Trading Activity in Stock Index Futures Markets: The Evidence of Emerging Markets

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This study investigates the trading activity of the Taiwan Futures Exchange (TAIFEX) and Singapore Exchange Derivatives Trading Limited (SGX-DT) Taiwan Stock Index Futures markets by analyzing the intraday patterns of volume and volatility. In addition, the market closure theory, which may explain such patterns, is examined. Overall, the trading pattern appears to be U-shaped for the TAIFEX futures and U+W-shaped for the SGX-DT. For the SGX-DT futures, volatility follows the same pattern as that of the number of price changes. For the TAIFEX futures, however, after the peak at the close of the spot market, the volatility in the TAIFEX futures drops consistently until the end of the day while volatility in the SGX-DT still reaches a smaller peak at the close of the futures market. In addition, a visual inspection of the intraday patterns of these two markets shows that the market closure theory can effectively explain the intraday patterns of these two markets. The empirical results support the market closure theory in that liquidity demand from traders rebalancing their portfolios before and after market closures creates larger volume and volatility at both the open and close. © 2002 Wiley Periodicals, Inc. Jrl Fut Mark 22:983–1003, 2002

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INTRODUCTION

A number of previous researchers have shown that intraday volume and volatility exhibit specific patterns. Wood, McInish, and Ord (1985), Harris (1986), and McInish and Wood (1990) all report evidence of greater return and volatility in NYSE stocks at the open and close, resulting in a U-shaped intraday pattern. Such a U-shaped pattern has also been found in the United Kingdom (see, e.g., Abhyankar et al., 1997; Kleidon & Werner, 1996), and Canada (McInish & Wood, 1990). In futures markets, similar U-shaped patterns also occur in soybean contract volume and volatility (Jordan et al., 1988); in S&P 500 index futures return, volume, and volatility (Ekman, 1992); and in foreign-exchange volatility (Harvey & Huang, 1991). Ederington and Lee (1993), however, found an L-shaped intraday pattern in the volatility of U.S. interest rate and currency futures.

Several theories have been proposed to explain this U-shaped pattern. Amihud and Mendelson (1987) attribute this market opening effect to "the trading mechanism" employed on the NYSE. Admati and Pfleiderer (1988) developed an asymmetric information model to explain how informed and uninformed traders would execute trades at the same time to create periods of high volatility and trade activity. Brock and Kleidon (1992) assert that much of the trading at the beginning and end of the trading day stems from the inability to trade when the market is closed.

This study investigates the trading activities of the Taiwan Futures Exchange (TAIFEX) and Singapore Exchange Derivatives Trading Limited (SGX-DT) Taiwan Stock Index Futures markets by analyzing the intraday patterns of volume and volatility. In addition, the market closure theory, which may explain such patterns, is examined.[1] The Taiwan stock index futures markets are of particular interest for empirical work in this area due to several factors. First, the Taiwan stock market is a rapidly expanding emerging market. Although extensive research has been conducted on the intraday patterns of stock and futures markets, few researchers have studied the intraday activities of emerging markets. It is well known that emerging stock markets are characterized by high volatility. The high volatility of emerging markets is marked by frequent,

[1]Note that the trading mechanism model of Amihud and Mendleson and the information model of Admati and Pfleiderer were not considered in the article because both of these models are incomplete descriptions of intraday patterns in volume and volatility. The trading mechanism model can potentially explain patterns at the open, but not at the close. The information model predicts that volume and volatility will move together, but does not specify when high volume/volatility should occur.

sudden changes in variance. Researchers found that stocks in emerging markets have a far stronger tendency to rise and fall together (Morck et al., 2000). Moreover, the market participants tend to engage in herding behavior (Chang et al., 2000). In addition, price manipulation is also likely to be easier in an emerging market where regulatory scrutiny is less stringent (Lee et al., 1999). Therefore, it is of significance to determine whether the trading patterns of emerging markets are different from those of other developed markets.

Second, the TAIFEX and SGX-DT futures markets possess unusual timing characteristics for their opening and closing periods. The TAIFEX closes 15 min after the stock market closes. This allows for an examination of the dual effect of the cash market close and the later futures market close by employing volume and volatility data. The SGX-DT futures market opens 15 min before the stock market opens and closes 15 min after the stock market closes. These distinctions allow us to examine the impact of opening and closing of trading on trading activity. Chang, Jain, and Locke (1995) report that volatility in the S&P 500 index futures market follows a W-shaped pattern (a U-shaped pattern during most of the day before the close of NYSE and a mini-U-shaped pattern until the close of the futures market). This evidence suggests that closing, irrespective of the trading mechanism, is associated with greater volatility. Lee and Mathur (1999) also found a similar W-shaped pattern for the NYSE and S&P 500 futures markets in volume and volatility; however, they found that the trading pattern of MMI futures market is distinct from such a W-shape. For the MMI futures, trading declines consistently after the close of the spot market. In contrast, the NYSE and S&P 500 futures continue to trade and reach a peak at the close of the futures market.

Finally, during the period of this study the SGX-DT futures contract extended its trading time from 2:30 p.m. to 7:00 p.m. This allowed for a comparison of the intraday patterns during cash trading and nontrading intervals. Diagler (1997) found that the T-bond futures possess individual U-shaped curves for both the day and night sessions, with the night session having a significantly lower level of volatility and activity. The author attributes this phenomenon to the cash nontrading and the minimal information created during these intervals.

It has to be mentioned that the trading structures of the TAIFEX and SGX-DT Taiwan stock index futures markets are different. The TAIFEX employs the electronic trading system while the SGX-DT futures are traded by the traditional open outcry trading system. There has long been a debate about what forces are important in determining the success of exchange-traded futures contracts. Daigler (1997) argues that open outcry is driven by a large number of market makers (scalpers), and these scalpers close their positions before the market closes for the day. Furthermore, TAIFEX has higher transaction costs and more stringent restrictions on foreign investors than SGX-DT. It will be interesting to see whether these differences between TAIFEX and SGX-DT result in different intraday patterns.

