Interday and intraday volatility: evidence from the Shanghai Stock Exchange

Gary Tian* and Mingyuan Guo
University of Western Sydney

After examining both the interday and intraday return volatility of the Shanghai Composite Stock Index, it was found that the open-to-open return variance is consistently greater than the close-to-close variance. The volatility of interday returns and variance ratio tests with five-minute intervals reveal that an L-shaped pattern, or more precisely, two L-shaped patterns starting with a small hump during both the morning and the afternoon session, with the morning session having a much higher interday volatility than the afternoon session. This broadly L-shaped interday volatility is also supported by an L-shaped intraday volatility pattern. The autocorrelation of the open-to-open return series also indicates that the temporary price deviation at the continuous open rather than the auction open is significant. This result suggests that high volatility of intraday returns for the market open is not due to the trading mechanisms (call auction in the market opening) but rather it is due to both the accumulated overnight information and the trading halt effect. The five-minute breaks after the auction and blind auction procedures are the two major driving forces which exaggerate the high intraday volatility observed at the market open.

* Gary Tian is the corresponding author, his email address is g.tian@uws.edu.au and his mailing address is Gary Tian, School of Economics and Finance, Parramatta Campus, University of Western Sydney, Locked Bag 1797, Penrith South DC NSW 1797 Australia. Telephone number is 61 2 9798 3139. We would like to thank Craig Ellis for his comments on the earlier draft of this paper. The authors remain responsible for all errors.

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1 Introduction

A very important issue in market microstructure analysis is the interaction between trading procedures and security price formation. The latter is associated closely with the evolution of security's return volatilities. Empirical studies on the interdaily evolution of return volatilities typically find that daily open-to-open volatility is higher than daily close-to-close volatility. Three general explanations have been offered for this phenomenon: the difference in trading mechanism between the market's open and close (Amihud and Mendelson, 1987), the monopoly power of the specialist (Stoll and Whaley, 1990), and the long halt of trade before the market's open (Amihud and Mendelson, 1991a and 1991b).

In this article, we examine the behaviour of both interday and intraday return volatility of the Shanghai Composite Stock Index in order to shed additional light on the issue. There have been no empirical studies made on the microstructure of the Chinese stock markets using intraday data. China's stock exchanges are relatively new players amongst the world's financial markets. The two official stock exchanges, the Shanghai Stock Exchange and the Shenzhen Stock Exchange, were established in December 1990 and July 1991. Since their establishment, they have expanded rapidly in terms of capitalization, turnover, and number of firms listed. In terms of market capitalization, the Chinese stock markets are now the second largest in the Asia-Pacific region after Japan, and are ahead of such major markets as Australia, Hong Kong and Korea (Eun and Wei, 2005). Recently, in order to liberalize its stock markets, China's domestic equity markets were opened to selected international institutional investors, designated as the so-called qualified foreign institutional investors (QFII) in 2003. Among these two stock markets in China, the market capitalization of the SHSE was 3,009.7 billion yuan (about US$367 billion) in 2003, 77.8% of total market capitalization in all Chinese stock markets. It is obvious that the SHSE plays a dominating role in Chinese stock markets, which is also the reason why the Shanghai Composite Index was selected for this study.

Like many other emerging markets, the SHSE is a limited order-driven market using electronic trading without market makers. However, the SHSE is unique in its institutional setting. First, there is a five minute break between the call auction open and normal morning open of continuous trading. We are not aware of any other market in the world that has such an arrangement. All other markets start with a call auction opening procedure and then switch to continuous trading straight away after the auction finishes. We can compare the performance of two trading mechanisms within the same market and within a very close time period. Unlike the Tokyo and Milan markets, the two different trading mechanisms in China used all in the morning open just five-minute apart, therefore, the impact of release of information can be ignored.

Second, there is a lunch break in the mid-day between the morning and afternoon trading sessions, the same as in all other Asian stock markets. Thirdly, as a result of the first and second point, there are technically three sessions in the Chinese stock market: the pre-open auction session, the morning trading session and the afternoon session. Both morning and afternoon sessions are thoroughly continuous markets similar to the Stock Exchange of Hong Kong (SEHK), which opens as a continuous market and remains a continuous market up to and including the close of trading. While most other markets (which adopt call auction for the market open) change into a transparent auction procedure in which information regarding order books are available to investors during the auction process, Chinese call auction is still totally without any information dissemination except for the final clearing price generated at the end of the auction. Meanwhile, China still maintains its unique five-minute break between morning call auction and morning open with continuous trading. The merits of these trading procedures are constantly debated among both academics and policy makers (Wang et al 2003, p. 7). In addition, unlike many other emerging markets which have stronger equity market integration with major markets such as through dual listing of Hong Kong stocks on the London Stock Exchange (LSE), Chinese stock markets are relatively isolated and more independent than other markets. Therefore, the markets provide a clear and simple case for the research of volatility and trading mechanisms because there is much less correlation of both the return and return volatility between the SHSE and other markets, which affects the pattern of the volatility of the markets under research. Thus, the SHSE offers an ideal setting to analyze the relations between volatility patterns and other factors such as trading procedures because of its unique features.

Empirical findings based on the volatilities of interday returns and variance ratio indicate that the high volatility of intraday returns at the market opening is not mainly due to the trading mechanism (call auction) but rather to the overnight trading halt. The results further suggest that the return variance in the active trading period (open-to-close) of the stock market is larger than that in the nontrading hours (close-to-open). The intraday returns and volatility provide further support for the results achieved by the interday data. The intraday returns broadly follow a U-shaped pattern (Wood et al., 1985) while the volatility of returns broadly follows an L-shaped pattern. This result is consistent with the previous findings on the Hong Kong market (Lam and Tong, 1999; Tang and Lui, 2002).

This paper is organized as follows: Section 2 presents the literature review on interday and intraday return volatility; Section 3 discusses the institutional background for the SHSE and the data; Section 4 reports and analyses the empirical results; In Section 5, a conclusion is made.

2 Literature Review

In an early study on the NYSE, Amihud and Mendelson (1987) and Stoll and Whaley (1990) compare the effects of a call auction market and continuous trading market on return volatility. The opening procedure of the New York Stock Exchange (NYSE) is essentially a call auction mechanism while all other trades are by the continuous trading mechanism. In the call auction mechanism, the buy and sell orders accumulated overnight are executed at a single price at the market opening. They reported that the interdaily stock returns computed using open-to-open prices have greater variance and show more evidence of reversals than comparable returns computed from close-to-close prices. Amihud and Mendelson (1987) attribute the result to differences in trading mechanisms between the opening and closing transactions and Stoll and Whaley (1990) attribute the result to the monopoly power of the specialist system.

While the greater volatility at the open may be attributed in part to trading mechanisms used by the NYSE, research into other exchange settings suggest that the noisiness of opening prices may well be due to the large amount of 'unprocessed' information that had accumulated overnight before the market open, rather than to the call auction opening procedure. Amihud and Mendelson (1991) examined the Japanese market where there are two trading sessions: the morning session and the afternoon session. Each session is based on the call auction for the opening and then the continuous trading session to the close. They find that the morning open-to-open volatility is high, but not the afternoon open-to-open volatility, and conclude that it is caused by the preceding long period of non-trading rather than the trading mechanism. Similarly, Amihud et al (1990) found that on the Milan Stock Exchange, where the market opens with continuous trading and moves to a call market, the call trading actually exhibits lower volatility. It is also consistent with Choe and Shin's (1993) findings in the Korea Stock Exchange (KSE) that the close-to-close volatility is higher when the market closes (in the morning) in continuous trade than when the market closes (in the morning) in call auction.

