our results may indicate that either there is not much downward manipulation on the SGX or our approach to detect day-end price manipulation does not successfully capture downward manipulation. The results are not reported for the sake of brevity but are available upon request.

Table 6
Frequency distribution of price reversal at the market's close

		Period 1		Period 2	
		% On-time	Chi-sq	% On-time	Chi-sq
Active (excluding STI)	Normal closes	57.07	6.3408	52.39	1.0294
	Non-normal closes	85.00	(0.0118)	64.71	(0.3103)
Inactive (excluding STI)	Normal closes	15.20	9.5753	25.04	3.9531
	Non-normal closes	46.15	(0.0020)	50.00	(0.0468)
STI	Normal closes	61.78	4.5177	71.54	0.1835
	Non-normal closes	91.67	(0.0335)	76.92	(0.6684)

Table 6 compares the frequency distributions of normal and non-normal closes on "on-time" and "not-on-time" days. Non-normal closes are identified in two steps: First, if a stock trades no higher (lower) than the day's morning open for 80% of the day, but closes higher (lower) than the morning opening price and this day-end reversal is followed by an offsetting reversal at the next morning's open, this stock satisfies the double price reversal criterion. Next, the same stock must satisfy either the return test or the volume test. Under the return test, the square of the last hour's return during a day must be greater than the stock's average squared last hour return for the period. Under the volume test, the last hour's trading volume during the day must be larger than the stock's average last hour trading volume for the period. If a stock passes the double price reversal test and either the return or volume test, we consider its closing price to have indications of manipulation. This closing transaction then belongs to "Non-normal closes" category. If not, it is defined as a "Normal close." After non-normal closes are identified, we sort them into upward (downward) closes depending upon whether closing prices are higher (lower) than the morning's opening price on the same day. This table reports only upward non-normal closes. Active stocks are stocks with an average of 50 or more trades per day during Period 1. Inactive stocks are stocks with an average of less than 50 trades per day during Period 1. STI denotes the Straits Times Index component stocks; Period 1 refers to the period between April 1, 2000 and July 31, 2000. Period 2 refers to the period between September 1, 2000 and December 31, 2000. *P*-values are reported in the parentheses.

Table 7
Magnitude of day-end price reversals

	On-time closes			Not-on-time closes			All closes		
	Period 1	Period 2	Δ	Period 1	Period 2	Δ	Period 1	Period 2	Δ
Active stocks (excluding STI)	2.4598	1.8629	−0.5969***	2.5035	2.3599	−0.1437	2.4759	1.9796	−0.4963***
Inactive stocks (excluding STI)	2.3926	2.0686	−0.3241*	3.7404	6.1835	2.4432***	3.1825	3.7732	0.5495***
STI	1.4093	0.9769	−0.4323***	1.0508	1.8302	0.7794***	1.3359	1.1215	−0.2144***

On days identified with price reversals from the frequency distribution in Section 5.1, we estimate the Stoll and Whaley (1991) measure of price reversals as defined by Eq. (9) below:

$$\mathrm{REV}_{d+1,i} = \begin{cases} r_{\mathrm{C},d,i} & \text{if } \mathrm{LPR}_{d,i} < 0 \\ -r_{\mathrm{C},d,i,} & \text{if } \mathrm{LPR}_{d,i} \geqslant 0 \end{cases} \tag{9}$$

where, the subscript i and d refer to stock i and day d; r_{C} is the closing return based on the last two trades of the day; LPR denotes the last two-hour's return prior to the market's close; REV denotes the actual magnitude of price reversals. A positive value for REV indicates a reversal and a negative value indicates a continuation. We modify the Stoll and Whaley measure REV to account for information-driven price changes typically associated with large-sized trades by computing a volume-weighted REV where the weight assigned is $(v_i)/\Sigma(v_i)$ and v represents the volume of the last trade of the day.*** indicates significance at the 1% level.