The results of the study show that although the closing periods of the TAIFEX and SGX-DT do have a high volume, the volume is less than that of the spot market closing interval. Similarly, while the opening interval of the SGX-DT market has a high volume, its volume is less than that of the 9:00 to 9:05 a.m. opening spot market interval. Volatility patterns, on the other hand, are distinct from volume. For the SGX-DT futures, volatility follows the same pattern as that of the number of price changes. For the TAIFEX futures, however, after the peak at the close of the spot market, the volatility in the TAIFEX futures drops consistently until the end of the day while volatility in the SGX-DT still reaches a smaller peak at the close of the futures market. This difference may be linked to the different mechanism of the SGX-DT and TAIFEX. For SGX-DT, there are a large number of market makers (scalpers), and the scalpers closing their positions before the futures market closure may result in larger trades and volatility for the closing period of the SGX-DT market. The afternoon session of the SGX-DT market also has larger values of volume at both its opening and closing time intervals; however, the volume is at much lower levels than that for the morning session. Because the cash stock market in Taiwan is not open in the afternoon, the level of trading activity is minimal for the afternoon session. Overall, these results are consistent with Daigler's Extended Market Closure theory where the cash market is dominant. The empirical tests of the market closure theory indicate that the clustering of trading around the spot market open and close is due to the desire of investors to exchange their exposure to price changes when the market is closed.

THEORIES OF INTRADAY PATTERNS

Amihud and Mendelson (1987) and Stoll and Whaley (1990) examine daily return variance for NYSE stocks. They find open-to-open return volatility to be significantly greater than close-to-close variance. The authors attribute this market opening effect to "the trading mechanism" employed on the NYSE, whereas Stoll and Whaley (1990) argue that it may also be attributable to market participants trading on private information. In a subsequent article, however, Amihud and Mendelson

(1991) attribute the higher opening price volatility primarily to information effects rather than to differences in trading mechanisms. The authors suggest that this pattern was caused by prices reacting only slowly to overnight information.

Admati and Pfleiderer (1988) developed an asymmetric information model to explain the strategy-trading behavior of informed and liquidity traders and the impact of their trading on volatility and trading volume. Their theory is based on an assumption that liquidity traders want to minimize adverse selection costs, while informed traders want to time their trades to maximize their advantage. The important consequence is that all strategic traders will choose to trade during the same time periods, which results in the intraday patterns of volume and volatility. However, this model does not address the precise timing of the patterns. Foster and Viswanathan (1990) use a similar game-theory model to explain patterns in returns volatility across weekdays, as well as intraday patterns. However, contrary to Admati and Pfleiderer, Foster and Viswanathan maintain that periods of high volume and high volatility need not move together.

An alternative explanation of intraday patterns was developed by Brock and Kleidon (1992). In their model, the liquidity demand from traders for rebalancing their portfolios before and after market closures creates larger bid–ask spreads at the open and close, as well as U-shaped patterns in volume and volatility. Gerety and Mulherin (1992) extend this market closure theory by arguing that investors are transferring the risk of holding a position while the market is closed. Using NYSE data, Gerety and Mulherin found that closing volume is positively related to expected overnight volatility, while volume at the open is positively related to both expected and unexpected volatility from the previous night, which is consistent with their argument.

Daigler (1997) extended Brock and Kleidon's market closure theory to an "extended market closure" theory applicable to derivatives markets. The mechanism of the derivatives markets, and in particular futures markets, is different from that of the equity market. There are a large number of market makers (scalpers), and both the scalpers and day traders close their positions before the market closes for the day. Arbitrageurs need to match their futures trades with trades in the underlying assets; therefore, both markets typically must be opened when arbitrageurs trade. Cash market dealers often hedge their inventory with futures shortly before the futures markets close. These activities, as interpreted by the extended market closure theory, imply that the opening and closing time for both the underlying cash and the futures markets will have large volume and high volatility. However, the volume and volatility should be greater for the dominant market at openings and closings. The extension of Daigler's model follows the contagion model of King and Wadhwani (1990), who state that trading in one market affects the price behavior in other related markets because the traders draw inferences from the primary market's observed price behavior. In particular, their model predicts a drop in price volatility upon the closing of an associated financial market. Daigler examined the behavior of the S&P 500, MMI, and T-bond futures contracts and found that the extended market closure theory explains most of the volatility and activity patterns of these futures contracts better than other theories.

DATA AND MARKET STRUCTURE OF TAIFEX AND SGX-DT

Futures contracts on the Taiwan stock index began trading on the SGX-DT on January 9, 1997, and on the TAIFEX on July 21, 1998. The SGX-DT futures contract uses the MSCI Taiwan index, which is composed of 77 larger stocks on the Taiwan stock exchange, as the underlying index. The TAIFEX futures contract uses the Taiwan capitalization weighted index, a value-weighted index of all common stocks (currently about 600) listed on the Taiwan Stock Exchange, as the underlying index. The return correlation between the two indices is 0.98. Table I