All the above-mentioned markets, including the NYSE, the AMEX, the LSE, and Asian markets including Tokyo Stock Exchange (TSE), the KSE and the SHSE to be discussed in this paper, open with a call market and then switch to a continuous market. Unlike these markets, the SEHK opens as a continuous market and remains a continuous market up to and including the close of trading. If halt of trade is the major reason, open-to-open volatility in the SEHK should still be higher even without a call auction. What Lam and Tong (1999) found is that the open-to-open volatility is actually a bit lower than the close-to-close volatility. Using one-minute interval interday data, they found two humps in the interdaily volatility pattern, a large one in the morning session and a small one in the afternoon session. They then argue that this is probably due to clustering of trading at these particularly times.

Gerety and Mulherin (1994) estimate transitory volatility throughout the trading day based on forty years of hourly Dow Jones sixty-five Composite price index data. They hypothesize that if the opening auction is responsible for higher open-to-open volatility, a sudden drop in interdaily variance after the open should be observed. Instead, their findings are in contrast with their hypothesis and the interday 24-hour volatilities decline steady, reflecting information processing. Hence, halt of trade seems more likely to be the driving force rather than a call auction process as argued by Amihud and Mendelson (1987). Overall, although there is still no consensus, the majority of surveys support the notion that it is overnight trading halt rather than an auction procedure that is the source of the higher open interday volatility.

In addition to the examination of the interday return volatility, intraday return volatility of share prices has been found to follow a particular pattern, which is associated with the market microstructure characteristics of the stock exchange. Wood et al. (1985) are the first to identify the distinct U-shaped return and return volatility pattern over the trading day. Later, both Harris (1986) and Jain and Joh (1988) reported a significant U-shaped intraday return and return volatility patterns in stock trading in the NYSE.

Recently, Ozenbas, Schwartz and Wood (2002) have examined intraday share price volatility over the year 2000 for five markets: the NYS, Nasdaq, the LSE, Euronext Paris and Deutsche Borse. They observed a U-shaped intraday volatility pattern, a particularly sharp spike for the opening half hour, and a general level of intraday volatility that is accentuated vis-à-vis volatility over longer differencing intervals in each of these markets. They suggest that the volatility accentuation is attributable to spreads, market impact, price discovery and momentum trading.

The theoretical explanations for the behaviour of these variables of the U-shaped patterns are not easy. Kyle (1985) suggests that traders can be classified into three classes: private information traders, random liquidity traders, and market makers. Admati and Pfleiderer (1988) and Foster and Viswanathan (1990) add a fourth type of trader to Kyle's model: discretionary liquidity traders. They take into account the impact, the costs, the size and the time of the trade. They suggest that public and private information, and trading noise are the causes of a systematic pattern in return volatilities, which leads traders to minimize trading during the periods of the open and close of the market.

When public information is released during the non-trading period (overnight), the liquidity traders (random liquidity traders and discretionary liquidity traders) would be more active at the open of the market. When the market is near to close, the informed traders, who get access to private information during the trading hours, would be more active towards the close of trading before the information becomes public during the overnight non-trading periods. This public/private information and noise trading hypotheses are well supported by the empirical evidence of a U-shaped pattern in return volatilities (French and Roll, 1986 and Stoll and Whaley, 1990).

In addition to the evidence from the US market, there are some studies on emerging markets, particularly the Asian stock exchanges with their two trading sessions during a day. Chang et al. (1993) analyzes intraday returns and return volatilities for the index of the Tokyo Stock Exchange and find a double U-shaped return pattern corresponding to its two trading sessions. Consistent to that reported for the Tokyo Stock Exchange, Cheung et al. (1994) also reported a double U-shaped volatility pattern for 15-minute intervals using the Hang Seng Index during the period April 1986 to December 1990. Examining the intra-daily seasonalities of the stock returns on the Turkish Stock Market in the period from 1996 to 1999, Bildik (2001) finds that stock return volatility follows a W-shaped pattern over the trading day, or more precisely a U-shaped pattern for the morning trading session and an L-shaped for the afternoon session on the Istanbul Stock Exchange. Copeland and Jones (2002) provide evidence that for the intraday effects in the Korean market, there exists a U-shaped pattern over the day. They find that both volume and volatility are found to be consistently higher at the start of the trading day. Without market makers in these Asian markets, relatively higher mean return and volatility (measured by standard deviation) at the openings of the trading sessions in these markets, irrespective of whether either auction or continuous procedure or both are used for their market open, are found by a majority of authors to be significantly generated by the accumulated overnight information and the closed-market effect (halt of trade).

Recently, the Singapore Stock Exchange (SSE) introduced a pre-trading routine (a periodic auction) that allowed brokers to place orders into the Exchange's computerized matching system for a period of 30 minutes prior to market's opening. Using 5-minute intraday data of the thirty-two most actively trading stocks for the period of six months prior to, and after, the introduction of this new system in August 2000, Young et al (2002) investigated the impact of the changes on volatility and the price discovery process and found that the pre-trading session significantly reduced opening stock market volatility, therefore helping in the price discovery process and the development of a more efficient and transparent market. The Opening vitality in the SSE dropped by over sixty-percent after the introduction of the pre-trading routine. Overall, although an intraday volatility pattern does not relate a higher open volatility to any driving forces, it does reveal the price discovery process and the pattern of the volatility, which provides further evidence to support the results found by using interdaily volatility.

Similar to Amihud and Mendelson (1987) and Stoll and Whaley (1990), we compare open-to-open and close-to-close volatility. However, this investigation is, not adequate because even in the NYSE it is not clear whether or not the opening is unique while the closing is similar to other times of a day. When there are two trading halts during a trading day: one one-and-half hour lunch break and one five-minute trading halt after the morning call auction in the SHSE, comparisons between open-to-open return variance and close-to-close return variance do not reveal much about trading mechanisms. Thus, following Gerety and Mulherin (1994), Lam and Tong (1999) and Choe and Shin (1993), we expand our tests to compare open-to-open return variance to interday return variance measured at each 5-minute interval during a trading day as well as five-minute intraday return and return volatility in the following sessions.

3 Trading Systems and Dataset

3.1 Trading Systems

The trading system in the SHSE is based on the electronic consolidated open limit order book (COLOB). Trading is carried out on the exchange in two sessions: the morning session from 09:30 to 11:30 and the afternoon session from 13:00 to 15:00. Before the morning session, there is a 10-minute open call (consolidated) auction session, which starts at 09:15 and ends at 09:25, for the determination of the centralized competitive opening price. During this 10-minute call auction period, investors can place limit orders and participate in the opening auction, but no orders will be allowed to be withdrawn during this period of time. There is also no information regarding order books available to investors during the auction process, except for the final clearing price generated at the end of the auction. Therefore, the morning call auction is totally without any information dissemination. Orders that are not executed in the opening auction are automatically transferred to the period of continuous trading. The determined opening price at 09:25 is continued to 09:30.

After a lunch break, the market reopens in the afternoon directly with a continuous auction without the consolidated auction. During the two continuous trading sessions, the electronic system is based on the matching of orders for the consecutive bidding according to price and time priorities. Closing prices of the stocks of the trading day in the SHSE are generated by taking a weighted average of the trading prices of the final minute of each trading day[1]. The information of the best three offers and bids and their associated volume as well as the price and volume for the latest transaction on the stock exchanges during the continuous trading sessions must be displayed on computer terminals viewable by investors

[1] Before December 1, 2001, the Shanghai Stock Exchange uses the last trading price as the close price.

on and off both exchanges. The market is closed on Saturdays and Sundays and other public holidays announced by the exchange.