5.2. The magnitude of price reversals

The previous section identified closing prices which showed indications of price manipulation. We confirm whether the closing returns, measured by the last two trades of the day, exhibit price reversals from the last two-hour period prior to the market's close using a quantitative measure. We use the Stoll and Whaley (1991) measure, defined by Eq. (9), to assess the magnitude of the price reversals:

$$\mathrm{REV}_{\mathrm{d+1,i}} = \begin{cases} r_{\mathrm{C,d,i}} & \text{if } \mathrm{LPR}_{\mathrm{d,i}} < 0 \\ -r_{\mathrm{C,d,i,}} & \text{if } \mathrm{LPR}_{\mathrm{d,i}} \geqslant 0 \end{cases} \tag{9}$$

where, the subscripts i and d refer to stock i and day d respectively; r_{C} is the closing return based on the last two trades of the day; LPR denotes the last two-hour period return prior to the market's close; and REV denotes the primary statistic of interest, the magnitude of price reversals.[14] When estimating REV we modify the Stoll and Whaley measure to account for the information-driven price changes associated with large-sized trades by computing a volume-weighted REV where the weight assigned is $v_i/\Sigma v_i$ and v represents the volume of the last trade of the day.

Table 7 reports the magnitude of the return reversals. The magnitude of reversals declined significantly for "active" and STI stocks but increased for "inactive" stocks, as illustrated in the last column. The decline for "active" and STI stocks is consistent with a reduction in manipulation after the introduction of the CMM but the increase in magnitude for "inactive" stocks does not sup-

[14] We also use one-hour and 30-min period returns when examining closing price reversals. The results are qualitatively similar to the two-hour case and are not reported for the sake of brevity.

Table 8
Return volatility from the last two trades

	Period 1		Period 2	
	On time	Near on time	On time	Near on time
Active (excluding STI)	1.6790	0.1412***	0.0002 +++	0.2426***
Inactive (excluding STI)	0.3681	0.2291	0.0006 +++	0.2549***
STI	1.6290	0.1651***	0.0001 +++	0.0471***+

The return volatility of the last two trades of the day at the market's close (v_c), is measured by the square of the closing trades return, adjusted for liquidity, and the time-interval between the last two trades. It is defined as:

$$v_c = \left(\frac{\log(p_c/p_{c,-1})}{T \times \log(Q_c + Q_{c,-1})} \right)^2 \tag{10}$$

where, p_c is the closing trade price; $p_{c,-1}$ is the immediately preceding trade price; T denotes the time-interval between the two trades in hours; Q_c is the size of the closing trade; and $Q_{c,-1}$ is the size of previous trade. "On-time" closes are defined the same as in Fig. 1. "Near-on-time" closes are "not-on-time" closes which take place during the one-minute interval prior to "on-time" closes and "early" closes and include the rest of the "not-on-time" closes. In Period 1, "near-on-time" closes occur between 4:58:30 P.M. and 4:59:30 P.M., whereas in Period 2, "near-on-time" closes occur between 4:59:00 P.M. and 5:00:00 P.M.. The asterisks indicate the significance of t-tests with the "on-time" and "near-on-time" volatilities and the plus symbol indicates the significance of t-test between Period 1 and Period 2.*** and +++ indicate significance at the 1% level,** and ++ indicate significance at the 5% level, and * and + indicate significance at the 10% level.

port this conclusion. When the magnitude of reversals is calculated separately for "on-time" and "not-on-time" closes, the magnitude of reversals declined significantly for all three groups of stocks for "on-time" closes while the magnitude of reversals for "not-on-time" closes declined insignificantly for "active" stocks and increased significantly for "inactive" and STI stocks. This pattern of change in the magnitude of reversals suggests: (i) the CMM is effective in reducing day-end price manipulation; (ii) liquid stocks are more affected than illiquid stocks; and (iii) some of the reduction may not be due to the CMM eliminating manipulation activities but could be the result of a shift in manipulation activities to other times of the day in order to avoid the closing call.[15] We examine this issue later.

5.3. Changes in return volatility

Further evidence supporting the favorable impact of the CMM is found when examining the volatility of the last two trades of the day based upon whether the closing transaction is "on-time" or "near-on-time." We maintain the same definition of "on-time" closes used in Fig. 1 but "near-on-time" closes represent a subset of "not-on-time" closes. "Near-on-time" refers to the closes which take place during the one-minute interval before the market's close. "Near-on-time" closes are very similar to "on-time" closes in terms of information flow and trading intensity. However, because of the tendency for manipulated closes to be "on-time," comparing "on-time" closes with "near-on-time" closes provides valuable insights into the seriousness of the manipulation problem and how the CMM impacted manipulation. In Period 1, "near-on-time" closes occur between 4:58:30 P.M. and 4:59:30 P.M., whereas in Period 2 "near-on-time" closes occur between 4:59:00 P.M. and 5:00:00 P.M.