TABLE I
Main Features and Sample Statistics of SGX-DT and TAIFEX Futures Markets

	SGX-DT Futures	*TAIFEX Futures*
1. Underlying asset	MSCI Taiwan Index	Taiwan capitalization weighted index
2. Contract size	SGX-DT multiplied by US$100	TAIFEX multiplied by NT$200
3. Contract month	March, June, September, December and spot month	Spot month, the next calendar month, and the next three-quarter months
4. Trading hours	08:45–12:15 14:45–19:00	9:00–12:15 Taiwan time (Taiwan and Singapore have the same time zone)
5. Tick size	0.1 × US$100 = US$10 (currently about NT$330)	1 × NT$200 = NT$200
6. Average daily volume	5,838 (7017 for periods of 1998/7/21–2000/1/31)	2693
7. Daily mean return	0.0067% (0.0887% for periods of 1998/7/21–2000/1/31)	0.0496%
8. Sample standard deviation	2.38% (2.20% for periods of 1998/7/21–2000/1/31)	1.71%

shows the main features and sample statistics of SGX-DT and TAIFEX futures contracts.[2]

The time and sales data on SGX-DT and TAIFEX futures prices were examined for the period of August 1, 1997 to January 31, 2000 and July 21, 1998 to January 31, 2000, respectively. The data were provided by the Singapore Exchange Derivatives Trading Limited and the Taiwan Futures Exchange, respectively. Because the nearby futures contracts are usually the most actively traded, the data for nearby futures contracts were used. To avoid thin markets and expiration effects, however, we rolled over to the next nearest contract 1 week prior to expiration of the current contract.

The SGX-DT futures market employs the traditional open outcry trading system without designated market makers. The trade prices are entered by the pit reporters, who stand adjacent to the trading pit, with a time stamp only after a price change has been observed.[3] In contrast, the TAIFEX futures contracts are traded by the Electronic Trading System (ETS). When a customer places an order to the associate person (AP) of a Futures Commission Merchant (FCM), the AP will enter the orders to the TAIFEX through the ETS. Once the trades are matched, the transaction results will be transmitted through the ETS back to the FCMs, who will, in turn, confirm these trades with their customers.

METHODOLOGY

For this study, the trading hours of the morning session in each market are divided into 5-min intervals. The first time interval between the SGX-DT (TAIFEX) data is 8:45:00–8:49:59 (9:00:00–9:04:59) and the last time interval is 12:10–12:15.[4] In other words, there are 36 intervals of 5 min for the SGX-DT data and 33 intervals for the TAIFEX data. For each interval, if no trades occur, the closing price of the last interval is

[2]Note that the average daily volume is much lower for the TAIFEX futures. This may arise from the fact that TAIFEX has higher transaction costs and more stringent restrictions. There is 0.05% transaction tax required when trading the TAIFEX futures. Moreover, there are more trading restrictions on foreign investors for TAIFEX. Also note that the daily mean return and standard deviation for the common sample period, 1998/7/21–2000/1/31, are higher for SGX-DT futures. The possible reason may be that the underlying MSCI Taiwan index substantially outperformed the Taiwan capitalization weighted index, but was more volatile. The daily mean return is 0.0893% for MSCI Taiwan index and 0.0598% for Taiwan capitalization weighted index. Similarly, the sample standard deviation for MSCI Taiwan index and Taiwan capitalization weighted index are 4.82 and 1.59%, respectively, with the MSCI Taiwan index more volatile.

[3]The afternoon session of the SGX-DT futures contracts are traded on its automatic trading system from 2:45 p.m. to 7:00 p.m. Singapore time.

[4]The market closed at 11:15 a.m. on each Saturday before March 21, 1998. To prevent the Saturday closing effect from confusing the empirical results, the Saturday data are deleted in this study.

retained as the open, high, low, and closing prices for that interval. During the sample period, the SGX-DT (TAIFEX) does not have trades reported in 0.05 (0.11) percent of the 5-min intervals. For the afternoon session of the SGX-DT data, the trading is divided into 30-min intervals to offset the thin trading, resulting in eight intervals.

Intraday returns are calculated for each interval as:

$$R_{i,t} = \ln(C_{i,t}/C_{i-1,t}) \tag{1}$$

where $R_{i,t}$ is the intraday return on day t in interval i, and $C_{i,t}$ represents the intraday closing price on day t in interval i. Volatility is measured in two ways. First, the squared returns are used as the proxy of volatility, which is calculated as follows:

$$\sigma_{i,t}^2 = [\ln(C_{i,t}/C_{i-1,t})]^2 \tag{2a}$$

For the first interval (i = 8:45 for SGX-DT, and i = 9:00 for TAIFEX), because there is no value for $C_{i-1,t}$, the volatility is calculated as follows:

$$\sigma_{i,t}^2 = [\ln(C_{1,t}/O_{1,t})]^2 \tag{2b}$$

where $O_{1,t}$ represents the intraday opening price on day t in the first interval. Second, the open, high, low, and closing prices for each interval are used to calculate each interval's Garman-Klass (Garman & Klass, 1980) (G-K) volatility measure. This measure is typically considered to be a superior measure of volatility and has been calculated as:

$$\sigma_{i,t}^2 = 1/2[\ln(H_{i,t}) - \ln(L_{i,t})]^2 - [2\ln(2) - 1] \times [\ln(C_{i,t}) - \ln(O_{i,t})]^2 \tag{3}$$

where $H_{i,t}$ and $L_{i,t}$ are the highest and lowest prices, respectively, in interval i on day t. The resultant Garman-Klass and squared returns volatility measures are multiplied by 100,000 to adjust for scale.

The number of contracts for each interval is used to examine the trading volume of the TAIFEX contracts. For the SGX-DT market however, the actual intraday volume data are not released to the public. Therefore, the number of price changes is used as a proxy for SGX-DT volume.