There are no designated dealers (specialists) to intervene in trading in the market. Investors place their orders with the brokers in the form of either a market order or limit order, and only good-to-day limit orders are accepted by the trading system. At the end of the trading day, all orders are purged from the COLOB. There are no other sophisticated order types, such as trading-at-open, trading-at-close, stop orders, buy-at-minus and sell-at-plus, are supported by the trading system. The minimum tick sizes for all stocks are 1 cent (RMB0.01 Yuan). Shares can't be sold on the same day once they are bought. The minimum trading size for purchase is 100 shares, while there is no minimum requirement for selling shares. Floor trading among member brokers, and short selling are strictly prohibited. During trading sessions on the SHSE, a stock is allowed to trade at a price plus or minus 10% from the previous day's closing price in order to avoid sharp price increases caused by 'buy manias' and sharp declines caused by 'sell panics'.

Overall, the operation of the SHSE is different from some other two-session order-driven markets. For example, the SEHK has a thoroughly continuous order-driven (i.e. no opening call market) trading, while in the Tokyo Stock Exchange, the periodic auction is used twice a day at the opening of both the morning and afternoon session and continuous order-driven trading markets in both the morning and the afternoon sessions in the trading day. In addition, there are also some differences in trading rules such as price limit, tick size and short-selling restriction between the SHSE and those more similar order-driven Asian markets. The Chinese stock markets are also different from all the other markets with morning auction opening procedure: not only due to the fact that there is no specialists involved in the markets, but also the Chinese stock markets take five-minute break between the periodic auction and the morning session with continuous trading mechanism.

A further difference lies in the broader nature of the trading environment. Like many other emerging markets, the SHSE has a relative immature infrastructure such as an inadequate disclosure, an opaque legal and governance framework, an inexperienced regulator and a heterogeneous investor structure. The co-existence of an inexperienced regulator with a few informed investors with financial strength, and an enormous member of uninformed and unprotected investors with budget constraint, gives informed investors an opportunity to manipulate stock prices to earn a profit at the expense of the uninformed investors (Lu and Lee, 2004).

3.2 Dataset

This paper uses intraday data from the Shanghai Composite Price Index, which is a value weighted index of all common stocks listed on the SHSE[2]. The Shanghai composite index took December 19, 1990 as its base day to calculate the base market capitalization. The index is the most widely-quoted index of the Chinese stock markets, both locally and internationally. We examine the five-minute interval Shanghai Composite Index series covering the three-year trading period from January 1, 2000 to December 31, 2002, a total of 716 trading days with more than 30,000 observations. The data were provided by the SIRCA. The dataset of the Shanghai Composite Index records information on the time-stamped transactions, including the code, the order of time interval, the trading date, the day, trading time, the opening value, the highest value, the lowest value and the closing value in each time interval in each trading day.

3.3 Returns

[2] All the common stocks issued and traded in the SHSE include both the A-shares and B-shares. The A-shares are domestic ordinary shares denominated and traded in RMB by Chinese citizens while the B-shares are ordinary shares offered to foreign investors, denominated in RBM, but traded in foreign currency. Moreover, while there is a separate auction procedure implemented five-minutes before the normal morning opens with continuous trading at 10.00 each trading day for the A-share market, the B-share market just opens at 10.00 with a continuous trading mechanism. However, the market capitalization of the A-shares is about 10-20 times larger than that of the B-shares and also the A-shares are much more actively traded each day. For this reason, we treat all the shares constructing the Shanghai Composite Index trade the same way as the A-shares in the SHSE with a separate auction procedure prior to the market open.

Interday returns are calculated as the logarithmic percentage returns of the Index on day t. Three interday open-to-open returns at the auction open at 09:25, the morning open at 09:30 and the afternoon open at 13:30 are computed as ln[open(t)/open(t-1)], while the interday close-to-close return at any other 5-minute interval is calculated as ln[close(t)/close(t-1)].

Intraday interval returns are computed by taking the first difference of the natural logarithm of the successive interval values of the indices. R_t, the return on stock indices at the interval t, is computed as ln (P_t / P_{t-1}), where, for each interval during the trading day, P_t is the closing value of the interval at time t and P_{t-1} is the closing value of proceeding interval at time t-1.

As there are two sessions in the trading day, the 5-minute returns consist of 48 observations over the two sessions from 09:30 to 11:30 and from 13:00 to 15:00 in a trading day with 34,368 observations over the three years. The first and last 5-minute intervals for the morning session are from 09:30 to 09:35 and from 11:25 to 11:30, respectively. The first and last 5-minute intervals for the afternoon session are from 13:00 to 13:05 and from 14:55 to 15:00, respectively. Thus, the 48 5-minute intervals throughout the trading day break up into 24 intervals for the morning session and 24 intervals for the afternoon session.

For calculating the 5-minute intraday returns, if there is no trading at the end of the 5 minutes, the closest trading price to the end of the 5-minute is the closing value of that 5-minute interval. The return for the first 5-minute interval of the trading day is calculated by comparing the closing value at t_1 (09:35) with the closing value at time t_0 (09:30) when the trading starts. The close-to-open (overnight or non-trading) return is computed by comparing the closing value at time t_0 (09:30) with the last value (closing value) at time t_{48} (15:00) of the previous day-end. Open-to-close returns are computed by comparing the last value (closing value) at time t_{48} (15:00) with the opening value (closing value at time t_0) at 09:30 of the trading day[3].

[3] Another way is to standardise return series by subtracting each observation from the mean of the sun of all corresponding intervals and then dividing the difference by the standard deviation of its corresponding 5-minute interval. The results may be obtained upon request.

In order to test mean differences of the intraday returns across different intervals for the market indices, the following econometric model is considered:

$$r_{\mathrm{t}} = \beta_1 D_{1t} + \beta_2 D_{2t} + \ldots + \beta_n D_{nt} + \sum_{i=1}^{k} \beta_i r_{t-i} + \varepsilon_t \qquad (1)$$

r_t is the intraday return at interval t. The D_{it} is a dummy variable for each interval of the trading day and ε_t is the disturbance term. The coefficients (β_t) are the expected mean returns at each interval t. For the 5-minute interval data, n equals 48 in Equation (1), so there are 48 dummy variables: $D_{1t}, \ldots, D_{48t}$. D_{1t} is a dummy variable equal to 1 if the mean occurs between the first interval (first 5-minutes) of the trading day and 0 otherwise. If the expected mean return is the same for each interval, the estimates of $\beta_1, \ldots, \beta_n$ of Equation (1) will be close to zero and the F-statistic measuring the joint significance of the dummy variables should be insignificant. Additional lagged returns $\sum_{i=1}^{k} \beta_i r_{t-i}$ as the explanatory variables are also included in the model in order to remove the autocorrelation[4].

In the study, Parametric tests, such as the mean equality test, and the non-parametric tests (such as Kruskal-Wallis test, Levene test and modified Levene test, Brown and Forsythe test), are applied. Nonparametric tests are shown to be statistically superior to parametric tests in detecting abnormal price reactions for small time intervals (Mucklow, 1994). Kruskal-Wallis tests report the asymptotic normal approximation to the U-statistic (with continuity and tie correction) and the p-values for a two-sided test. The Levene test (Levene (1960)) and the Brown and Forsythe (1974) test (a modified Levene test) are used for the equality of variances. The Levene test is based on an analysis of variance of the absolute difference from the mean. The Brown and Forsythe test employs absolute deviations from the class means. When empirical distributions are not normal, the

[4] The intraday returns can be serially dependent, especially the index return, as a result of thin or non-synchronous trading or even slow reaction of the market to news (Niarchos and Alexakis, 2003). In addition, mis-specifing the dynamics of the intraday returns can produce slow decay of the autocorrelation.