Table 8 reports the dramatic results. In Period 1, the return volatility of the last two trades for "on-time" closes was significantly higher than for "near-on-time" closes for active and STI stocks in Period 1 but not for inactive stocks. Given the very similar nature of "on-time" and "near-on-time" closes, we believe that the significantly higher volatility "on-time" closes is at least partially due to day-end price manipulation which tends to make closing trades "on-time." Between the two periods, volatility declined dramatically for all "on-time" closing stock groups but not for "near-on-time" days, with the exception of STI stocks. This is consistent with CMM reducing return volatility and manipulation at the market's close as the CMM is applicable to "on-time" closes only in Period 2. The return volatility of "near-on-time" STI stocks is significantly lower in Period 2 than in Period 1 possibly due to the positive spillover effect.

The results summarized in Tables 6–8 strongly indicate that the CMM effectively reduces price manipulation at the market's close.

5.4. Did price manipulation shift to earlier in the day?

Rather than stopping manipulative trading, it is possible that manipulators may have changed their activities to earlier times during the day to avoid the closing call. To address this issue we examine the return reversals of trades that occurred during the day's trading session but not at the market's open and close. We compute the Stoll and Whaley reversal measures for all trades except the closing and opening trades and average them across sample stocks and across all trading days in each period.

Table 9 presents the results. The magnitude of reversals declined significantly for active and STI component stocks, suggesting that there was no significant shift in manipula-

[15] We are grateful to an anonymous referee for alerting us to this issue.

Table 9
Magnitude of trade-to-trade return reversals

	Period 1	Period 2	Δ
Active stocks (excluding STI)	0.3610	0.1059	−0.2551***
Inactive stocks (excluding STI)	0.0863	0.4063	0.3200***
STI	0.0332	0.0167	−0.0165**

We estimate trade-to-trade return reversals using the Stoll and Whaley (1991) measure of price reversals as defined below:

$$\mathrm{REV}_t = \begin{cases} r_{t-1,t} & \text{if} r_{t-2,t-1} < 0 \\ -r_{t-1,t} & \text{if} r_{t-2,t-1} \geqslant 0 \end{cases} \tag{11}$$

where, the subscript t is time t; $r_{t-1,t}$ is the return from time $t-1$ trade to the time t trade; $r_{t-2,\,t-1}$ denotes the return from the time $t-2$ trade to the time $t-1$ trade. A positive value for REV indicates a reversal and a negative value indicates a continuation. We modify the Stoll and Whaley measure REV to account for information-driven price changes typically associated with large-sized trades by computing a volume-weighted REV where the weight assigned is $(v_i)/\Sigma(v_i)$ and v represents the volume of the trade at time t. *** indicates significance at the 1% level.

tive trading to other times in the day in these two subgroups of stocks. In contrast, inactive stocks show a significant increase in reversals, consistent with a shift in manipulative behavior from the day's end to other times in the day. Overall, the findings suggest that there was no shift in manipulative trading away from the market's close for liquid stocks but that illiquid stocks did experience a shift in manipulative trades away from the market's close to earlier times in the day. Therefore, the reduction in price manipulation at the market's close, as suggested in the previous sections, is due mainly to manipulators reducing their manipulative activity rather than shifting their manipulative activity to other times in the day. Although there is evidence of a shift in manipulative behavior away from the close, this problem is limited to illiquid stocks.

6. Conclusion

This paper has examined the impact of the change in trading method on the SGX's price discovery process and on market manipulation. After the introduction of the CMM, the SGX experienced an unambiguous improvement in its price discovery process for liquid stocks. This improvement is evidenced by a significant reduction in volatility at the open and close, less negative return correlations, and smaller pricing errors. We also observe that the CMM significantly reduced volatility and pricing errors even when the CMM is not used to open or close the market, which strongly supports the findings of Pagano and Schwartz (2003) regarding the existence of a positive spillover effect.

Challenging conventional wisdom, we find that illiquid stocks do not benefit as much, and in some cases at all, from the CMM. We find that the opening call significantly reduces return volatility for illiquid stocks, but that the closing call does not. We also find a smaller spillover effect for illiquid stocks.

On the basis of a frequency distribution analysis, Stoll and Whaley reversal measures, and an examination of the return volatility of the last two trades of the day, we find that price manipulation activity declined for "active" as well as STI component stocks. However, inactive stocks remain vulnerable to price manipulation. We also find evidence that price manipulation shifted away from the market's close. However, that shift is significant only for illiquid stocks.

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