The statistical inference of the intraday pattern of the futures market is examined by the following equation based on Foster and Viswanathan (1993) and Chan et al. (1995):

$$Y_{i,t} = a_0 + \sum_{i=1}^{18} a_i D_i + \varepsilon_{i,t} \tag{4}$$

where $Y_{i,t}$ is the variable (volume or volatility) being examined, and D_is are dummy variables defined as follows:

$D_1 = 1$ if $i = 1$ (8:45–8:50 interval), 0 otherwise;
$D_2 = 1$ if $i = 2$ (8:50–8:55 interval), 0 otherwise;
$D_3 = 1$ if $i = 3$ (8:55–9:00 interval), 0 otherwise;
$D_4 = 1$ if $i = 4$ (9:00–9:05 interval), 0 otherwise;
$D_5 = 1$ if $i = 5$ (9:05–9:10 interval), 0 otherwise;
$D_6 = 1$ if $i = 6$ (9:10–9:15 interval), 0 otherwise;
$D_7 = 1$ if $i = 7$ (9:15–9:20 interval), 0 otherwise;
$D_8 = 1$ if $i = 8$ (9:20– 9:25 interval), 0 otherwise;
$D_9 = 1$ if $i = 9$ (9:25–9:30 interval), 0 otherwise;
$D_{10} = 1$ if $i = 10$ (11:30–11:35 interval), 0 otherwise;
$D_{11} = 1$ if $i = 11$ (11:35–11:40 interval), 0 otherwise;
$D_{12} = 1$ if $i = 12$ (11:40–11:45 interval), 0 otherwise;
$D_{13} = 1$ if $i = 13$ (11:45–11:50 interval), 0 otherwise;
$D_{14} = 1$ if $i = 14$ (11:50–11:55 interval), 0 otherwise;
$D_{15} = 1$ if $i = 15$ (11:55–12:00 interval), 0 otherwise;
$D_{16} = 1$ if $i = 16$ (12:00–12:05 interval), 0 otherwise;
$D_{17} = 1$ if $i = 17$ (12:05–12:10 interval), 0 otherwise;
$D_{18} = 1$ if $i = 18$ (12:10–12:15 interval), 0 otherwise.

The coefficients for the dummy variables, a_1 through a_{18}, measure the variations in the variable during the intervals immediately after the cash and futures open and prior to their closing, relative to the interval between 9:30 a.m. and 11:30 a.m.

Both SGX-DT and TAIFEX futures volume grow with time. For volume a time trend (T) is therefore included in Equation 4,

$$Y_{i,t} = a_0 + \lambda T + \sum_{i=1}^{18} a_i D_i + \varepsilon_{i,t} \tag{5}$$

Equations 4 and 5 are estimated by the Generalized Method of Moment (GMM) of Hansen (1982) to ensure robustness to autocorrelation and heteroscedasticity. Because the system is just identified, the GMM estimates are identical to those from OLS, but the standard errors differ.

INTRADAY PATTERNS IN TAIWAN STOCK INDEX FUTURES

Patterns in Volume

Figures 1 and 2 show the volume patterns of the SGX-DT and TAIFEX, respectively. Careful examination of the figures reveals that while the closings (12:10 to 12:15 interval) of the SGX-DT do have a high volume, the volume is less than that of the stock market closing interval from 11:55 to 12:00 Taiwan time. (Taiwan and Singapore have the same time

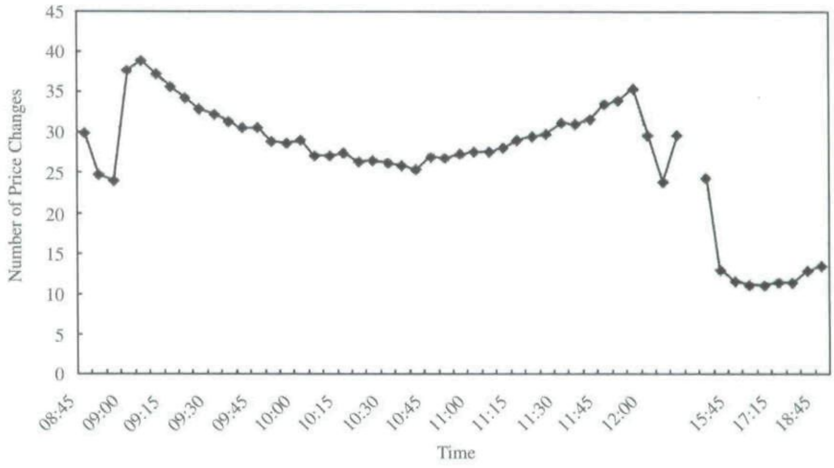

FIGURE 1
Intraday pattern of number of price changes in the SGX-DT futures market.

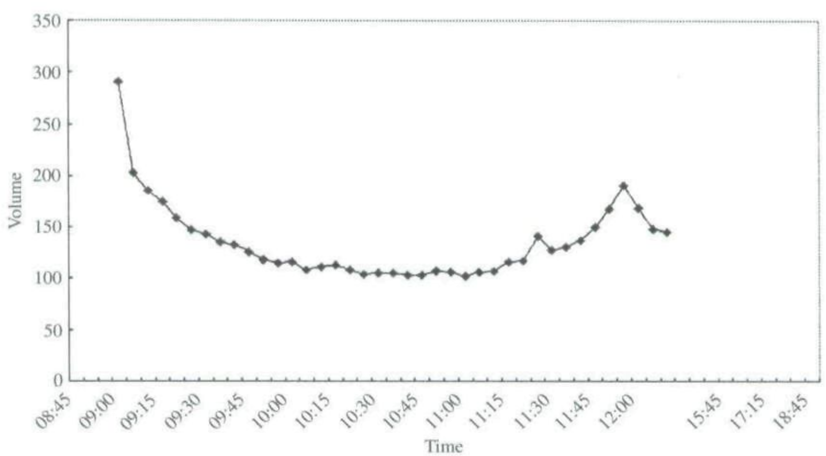

FIGURE 2
Intraday pattern of volume in the TAIFEX futures market.

zone.) Moreover, although the opening interval of the SGX-DT market has a high volume, its volume is less than that of the 9:00 to 9:05 a.m. opening stock market interval. These results are consistent with Daigler's Extended Market Closure theory where the cash market is dominant. For TAIFEX, the morning opening periods have the highest volume compared to the rest of the day. The 15 min before the closing of the TAIFEX also sees more trades occurring. Overall, the results for TAIFEX futures show a U-shaped pattern, similar to the findings in Ekman (1992) for the S&P 500 index futures pattern in volatility. The results for SGX-DT futures show that there is an additional U-shaped pattern for the futures trading prior to the opening of the cash market, resulting in a U+W-shaped pattern, similar to the finding in Lee and Mathur (1999) for the MMI futures pattern in volatility.