Brown and Forsythe test can provide robust results based on deviations from the median.

4 Empirical analysis

4.1 Interday return volatility

We first analyse interday mean return and return variances measured at various times of the day by rolling the time from the auction open to the afternoon close by 5 minutes. Table 1 and Figure 1 shows the interday descriptive statistics of mean interday returns, variances and the tests of variance ratio for the call auction open (09:25), the morning open (09:30) (in the continuous trading), first interval at 09:35, other related 5-minute intervals. In Figure 1, the bottom line represents the plot of interdaily mean return through time. The mean return has a big drop at the morning open at 09:30 after the minor negative opening at the call auction. Within the next half hour until 10:30, the mean return first jumps back to near the auction open level and then constantly declines before a slightly rise at the market close.

The line at the top shows the interdaily volatility through time. Variance ratios for each interday return compared to the afternoon close-to-close are reported as the line in the middle. According to Amihud and Mendelson (1987), one would expect that the variance ratio test of the call auction would be larger and significantly different, but the variance ratio test of all other interday returns in the continuous trading period, are not larger and significantly different compared to the close-to-close interday return; the market volatility in the call auction may indeed be affected by the call auction method alone.

When we compare the variance ratios between the call auction and the afternoon open, the result may suggest that call auction trading alone increases return volatility. The result (1.23) is basically consistent with the variance ratio of 1.20 found by Amihud and Mendelson (1987) and of 1.13 found by Stoll and Whaley (1990), who show that the interday 24-hour open-to-open return variance is higher than the interday 24-hour close-to-close return variance in the US stock market. We think that the pattern documented here is different from that in the US market although there is not any study that analyses a less-than-hourly intraday pattern of interday return volatility in the U. S. markets.

Our results reveal that the return variance is the second highest at the auction open at 09:25, 5min later when the markets start with continuous trading, the variance is the highest at the morning open before the variance falls back at 09:35. The variances at these three point of times (2.535, 2.671 and 2.517) are the greatest, and the variance ratio tests indicate that all these first three interday return variances are all significantly different from the interday close-to-close interday return variance. After the lunch break, interday return variance increases and the variance ratios are larger than one for the first three 5-minute intervals (although they are not significantly different from the interday close-to-close in the SHSE) before the ratios fall below 1 for the rest of the afternoon until the market's close. It is interesting to note that the variance of open-to-open returns in the continuous morning opening at 09:30 is actually higher than the variance of the open-to-open returns at the auction opening. The higher open-to-open return variance at the morning open than that during the auction open might be caused by the halt-of-trading effect, rather than the accumulated information during that five-minute period. It is too short a time period between these two openings to judge the effect of the auction open and the morning open with continuous trading. However, the arrangement of a five-minute break between the call auction and the beginning of the continuous trading is more than necessary and should be cancelled due to the extra volatility created by this mechanism which certainly fails to improve the market quality.

[Insert Table 1]

[Insert Figure 1]

Thus, the hypothesis that the volatility is entirely caused by trading mechanism at the market open is rejected because there is not a sudden drop observed in interdaily variance after the market open according to the hypothesis suggested by Gerety and Mulherin (1994). Rather, this result provides evidence to suggest that on the Chinese stock market the accumulated overnight information not the halt of trade is the driving forces for higher return volatility at the market open. The highest volatility at the morning open with continuous trading is more consistent with the effect of the lack of trading continuity due to the trading halt. To a much lesser extent, a high level of interday volatility at the afternoon market open could also be attributed to the lack of trading continuity and the information accumulated during that lunch break. The effect of these factors should be much less than the other two breaks due to the statistical insignificance of the high volatility ratio tests during the afternoon open.

4.2 Autocorrelation

Studying the correlations in various return series provides further insight into the nature of the price discovery process. According to Stoll and Whaley (1990), if there is transitory price dispersion at the market open, then the open-to-open return series will be negatively correlated due to price reversal. Table 1 computes the first-order correlation coefficients for various return series. Comparing the first-order autocorrelation coefficient at the auction open to the continuous morning open finds the former insignificant (with P-value of 0.262) although the value is negative (-0.042), while the latter is marginally significant (with P-value of 0.108) and more negative (-0.06) than the former. The autocorrelations of the open-to-open return at 09:35 were also negative and statistically significant. Therefore, we found that these were predominantly more negative than those of the corresponding close-to-close returns, consistent with more noise and with a mean-reversion pattern at the continuous opening rather than auction opening. This result (of the higher variance and the more negative autocorrelation at the continuous opening) suggests that the auction open is better used for price discovery than the continuous open for the period after a long break without trading, which precedes the opening transaction. The morning's clearing transaction does not cause greater pricing errors than the continuous market in the morning. The more negative and more significant autocorrelation coefficient of the daily return series at 09:35 further indicates that high volatility has nothing to do with the opening auction, and rather it can be attributed to the overnight trading-halt effect.

If we treat the continuous trading following the auction without any break, Gerety and Mulherin (1994) suggest that because there are some other interdaily volatility ratios which are significantly bigger than the auction open, the auction procedure should not be attributable to the transitant volatility at the open. Besides, autocorrelation coefficients also indicate that price reversal happened at the continuous open rather than at the auction open, which suggests there is a greater chance of price error at the continuous open than during the auction open. Without the specialists used in the SHSE, we can say it is the trading halt which made volatility higher and reversed the autocorrelation at the market's continuous open.

If we treat two openings implemented at separate times as they are, both the low volatility ratio and an insignificant level of autocorrelation suggest that the auction is a more efficient method for opening the market. The auction is used in the five minutes prior to the continuous open, with everything equal (assuming the new information released during this five minutes is trevious), the overnight information should become more digested and transmitted during the auction than at the beginning of continuous trading. In other words, the information asymmetry should be much more sever during the auction than at the beginning of the continuous trading period. Therefore, the results of lower volatility and insignificantly negative autocorrelation at the auction further reinforces the conclusion we just made that using the auction to open the market is a better choice compared to purely continuous trading. We can make two implications from our results: first, auction procedure is a more effective trading method for market opening; Secondly, the five-minute is not useful at all as it creates more volatility at the market open.

4.3 Volatility in Trading and non-Trading Periods

Studies focused on the volatility in trading and non-trading periods will help us to understand the price formation of security and its association with trading mechanisms the exchange adopts. Existing studies found that the return variance in the active trading hours (open-to-close) of the security market is larger than that in the nontrading hours (close-to-open) (French and Roll, 1986; Barcaly, Litzenberger and Warner, 1990; Stoll and Whaley, 1990). French and Roll (1986) test the private information hypothesis and report that return variances are reduced by both the election day closing and the exchange holidays, whereas Barclay et al. (1990) support the same hypothesis using an opposite case in which return variances are increased by Saturday trading on the Tokyo Stock Exchange. The large difference between the variances of the trading and the non-trading periods is mainly attributable to the greater intensity of information arriving during the business hours. Table 2 shows the descriptive statistics of mean return and variance during the overnight period (close-to-open or C-O), morning session, lunch break, afternoon session, and daily trading period (open-to-close or O-C).

[Insert Table 2]

In Table 2, we show that the volatility in terms of the variance of the open-to-close period is more than four times that of the close-to-open (overnight) period (1.703% versus 0.388%). This is consistent with the U.S. results as reported by Lockwood and Linn (1990) in that the open-to-close return variance exceeds that of close-to-open return by a factor of 2.34 to 3.37. The results also support the hypothesis that private information is disclosed during trading hours. It should be noted that the return volatility in the morning trading session (0.604%) is greater than the volatility measured during the afternoon trading session (0.529%). This confirms further that private information is not produced at a constant rate even during the trading period. It also implies fewer price reversals occur as trade proceeds.