The afternoon session of the SGX-DT market also has larger values of volume at both its opening and closing time intervals; however, the volume is at much lower levels than for the morning session, suggesting that information created during these intervals is minimal. Because the cash stock market in Taiwan is not open in the afternoon, the overall level of trading activity is minimal for the afternoon session. This provides additional support for the importance of cash market closure on trading activity.

Patterns in Volatility

The intraday volatility data of the SGX-DT and TAIFEX are shown in Figures 3 and 4, respectively. To be consistent with the sample period of the TAIFEX, this study also plots the patterns for the period of July 21, 1998 to January 31, 2000 for SGX-DT. In average, the patterns of the SGX-DT are very similar for these two periods. The volatility for SGX-DT

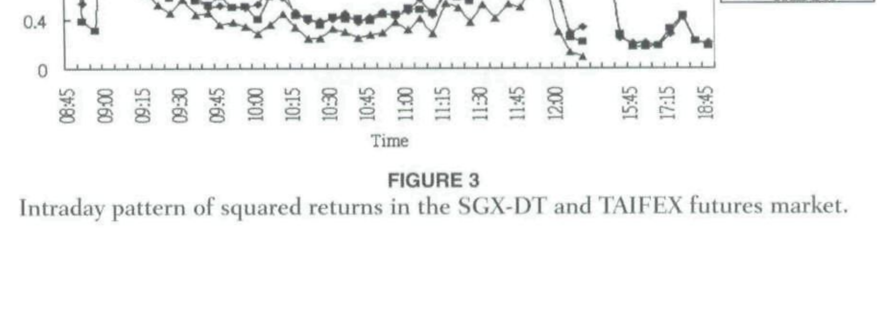

FIGURE 3
Intraday pattern of squared returns in the SGX-DT and TAIFEX futures market.

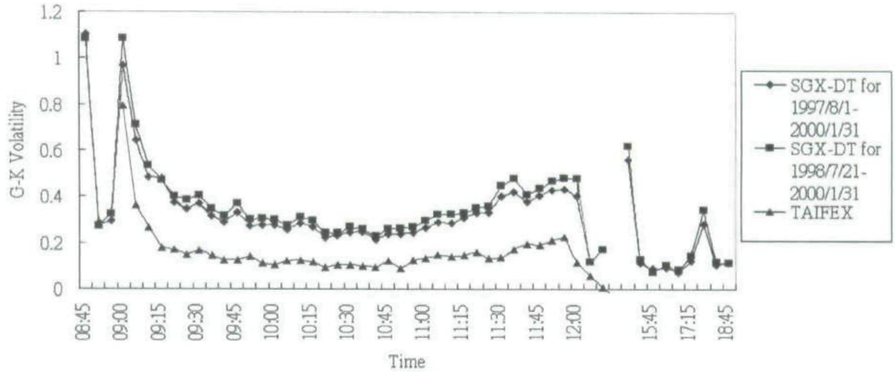

FIGURE 4
Intraday pattern of G-K volatility in the SGX-DT and TAIFEX futures market.

futures are higher than that for TAIFEX futures, this may arise from that the underlying MSCI Taiwan index is more volatile than the Taiwan capitalization weighted index.

For the TAIFEX market, an opening peak occurs in the first time interval, as was seen in the volume patterns. There is also no peak at the TAIFEX closing (the 12:10 to 12:15 p.m. interval), the highest closing volatility interval occurs at the cash stock market closing (the 11:55 to 12:00 interval). For the SGX-DT futures, although there is a peak at the futures closing, the highest closing volatility interval occurs at the cash stock market closing (the 11:55 to 12:00 a.m. interval) for both volatility measures. Contrary to the close, there is a large peak at the start of SGX-DT futures trading prior to the opening of the cash market. Perhaps market participants hunting for appropriate starting prices cause significant volatility in futures prices at market openings. Overall, these results are consistent with the Extended Market Closure theory where the cash market is dominant.

The volatility patterns of the afternoon session of the SGX-DT market are similar to its volume patterns. However, careful examination of the figures reveals that the peak in closing volatility occurs during the 17:45 to 18:15 interval, rather than during the futures closing interval. This difference is a unique finding, which may suggest that factors other than market closure may be an important component for the closing of this market.