In terms of unit time volatility, Amihud and Mendelson (1991) find that the two-hour midday break in Japan has a higher return volatility than the overnight break. They argue that this difference could result from the greater intensity of information arrival during the day compared to the overnight period. In contrast, Lam and Tong (1999) show that an overnight variance of 0.027 is more than double the midday break variance of 0.001 in terms of unit time volatility. They argue that the higher overnight variance was attributed to probably the trading of some component stocks in London overnight. The results in Table 2 also show that the per-hour overnight volatility is five times greater than the lunch break in the Shanghai index (0.021% vs. 0.004%), which is consistent with the findings of Lam and Tong (1999) for the Hong Kong market but inconsistent with those of Amihud and Mendelson (1991) for the Japanese market. Without the complication like Hong Kong market, a lower volatility during the 11:30 to 13:00 period could just reflect a lower intensity of new information arriving over these one and half hours than that overnight.

Meanwhile, the sum (1.527) of the mean variances of the four periods, including the morning session (0.604), lunch (0.006), afternoon (0.529) and overnight (0.388) is less than 25.73% of the mean daily variance of close-to-close return (2.056)[5]. These results are consistent with Chang et al (1995) and Tong and Lam (1999) but not with Amihud and Mendelson (1991) or Bildik (2001). Amihud and Mendelson (1991) find that the sum of the variances of the four separate time intervals, including overnight, morning session, lunch break, and afternoon session, exceeds the close-to-close return variance by 21.7%. Our result implies that the covariances between each pair of consecutive trading periods are positive. This result supports the argument proposed by Lam and Tong (1999), who argue that the difference between that of Amihud and Mendelson (1991) and

[5] The computation for these return series are for Morning: 09:30 – 11:30, for lunch break: 11:30am – 13:00 (afternoon opening price), for afternoon: 13:00 – 15:00 and for overnight: 15:00 – 09:30 next day.

theirs is possibly due to the fact the former looked at individual stocks instead of looking at a stock index. Individual stocks tend to exhibit negative autocorrelation due to the bid-ask bounce, whereas stock indices tend to exhibit positive correlation due to various reasons (Lo and MacKinlay, 1990).

4.4 Intraday Return and volatility

Table 3 and Figure 2 provide the 5-minute intraday returns (in percentage) for the year 2000-2002. From the bottom lines of Table 3, negative mean 5-minute returns ("All") are observed during the 3-year period and they are close to zero, equal to -0.0014% and the tests further show that the mean returns are not significantly different from zero at a 5% level of significance (P-values are 0.0783). The skewness is generally not obvious but the values of excess kurtosis are larger during the three-year period. The Jarque-Bera and Anderson-Darling tests of normality have p-values less than 0.01, thus each test would reject the null hypothesis of normality. These indicated that the returns data is non-normal and has a fat-tailed distribution on the Chinese stock market.

[Insert Table 3 Here]

[Insert Figure 2 Here]

The right-hand plot of Figure 2 show that there are large, positive mean returns at the beginning of the trading day and a big upward increase in returns at the end of the trading day, which presents typical U-shaped patterns. These intraday effects are consistent with the previous literature on the US market (Wood, McInish and Ord, 1985; Harris, 1986; Jain and Joh, 1988; Lockwood and Linn, 1990) and other countries such as the Hong Kong market (Cheung, 1995) and the Turkish market (Bildik, 2001). It is interesting to see these price changes (high returns) in the morning open in the Shanghai index. Possible reasons are the overnight halt of trade and the effect of accumulated information released, which reflects the new price-discovery process, and the high returns at the trading closing will be attributed to informed traders with private information for the next day’s opening. Different informed and uninformed traders may lead to new price discovery. In addition, large closing returns imply that the specialist-related explanation of Miller (1989) should be refuted in the Chinese stock market since there is no specialist system. The findings show that the large price changes at market openings and closings needs to be improved in the Chinese exchange, which underscores the importance of making the trading systems more efficient.

In Table 4, results of the F-tests for the equality of mean return show that the null hypothesis for equality of intraday returns across the 5-minute intervals is rejected at a 1% level. The results of KW-tests for the equality of mean return median confirm that the null hypothesis for equality of intraday return medians across the 5-minute intervals is also rejected at a 1% level. Both the F-tests and KW-tests have consistent results. This result confirms that there is a strong systematic intraday return pattern existing on the Chinese stock market. It should be noted that the first two intervals from 09:30 to 09:35 and from 09:35 to 09:40 of the morning session are significantly important at a 1% level for the index.

[Insert Table 4]

Table 5 and Figure 2 present the standard deviation of the mean 5-minute returns. With the largest volatility at the beginning of the morning session, the two indices have distinct L-shaped patterns, inconsistent with the U-shaped patterns observed in the US market by Wood et al. (1985), Harris (1986), Jain and Joh (1988) and Goodhart and O’Hara (1997)).

[Insert Table 5]

The mean volatility of 0.363% during the opening, or the first 5-minute interval, is almost triple that of the rest of the day. Volatility goes down sharply during the next 25 minutes. The lowest volatility of 0.096% occurs before the 5-minute ending of the morning session. The volatility begins to rise in the last 5-minutes of the morning session to 0.123%. At the beginning of the afternoon session volatility continues to rise to a higher level, 0.194%, in the first 5 minutes, which represents the largest volatility throughout the afternoon session. After that it comes down again (with lowest 0.093% at 13:20) and fluctuates until the end of the day to 0.116%, which is 1/3 of its value at the opening. A large opening volatility supports the fact that the mean return at the opening is significantly higher than that of most other intervals during the day.

In Table 5, the results from the Levene-tests show that the null hypothesis of equality of volatility of mean 5-minute returns across the 5-minute intervals is rejected at a 1% level. The Brown-Forsythe tests have the same results as the Levene tests. Thus, intraday volatility in terms of the variance of 5-minute returns is not distributed equally across the 5-minute intervals and the time-of-day effect on the intraday return volatilities can not be rejected. These results support the observation made before that there are systematic intraday volatility patterns existing in the Chinese stock market. It can be said that volatility follows a broadly L-shaped pattern if the increase in volatility at the opening of the second session is ignored, which is in contrast to the U-shaped volatility patterns documented in previous literature in most other markets.

The high volatility at the open would be evidence for price change during the opening processing period. During the trading halts, information released by the central government, related management agencies and the companies, about macroeconomic, social or political news, and the trading information, significantly affect the market's outlook as well as investment decisions[6]. On the other hand, there are slightly higher volatilities at the morning closing; the volatilities continuously fell during the last few five-minutes until the market's close in the afternoon session, which is not consistent with the pattern as documented in the US market. One possible reason is that the market portfolio's rebalancing force, which causes higher volatility at the close, does not exist on the Chinese market, and this is consistent with the Hong Kong market (Lam and Tong, 1999; Tang and Lui, 2002).

[6] In China, most important events, including government policy information and firm-specific information, are released in the evening.

5 Conclusion

The object of this paper is to examine the behaviour of interday and intraday return and return volatility in the SHSE, which is a limited order-driven markets using electronic trading without market makers.

The volatility of interday returns and variance ratio tests suggest an L-shaped pattern, or more precisely two L-shaped patterns starting with a small hump during both the morning and afternoon session. During the morning opening, both auction and continuous trading have much higher interday volatility. The autocorrelation of the open-to-open return series also indicates that the temporary price deviation at the continuous open rather than the auction open is significant. High volatility of intraday returns for the market's open is not due to the trading mechanisms (call auction in the market opening) but rather it is due to both the overnight trading halt and accumulated information. By comparing the volatility of trading and non-trading periods, we also found that the return variance in the active trading period (open-to-close) of the stock market is larger than that in the nontrading hours (close-to-open), while overnight volatility is bigger than that of the lunch break.

This broadly L-shaped interday volatility is also supported by the L-shaped intraday volatility pattern, while over a trading day, intraday returns broadly follow a U-shaped pattern as reported by Wood et al. (1985). The noticeable L-shaped volatility pattern is due to flow of information and market microstructure, which are related to the generation and dissemination of information, the arrival of orders and the rules and institutional features of a stock market that determine how orders are transformed into trades.

Overnight information has an enormous impact on stock volatility. This implies that accumulated information (public and private) from overnight is reflected in prices immediately at the opening of the day. Therefore, in contrast to other 5-minute intraday price changes that reflect the news released during the corresponding 5-minute interval, the first few 5-minute return volatilities reflect the assimilating information that was released and accumulated due to a much longer overnight trading halt. These abnormal trading activities of different traders in the market's opening are related to their different information (public and private) that causes the L-shaped volatility in the markets.

Furthermore, private information is most likely asymmetric among investors. Private information accumulated over the trading halt is incorporated in the stock prices when the trading opens. Traders who have no access to private information would trade on random factors unrelated to information. Insiders including manipulators may try to trade along with the trading activities of private information traders in order to obtain the private information indirectly.

The purpose of using the auction procedure is to stabilize prices after the overnight trading halt. However, the blind arrangement actually defeated the whole purpose of providing this open procedure particularly in the case of the Chinese stock markets. The Chinese market with its short history is dominated by high share of domestic inexperienced investors in share trading. They tend to show severe 'herd behaviour'. These small liquidity providers do not have much interest in participating in the morning call auction and even the following first few minutes after the market opens with continuous trading in 10:00 due to the information asymmetry.

Meanwhile, there is wide spread manipulation due to its special shareholding structure and general trading environment. Like many other emerging markets, the SHSE has a relatively immature infrastructure such as an inadequate disclosure system, an opaque legal and governance framework, an inexperienced regulator and a heterogeneous investor structure. The co-existence of an inexperienced regulator with a few informed investors with financial strength, and an enormous number of uninformed and unprotected investors with budget constraints, gives informed investors an opportunity to manipulate stock prices to earn a profit at the expense of the uninformed investors (Lu and Lee, 2004).

The market makers such as the specialists on the NYSE and, to a lesser extent, dealers in the LSE are involved markedly at the market call auction in order to exploit monopolist profits due to the asymmetric information between them and normal liquidity providers. Chinese insiders and manipulators were not able to do this due to there not being enough liquidity during the open process. Instead, Chinese insiders and manipulators intend to manipulate market prices by placing and withdrawing their offers during the call auction process and when the market opens. That is the reason for a higher volatility at these two opens in the morning.

Having the blind auction reduced an auction's role of producing an effective market clearing price at the end of the auction, since it pushes away many uninformed investors who are instead choosing to participate in the more transparent continuous trading period. Moreover, the five-minute break after auction creates another trading halt effect. This trading halt effect does not necessarily lead to an accumulation of substantial information during such a short period of time compared to the overnight halt but rather brings uncertainty into the market when it opens again. In addition to the delaying the participation of uninformed small investors from the blind auction, the interday volatility at the market open at 10.00 thus reaches its highest level during a trading day.

In conclusion, the high volatilities observed at the market open are costly to the market in aggregate, which discourages trade and make investors' returns more uncertain. The five-minute break after the auction and blind auction procedure itself are the two major reasons for the high intraday volatility observed. Converting the blind procedure into a transparent one and eliminating the five-minute break after the auction should improve the market quality in terms of lower volatility at the market open.

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Table 1 Interday 24-hour returns, return volatility, variance ratio test and autocorrelation, the Shanghai Composite Index, 2000 - 2002

No	Time	Mean	Var.	Variance Ratio Test	P Value	Auto. Corr.	P Value	No	Time	Mean	Var.	Variance Ratio Test	P Value	Auto. Corr.	P Value
0	**Auction Call**	-0.0002	2.535	1.233^{***}	0.005	-0.042	0.262								
	Morning Open	-0.0034	2.671	1.299^{***}	0.000	-0.06	0.108		**Afternoon Open**	-0.0020	2.062	0.999	0.993	0.027	0.467
1	**09:35-09:35**	-0.0003	2.517	1.224^{***}	0.007	-0.067^{*}	0.072	25	**13:05-13:05**	-0.0025	2.189	1.065	0.401	0.005	0.904
2	**09:40-09:40**	0.0002	1.997	0.971	0.698	0.025	0.51	26	**13:10-13:10**	-0.0030	2.190	1.065	0.398	0.009	0.806
3	**09:45-09:45**	0.0006	1.824	0.887	0.110	0.098^{***}	0.008	27	**13:15-13:15**	-0.0031	2.080	1.012	0.875	0.028	0.461
4	**09:50-09:50**	0.0006	1.879	0.914	0.230	0.095^{**}	0.011	28	**13:20-13:20**	-0.0030	1.995	0.97	0.688	0.048	0.196
5	**09:55-09:55**	0.0006	1.908	0.928	0.321	0.093^{**}	0.012	29	**13:25-13:25**	-0.0031	1.991	0.968	0.668	0.065^{*}	0.081
6	**10:00-10:00**	0.0006	1.926	0.937	0.385	0.083^{**}	0.026	30	**13:30-13:30**	-0.0035	2.024	0.985	0.835	0.068^{*}	0.069
7	**10:05-10:05**	0.0004	1.961	0.954	0.531	0.061	0.103	31	**13:35-13:35**	-0.0038	2.024	0.984	0.834	0.064^{*}	0.088
8	**10:10-10:10**	0.0000	1.971	0.959	0.576	0.042	0.255	32	**13:40-13:40**	-0.0040	2.010	0.978	0.766	0.066^{*}	0.079
9	**10:15-10:15**	-0.0003	2.015	0.98	0.790	0.014	0.706	33	**13:45-13:45**	-0.0038	2.004	0.975	0.734	0.079^{**}	0.035
10	**10:20-10:20**	-0.0003	2.046	0.995	0.949	0.002	0.963	34	**13:50-13:50**	-0.0038	1.980	0.963	0.615	0.099^{***}	0.008
11	**10:25-10:25**	-0.0002	2.051	0.998	0.978	-0.006	0.864	35	**13:55-13:55**	-0.0038	1.956	0.951	0.506	0.098^{***}	0.009
12	**10:30-10:30**	-0.0002	2.014	0.98	0.786	0.007	0.846	36	**14:00-14:00**	-0.0041	1.915	0.932	0.345	0.101^{***}	0.007
13	**10:35-10:35**	-0.0004	1.996	0.971	0.697	0.01	0.787	37	**14:05-14:05**	-0.0040	1.947	0.947	0.467	0.111^{***}	0.003
14	**10:40-10:40**	-0.0005	1.971	0.959	0.574	-0.002	0.963	38	**14:10-14:10**	-0.0038	1.991	0.968	0.668	0.102	0.006
15	**10:45-10:45**	-0.0009	1.971	0.959	0.576	-0.001	0.976	39	**14:15-14:15**	-0.0037	1.977	0.962	0.602	0.096^{**}	0.01
16	**10:50-10:50**	-0.0012	1.922	0.935	0.368	0.016	0.659	40	**14:20-14:20**	-0.0039	1.935	0.942	0.421	0.098^{***}	0.009
17	**10:55-11:55**	-0.0014	1.875	0.912	0.219	0.027	0.471	41	**14:25-14:25**	-0.0044	1.930	0.939	0.400	0.093^{**}	0.013
18	**11:00-11:00**	-0.0012	1.846	0.898	0.152	0.041	0.268	42	**14:30-14:30**	-0.0047	1.926	0.937	0.385	0.097^{***}	0.009
19	**11:05-11:05**	-0.0011	1.832	0.891	0.125	0.058	0.122	43	**14:35-14:35**	-0.0047	1.924	0.936	0.376	0.099^{***}	0.008
20	**11:10-11:10**	-0.0011	1.872	0.911	0.211	0.059	0.111	44	**14:40-14:40**	-0.0053	1.944	0.946	0.457	0.092^{**}	0.014
21	**11:15-11:15**	-0.0012	1.884	0.916	0.243	0.054	0.15	45	**14:45-14:45**	-0.0057	1.982	0.964	0.628	0.083^{**}	0.027
22	**11:20-11:20**	-0.0013	1.865	0.907	0.193	0.069^{*}	0.066	46	**14:50-14:50**	-0.0056	2.000	0.973	0.714	0.08^{**}	0.032
23	**11:25-11:25**	-0.0015	1.867	0.909	0.200	0.074^{**}	0.047	47	**14:55-14:55**	-0.0056	2.024	0.984	0.834	0.062^{*}	0.098
24	**11:30-11:30 (Morning Close)**	-0.0018	1.916	0.932	0.349	-0.064^{*}	0.086	48	**15:00-15:00 (Close-Close)**	-0.0049	2.056	1	1	0.041	0.271