STATISTICAL TESTS OF SIGNIFICANCE

Table II presents the GMM with Newey-West heteroskedasticity and autocorrelation consistent (HAC) estimates of the intraday variations in volume and volatilities. Overall, the results match the intraday

TABLE II

Generalized Method of Moments Estimates of Variations in Volume, Squared Returns, and G-K Volatility for SGX-DT and TAIFEX Stock Index Futures

	Number of Price Change		*Squared Returns*		*G-K Volatility*	
	Coefficient	*t-Statistics*	*Coefficient*	*t-Statistics*	*Coefficient*	*t-Statistics*
Panel A: The Estimates of SGX-DT Morgan Taiwan Stock Index Futures						
T	0.0008	32.24*				
D_1(8:45–8:50)	1.7630	3.608*	1.5652	5.47*	1.2596	7.89*
D_2(8:50–8:55)	−3.3660	−7.19*	0.0243	0.25	0.0848	1.57
D_3(8:55–9:00)	−4.2141	−9.79*	0.4679	0.94	0.0274	0.47
D_4(9:00–9:05)	9.6232	20.09*	1.3337	6.05*	0.7597	7.91*
D_5(9:05–9:10)	10.8346	22.52*	1.1376	2.85*	0.4796	7.35*
D_6(9:10–9:15)	9.1178	18.72*	0.4995	4.69*	0.2845	6.89*
D_7(9:15–9:20)	7.6101	16.43*	0.3712	4.62*	0.2587	4.50*
D_8(9:20–9:25)	6.2017	13.63*	0.1939	2.95*	0.1224	5.29*
D_9(9:25–9:30)	4.7811	11.14*	0.1266	2.32*	0.0887	3.89*
D_{10}(11:30–11:35)	2.9352	6.69*	0.2523	2.01*	0.1097	2.93*
D_{11}(11:35–11:40)	2.7878	6.10*	0.2300	1.96*	0.1246	2.57*
D_{12}(11:40–11:45)	3.4099	7.11*	0.2019	2.87*	0.1104	3.79*
D_{13}(11:45–11:50)	5.2839	11.24*	0.3703	3.50*	0.1549	5.28*
D_{14}(11:50–11:55)	5.8542	12.37*	0.2825	5.19*	0.1603	6.18*
D_{15}(11:55–12:00)	7.1465	15.29*	0.2378	3.54*	0.1723	6.35*
D_{16}(12:00–12:05)	1.3701	3.07*	0.1195	0.56	0.1355	0.91
D_{17}(12:05–12:10)	−4.4049	−10.54*	−0.2188	−2.96*	−0.1397	−7.54*
D_{18}(12:10–12:15)	1.4724	3.45*	−0.1703	−3.40*	−0.0509	−1.68
R^2		0.2937		0.0108		0.0371

	Intraday Volume		*Squared Returns*		*G-K Volatility*	
	Coefficient	*t-Statistics*	*Coefficient*	*t-Statistics*	*Coefficient*	*t-Statistics*
Panel B: The Estimates of TAIFEX Taiwan Stock Index Futures						
T	0.0041	8.01*				
D_4(9:00–9:05)	176.55	16.39*	0.8735	4.98*	0.6649	6.00*
D_5(9:05–9:10)	89.203	13.79*	0.6314	6.00*	0.2354	8.76*
D_6(9:10–9:15)	71.183	11.92*	0.4592	5.68*	0.1405	4.74*
D_7(9:15–9:20)	60.453	10.01*	0.2523	4.21*	0.0496	3.39*
D_8(9:20–9:25)	45.666	8.52*	0.1539	2.14*	0.0434	1.92
D_9(9:25–9:30)	33.176	6.86*	0.0879	1.85	0.0200	1.50
D_{10}(11:30–11:35)	13.657	2.85*	0.1556	2.14*	0.0098	0.75
D_{11}(11:35–11:40)	17.208	3.28*	0.0420	0.99	0.0415	2.07*
D_{12}(11:40–11:45)	24.165	4.39*	0.1576	2.55*	0.0677	2.93*
D_{13}(11:45–11:50)	36.298	5.88*	0.1308	2.70*	0.0626	2.43*
D_{14}(11:50–11:55)	54.311	8.56*	0.3116	2.14*	0.0806	3.27*
D_{15}(11:55–12:00)	77.823	10.95*	0.3664	4.27*	0.0979	4.07*
D_{16}(12:00–12:05)	54.879	8.41*	−0.0618	−1.69	−0.0128	−1.02
D_{17}(12:05–12:10)	34.096	6.26*	−0.2294	−9.02*	−0.0712	−7.72*
D_{18}(12:10–12:15)	31.471	5.59*	−0.2715	−10.16*	−0.1191	−13.82*
R^2		0.1307		0.0189		0.0324

Note.

$$Y_{i,t} = a_0 + \lambda T + \sum_{i=1}^{18} a_i D_i + \varepsilon_{i,t}$$

where $Y_{i,t}$ is the variable (volume or volatility) being examined, T is the time trend, and D_is are dummy variables. An asterisk beside the t-statistic indicates significance at the 5% level.

patterns plotted. Moreover, there is strong evidence of intraday variations in trading volume and volatilities for both markets. The SGX-DT results are presented in Panel A. The coefficients of D_4 through D_{15} for SGX-DT volume and volatility measures are significantly positive, suggesting that both futures trading volume and volatility are higher during the cash stock open (9:00 to 9:30) and during the cash stock close (11:30 to 12:00) than during the rest of the day.

Panel B reports the results for TAIFEX futures. Most of the cash opening and closing dummy variable coefficients are positive and significant at the 5% level. This result suggests that both futures trading volume and volatility are higher during the cash stock opening (9:00 to 9:20) and during the cash stock closing (11:40 to 12:00) than during the rest of the day. The dummy variable for the cash stock market opening (D_4) is positive and significant in the volume, squared returns, and G-K volatility equations. Moreover, the coefficients are higher than other intervals, suggesting that volume and volatility are highest during the cash stock opening. Note that the coefficients of D_1–D_3 are missing because the TAIFEX opens at 9:00 a.m.

Overall, the trading pattern appears to be U-shaped for the TAIFEX futures and U+W-shaped for the SGX-DT. For the SGX-DT futures, volatility follows the same patterns as that of the number of price changes. For the TAIFEX futures, however, after the peak at the close of the spot market, the volatility in the TAIFEX futures drops consistently until the end of the day while the SGX-DT futures are still volatile and reach a smaller peak at the close of the futures market. This difference may be linked to the different mechanism of the SGX-DT and TAIFEX. For SGX-DT, there are a large number of market makers (scalpers), and the scalpers closing their positions before the futures market closure may result in larger trades and volatility for the closing period of the SGX-DT market. In addition, after a visual inspection of the intraday patterns of these two markets, it is found that the market closure theory can explain well the intraday patterns of these two markets. Next, we will empirically test the market closure theory.

EMPIRICAL TESTS OF THE MARKET CLOSURE THEORY

According to Gerety and Mulherin (1992), investors are different in their willingness and ability to hold positions overnight. Those investors having relatively less ability to bear overnight risk will exchange their positions with investors having a greater ability to bear overnight risk; therefore, the volume at the end of the day should be directly related to the volatility expected to occur overnight. The greater the expected overnight volatility, the heavier the volume at the close will be. Correspondingly, if the investors that transfer overnight risk reacquire their positions at the next day's open, then the same factors affecting volume at one day's close should also affect volume at the next day's open. Hence, opening volume should be directly related to the expected volatility from the previous night. In addition, the higher the unexpected overnight volatility, the higher the investors' demand for rebalancing portfolios at the open, and consequently, the higher the volume at the open will be.

To perform the empirical tests, we computed estimates of expected and unexpected overnight volatility. The estimation procedure follows a two-step approach of the type originally pioneered by Barro (1977) and subsequently used by Schwert and Seguin (1990) and Zhang et al. (2001). In the first step, the overnight volatility is computed. The volatility equation is then estimated using ARMA models. The fitted values from this equation serve as estimates for expected volatility in a second volume/volatility equation, and the residuals from the volatility equation are used to measure unexpected volatility in the second step.

We use the conditional means and residuals from the ARMA model as the corresponding anticipated and unanticipated sequences. The ARMA model is of the following form:

$$\sigma^2_{\text{overnight},t} = a_0 + a_1 \sum_{i=1}^{36} \sigma^2_{i,\,t} + \sum_{j=1}^{p} b_j \sigma^2_{\text{overnight},t-j} + \sum_{k=1}^{q} c_k \varepsilon_{t-k} + \varepsilon_t \qquad (6)$$

where $\sigma^2_{\text{overnight},t}$ is the overnight volatility on day t,

$$\sum_{i=1}^{36} \sigma^2_{i,t}$$

is the sum of squared 5-min returns from the open to the close on day t, $\sigma^2_{\text{overnight},t-j}$ and ε_{t-k} are the AR and MA terms for volatility, respectively, p and q are lag lengths chosen by the Schwarz criterion. The sum of intraday squared returns is advocated by Andersen and Bollerslev (1998) as being an accurate measure of the volatility, with the higher the frequency, the better the results. The lagged overnight volatilities would capture the effects of overseas

TABLE III
The ARMA Results for SGX-DT and TAIFEX

Variable	*Coefficient*	*t-Statistic*
	Panel A: SGX-DT	
a_0	9.4882	2.79*
a_1	0.2401	4.80*
b_1	0.1798	4.46*
Durbin-Watson statistic		1.9847
R^2		0.1401
	Panel B: TAIFEX	
a_0	7.2044	2.02*
a_1	0.1313	2.16
Durbin-Watson statistic		2.0378
R^2		0.1600

Note.

$$\sigma^2_{\text{overnight},t} = a_0 + a_1 \sum_{i=1}^{36} \sigma^2_{i,t} + \sum_{j=1}^{p} b_j \sigma^2_{\text{overnight},t-j} + \sum_{k=1}^{q} c_k \varepsilon_{t-k} + \varepsilon_t$$

$\sigma^2_{\text{overnight},t}$ is the overnight volatility on day t, $\sum_{i=1}^{36} \sigma^2_{i,t}$ is the sum of squared 5-min returns from the open to the close on day t, $\sigma^2_{\text{overnight},t-j}$ and ε_{t-k} are the AR and MA terms for volatility, respectively, p and q are lag lengths chosen by the Schwarz criterion. An asterisk beside the t-statistic indicates significance at the 5% level.

events—particularly information from U.S. trading—on volatility.[5] The conditional means

$$E[\sigma^2_{\text{overnight},t}] = a_0 + a_1 \sum_{i=1}^{36} \sigma^2_{i,t} + \sum_{j=1}^{p} b_j \sigma^2_{\text{overnight},t-j} + \sum_{k=1}^{q} c_k \varepsilon_{t-k}$$

represents the expected overnight volatility, $\sigma^2_{e,t}$, whereas the residuals ε_t represent the unexpected overnight volatility, $\sigma^2_{u,t}$. The results of the ARMA models are presented in Table III. The SGX-DT results are presented in Panel A and the TAIFEX results are in Panel B. The ARMA models identified for the SGX-DT and TAIFEX are ARMA (1,0) and ARMA (0,0), respectively. The Durbin-Watson Statistics show that there is no serial correlation in the residual sequence.

In the second step, the values for $\sigma^2_{e,t}$ and $\sigma^2_{u,t}$ are used to estimate the relationships between (1) the closing volume and the overnight expected volatility as well as the unexpected volatility, and (2) the opening volume and overnight expected and unexpected volatility:

$$V_{\text{close},t} = c_0 + c_1 T + c_2 \sigma^2_{e,t} + c_3 \sigma^2_{u,t} + c_4 r_{\text{close},t} + \xi_t \tag{7}$$

$$V_{\text{open},t+1} = d_0 + d_1 T + d_2 \sigma^2_{e,t} + d_3 \sigma^2_{u,t} + d_4 r_{\text{open},t+1} + \zeta_{t+1} \tag{8}$$

[5]The author thanks the anonymous reviewers for providing helpful suggestions.

where $V_{\text{close},t}$ is the closing volume on day t, $V_{\text{open},t+1}$ is the opening volume on day $t + 1$,[6] T is the time trend, $\sigma^2_{e,t}$ is the overnight expected volatility on day t, $\sigma^2_{u,t}$ is the overnight unexpected volatility on day t, $r_{\text{close},t}$ is the closing return on day t, and $r_{\text{open},t+1}$ is the opening return on day $t + 1$. The time trend (T) is included in the regression equation because it is found that in the sample period, the volume grows with time. The return is included in the regression equation because prior research (Karpoff, 1987) indicates that return is expected to be positively associated with trading volume.