Notes: *. 10% level of significance. **: 5% level of significance. ***: 1% level of significance.

Table 2 Descriptive statistics for the returns of the trading and non-trading period of the Shanghai Composite Index, 2000 - 2002 (In percentage)

		Shanghai Composite Index in Percentage		
	Time	**Mean**	**Variance**	**Variance Ratio**
1	**Overnight**	0.0655	0.388	0.733
2	**Morning**	-0.1407	0.604	1.142
3	**Lunch Break**	0.0083	0.006	0.011
4	**Afternoon**	0.0705	0.529	1.000
	(1)+(2)+ (3)+(4)		1.527	
5	**Open-close**	-0.0665	1.703	3.219
6	**Close-close**	-0.0049	2.056	3.887

Note: The computation for these return series are for morning 09:30 – 11:30, for lunch break: 11:30 – 13:00 (afternoon opening price), for afternoon: 13:00 – 15:00 and for overnight: 15:00 – 09:30 next day.

Table 3 Descriptive statistics of the intraday 5-minute returns in percentages of the Shanghai Composite Index, 2000 - 2002

No	Interval	Size	Mean	Max	Min.	Std.	Skew.	ExKurt.	J.Bera	Cum.	No	Interval	Size	Mean	Max	Min.	Std.	Skew.	ExKurt.	J.Bera	Cum.
1	**9:30-9:35**	716	0.0306	2.39	-2.39	0.363	-0.02	12.24	2545.1	0.03	25	**13:00-13:05**	716	0.0036	1.06	-2.27	0.194	-2.047	32.27	26061	-0.137
2	**9:35-9:40**	716	-0.0403	1.62	-1.37	0.266	0.615	9.93	1477.7	-0.01	26	**13:05-13:10**	716	-0.0252	0.73	-0.49	0.091	1.114	15.19	4584.1	-0.162
3	**9:40-9:45**	716	-0.0110	1.18	-1.09	0.201	0.774	9.65	1390.4	-0.02	27	**13:10-13:15**	716	-0.0179	1.3	-0.54	0.106	2.93	40.33	42598	-0.18
4	**9:45-9:50**	716	-0.0025	0.88	-0.83	0.151	0.252	8.19	812.5	-0.02	28	**13:15-13:20**	716	-0.0049	0.95	-0.71	0.093	0.952	28.76	19911	-0.185
5	**9:50-9:55**	716	-0.0070	0.74	-0.73	0.151	-0.33	7.78	694.4	-0.03	29	**13:20-13:25**	716	-0.0002	0.72	-0.42	0.097	0.581	10.48	1711.3	-0.185
6	**9:55-10:00**	716	-0.0103	0.73	-0.82	0.141	-0.11	9.31	1189.1	-0.04	30	**13:25-13:30**	716	0.0027	0.68	-0.49	0.109	0.376	9.07	1116.6	-0.182
7	**10:00-10:05**	716	-0.0080	0.85	-0.76	0.125	-0.22	10.11	1515.1	-0.05	31	**13:30-13:35**	716	0.0056	0.83	-0.46	0.117	0.463	9.44	1263.7	-0.177
8	**10:05-10:10**	716	-0.0090	0.87	-1.25	0.153	-0.91	14.45	4013.7	-0.06	32	**13:35-13:40**	716	0.008	0.9	-0.63	0.114	0.668	12.94	3003.3	-0.169
9	**10:10-10:15**	716	-0.0062	0.95	-0.67	0.135	0.159	9.51	1268.4	-0.06	33	**13:40-13:45**	716	0.0124	0.65	-0.58	0.114	0.283	8.41	883	-0.156
10	**10:15-10:20**	716	-0.0114	0.93	-0.88	0.15	-0.13	11.59	2203.4	-0.08	34	**13:45-13:50**	716	0.0088	1.06	-1.02	0.134	0.663	18.5	7215.8	-0.148
11	**10:20-10:25**	716	-0.0071	1.09	-0.74	0.138	0.428	12.22	2560.5	-0.08	35	**13:50-13:55**	716	0.005	0.72	-0.72	0.124	-0.013	11.38	2095.3	-0.143
12	**10:25-10:30**	716	-0.0024	0.59	-0.79	0.129	-0.75	9.81	1450.2	-0.09	36	**13:55-14:00**	716	0.0052	0.69	-0.59	0.126	0.336	9.41	1241.1	-0.137
13	**10:30-10:35**	716	0.0064	0.82	-1.21	0.136	-0.86	16.43	5472	-0.08	37	**14:00-14:05**	716	0.0029	0.57	-0.7	0.125	-0.394	8.69	985.1	-0.135
14	**10:35-10:40**	716	0.0017	0.86	-1.09	0.137	-0.09	14.68	4070.3	-0.08	38	**14:05-14:10**	716	0.003	0.57	-0.7	0.136	-0.25	7.8	694.6	-0.132
15	**10:40-10:45**	716	-0.0032	0.98	-0.57	0.131	1.103	12.21	2674.9	-0.08	39	**14:10-14:15**	716	0.0043	1.12	-0.7	0.136	0.903	15.78	4967.7	-0.127
16	**10:45-10:50**	716	-0.0088	0.86	-0.65	0.13	0.396	10.74	1807.2	-0.09	40	**14:15-14:20**	716	0.0032	1.14	-0.65	0.142	0.939	13.29	3266.1	-0.124
17	**10:50-10:55**	716	-0.0051	0.72	-0.52	0.116	0.524	9.16	1165.5	-0.09	41	**14:20-14:25**	716	-0.0034	1.01	-1.02	0.144	-0.427	13.06	3038.3	-0.127
18	**10:55-11:00**	716	-0.0068	0.86	-0.52	0.119	0.94	12.32	2699.3	-0.1	42	**14:25-14:30**	716	-0.0044	0.57	-0.76	0.137	-0.435	7.81	713.3	-0.132
19	**11:00-11:05**	716	-0.0141	0.68	-0.98	0.117	-0.19	15.61	4746.4	-0.12	43	**14:30-14:35**	716	0.0052	0.9	-0.75	0.15	0.245	8.91	1050.9	-0.127
20	**11:05-11:10**	716	-0.0135	0.57	-0.69	0.111	-0.11	8.75	987.7	-0.13	44	**14:35-14:40**	716	0.0019	0.88	-0.87	0.154	-0.218	9	1079.1	-0.125
21	**11:10-11:15**	716	-0.0072	0.53	-0.9	0.112	-0.62	12.42	2692.7	-0.14	45	**14:40-14:45**	716	-0.0149	0.75	-0.97	0.158	-0.718	9.1	1172.2	-0.14
22	**11:15-11:20**	716	-0.0107	0.47	-0.76	0.1	-0.59	10.38	1668.6	-0.15	46	**14:45-14:50**	716	-0.0208	0.67	-1.45	0.148	-1.452	18.15	7096.5	-0.16
23	**11:20-11:25**	716	-0.0072	0.48	-0.65	0.096	-1.11	12.52	2852	-0.15	47	**14:50-14:55**	716	-0.0078	0.74	-0.95	0.128	-0.94	13.55	3427.7	-0.168
24	**11:25-11:30**	716	0.0125	0.68	-1.76	0.123	-4.67	69.55	134743	-0.14	48	**14:55-15:00**	716	0.1017	0.77	-0.44	0.116	0.193	7.96	738.5	-0.067
	Overnight	715	0.0655	8.70	-2.26	0.623	8.22	101.477	296966			**All**	34368	-0.0014	2.39	-2.39	0.146	-0.024	22.422	540173	