The results of the regressions are presented in Table IV (closing volume) and Table V (opening volume). In Table IV, the coefficient for expected volatility, c_2, is positive and significant in the SGX-DT and TAIFEX markets, while the coefficient of unexpected volatility, c_3, is not significantly different from zero. Hence, trading volume at the closing interval is directly related to the expected overnight variability, and not to the unexpected volatility, which is consistent with the results of Gerety and Mulherin.

In Table V, the coefficient of expected volatility, d_2, is positive and statistically significant in both markets, suggesting that trading at the opening interval is influenced by the previous night's expected overnight volatility. Moreover, unanticipated overnight information may also affect

TABLE IV

Relationship Between Closing Volume and Overnight Expected and Unexpected Volatility

	SGX-DT Coefficient	*t-Statistics*	*TAIFEX Coefficient*	*t-Statistics*
c_0	18.036	14.68*	117.9	4.22*
c_1	0.0409	16.73*	0.0586	0.79
c_2	0.2189	5.10*	8.0903	3.15*
c_3	−0.0089	−1.01	−0.4049	−1.17
c_4	−6.6607	−4.05*	−21.490	−0.84

Note.

$$V_{\text{close},t} = c_0 + c_1 T + c_2\sigma^2_{e,t} + c_3\sigma^2_{u,t} + c_4 r_{\text{close},t} + \xi_t$$

where $V_{\text{close},t}$ is the closing volume on day t, T is the time trend, $\sigma^2_{e,t}$ is the expected volatility, $\sigma^2_{u,t}$ is the unexpected volatility, and $r_{\text{close},t}$ is the closing return on day t. An asterisk beside the t-statistic indicates significance at the 5% level.
All estimates are corrected for the time series properties of the residuals using an AR process chosen by the Schwarz criterion.

[6]Note that the closing and opening volume estimated in Equation 7 corresponds to the open/close of the underlying stock market because it is at the spot opens and closes that the volume is of the higher level.

TABLE V
Relationship Between Opening Volume and Overnight Expected and Unexpected Volatility

	SGX-DT Coefficient	*t-Statistics*	*TAIFEX Coefficient*	*t-Statistics*
d_0	19.243	14.99*	293.5	11.1*
d_1	0.0452	17.74*	−0.1129	−1.04
d_2	0.2253	5.01*	7.8535	3.21*
d_3	0.0087	2.93*	1.6319	5.85*
d_4	−0.9858	−0.91	5.6101	0.51

Note.

$$V_{open,t+1} = d_0 + d_1 T + d_2\sigma^2_{e,t} + d_3\sigma^2_{u,t} + d_4 r_{open,t+1} + \zeta_{t+1}$$

where $V_{open,t+1}$ is the opening volume on day $t + 1$, T is the time trend, $\sigma^2_{e,t}$ is the expected volatility, $\sigma^2_{u,t}$ is the unexpected volatility, and $r_{open,t+1}$ is the opening return on day $t + 1$. An asterisk beside the t-statistic indicates significance at the 1% level.
All estimates are corrected for the time series properties of the residuals using an AR process chosen by the Schwarz criterion.

opening volume; the coefficient of unexpected volatility, d_3, is positive and statistically significant in both markets. Overall, the above results are consistent with the market closure theory.

SUMMARY AND CONCLUSION

Although extensive research has been conducted on the intraday patterns of stock and futures markets, few researchers have studied the intraday activities of the emerging markets. This article has investigated the trading activity of the SGX-DT and TAIFEX Taiwan Stock Index Futures contracts by examining intraday patterns in volume and volatility. In addition, the market closure theory was empirically tested. Results of the current article may provide a better understanding of the microstructure of the emerging financial markets.

Overall, the trading activities of the TAIFEX and SGX-DT futures markets are similar to those of other developed markets. The trading patterns show a U-shaped pattern for the TAIFEX futures and an U+W-shaped one for the SGX-DT. This is similar to the findings of Chang et al. (1995) for S&P 500 futures and those of Lee and Mathur (1999) for NYSE, S&P 500 and MMI futures. For the SGX-DT futures, although the opening SGX-DT interval has high volume, the volume is lower than that of the cash stock market opening interval. Similarly, although there is a peak at the futures closing, the highest closing volatility interval occurs at the cash stock market closing for both volatility measures. For the TAIFEX futures, however, after the peak at the close of the spot market, the volatility drops consistently until the end of the day. The above results seem to support the extended market closure theory where the cash market is dominant.

The intraday patterns of the afternoon session of the SGX-DT futures are also U-shaped; however, the level of volume and volatility is much lower than that of the morning session. Because the cash stock market is not open in the afternoon, these results provide additional support for the importance of cash market closure on volume and volatility of the futures market.

The empirical tests of the market closure theory indicate that trading volume during the closing interval and the following day's opening interval are both directly related to expected overnight volatility. Moreover, unanticipated overnight information may also affect the following day's opening volume. These results are consistent with the market closure theory in that much of the clustering of trading around the open and the close is due to the desire of investors to exchange their exposure to price changes when the market is closed.

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