Note: Time of the trading day effect: OLS Results ($R^2 = 0.016$, $Q_1 = 0.011$, $Q_5 = 2.14$), $r_t = \beta_1 D_{1t} + \beta_2 D_{2t} + \ldots + \beta_n D_{nt} + \sum_{i=1}^{3} \beta_i r_{t-i} + \varepsilon_t, \quad n = 1, 2, \ldots, 49$

Mean = 0 test of significance: (1) Mean returns of intervals: 1, 2, 26, 46 and 48 are different than zero at 1% level of significance (2) Mean return of intervals: 4, 19, 24 and 45 at 5% level of significance. (3) Mean return of intervals: 10, 20, 22 and 33 at 10% level of significance. (4) Mean return of interval 49 (Overnight): at 1% level of significance.
(5) All does not include overnight returns

Table 4 Mean intraday 5-minute returns by trading time in percentage of the Shanghai Composite Index, 2000 - 2002

No	**Time**	**Overall**	**No**	**Time**	**Overall**
1	**9:30-9:35**	0.0306 [c]	25	**13:00-13:05**	0.0036
2	**9:35-9:40**	-0.0403 [c]	26	**13:05-13:10**	-0.0252 [c]
3	**9:40-9:45**	-0.0110 [a]	27	**13:10-13:15**	-0.0179 [c]
4	**9:45-9:50**	-0.0025	28	**13:15-13:20**	-0.0049
5	**9:50-9:55**	-0.0070	29	**13:20-13:25**	-0.0002
6	**9:55-10:00**	-0.0103	30	**13:25-13:30**	0.0027
7	**10:00-10:05**	-0.0080	31	**13:30-13:35**	0.0056
8	**10:05-10:10**	-0.0090	39	**14:10-14:15**	0.0043
9	**10:10-10:15**	-0.0062	40	**14:15-14:20**	0.0032
10	**10:15-10:20**	-0.0114 [a]	41	**14:20-14:25**	-0.0034
11	**10:20-10:25**	-0.0071	42	**14:25-14:30**	-0.0044
12	**10:25-10:30**	-0.0024	43	**14:30-14:35**	0.0052
13	**10:30-10:35**	0.0064	44	**14:35-14:40**	0.0019
14	**10:35-10:40**	0.0017	45	**14:40-14:45**	-0.0149 [c]
15	**10:40-10:45**	-0.0032	46	**14:45-14:50**	-0.0208 [c]
16	**10:45-10:50**	-0.0088	47	**14:50-14:55**	-0.0078
17	**10:50-10:55**	-0.0051	48	**14:55-15:00**	0.1017 [c]
18	**10:55-11:00**	-0.0068			
19	**11:00-11:05**	-0.0141 [b]		**Overnight**	0.0655 [c]
20	**11:05-11:10**	-0.0135 [b]		**All**	-0.0014
21	**11:10-11:15**	-0.0072			
22	**11:15-11:20**	-0.0107 [a]		**F-test**	12.073***
23	**11:20-11:25**	-0.0072		**KW-test**	1119***
24	**11:25-11:30**	0.0125 [b]			

Notes: (1) F-test 2 is the F statistic testing the equality of the intraday returns. (2) KW-test 2 is the non-parametric Kruskal Wallis statistic testing the equality of the intraday returns. (3) 10% level of significance: *****. 5% level of significance: ******. 1% level of significance: *******. (4) 10% level of significance: **a**. 5% level of significance: **b**. 1% level of significance: **c**.

Table 5 Mean 5-minute return standard deviations of the Shanghai Composite Index, 2000 - 2002 (in Percentage)

No.	Time	Overall	No.	Time	Overall
1	**9:30-9:35**	0.363	25	**13:00-13:05**	0.194
2	**9:35-9:40**	0.266	26	**13:05-13:10**	0.091
3	**9:40-9:45**	0.201	27	**13:10-13:15**	0.106
4	**9:45-9:50**	0.151	28	**13:15-13:20**	0.093
5	**9:50-9:55**	0.151	29	**13:20-13:25**	0.097
6	**9:55-10:00**	0.141	30	**13:25-13:30**	0.109
7	**10:00-10:05**	0.125	31	**13:30-13:35**	0.117
8	**10:05-10:10**	0.153	32	**13:35-13:40**	0.114
9	**10:10-10:15**	0.135	33	**13:40-13:45**	0.114
10	**10:15-10:20**	0.150	34	**13:45-13:50**	0.134
11	**10:20-10:25**	0.138	35	**13:50-13:55**	0.124
12	**10:25-10:30**	0.129	36	**13:55-14:00**	0.126
13	**10:30-10:35**	0.136	37	**14:00-14:05**	0.125
14	**10:35-10:40**	0.137	38	**14:05-14:10**	0.136
15	**10:40-10:45**	0.131	39	**14:10-14:15**	0.136
16	**10:45-10:50**	0.130	40	**14:15-14:20**	0.142
17	**10:50-10:55**	0.116	41	**14:20-14:25**	0.144
18	**10:55-11:00**	0.119	42	**14:25-14:30**	0.137
19	**11:00-11:05**	0.117	43	**14:30-14:35**	0.150
20	**11:05-11:10**	0.111	44	**14:35-14:40**	0.154
21	**11:10-11:15**	0.112	45	**14:40-14:45**	0.158
22	**11:15-11:20**	0.100	46	**14:45-14:50**	0.148
23	**11:20-11:25**	0.096	47	**14:50-14:55**	0.128
24	**11:25-11:30**	0.123	48	**14:55-15:00**	0.116
				Overnight	0.623
				All	0.146
				Levene-test	43.83***
				Brown-Forsythe test	43.021***

Notes: *: 10% level of significance; **: 5% level of significance. ***: 1% level of significance.

Figure 1 five-minute Interdaily mean return, variance, variance ratio and autocorrelation, Shanghai composite Index

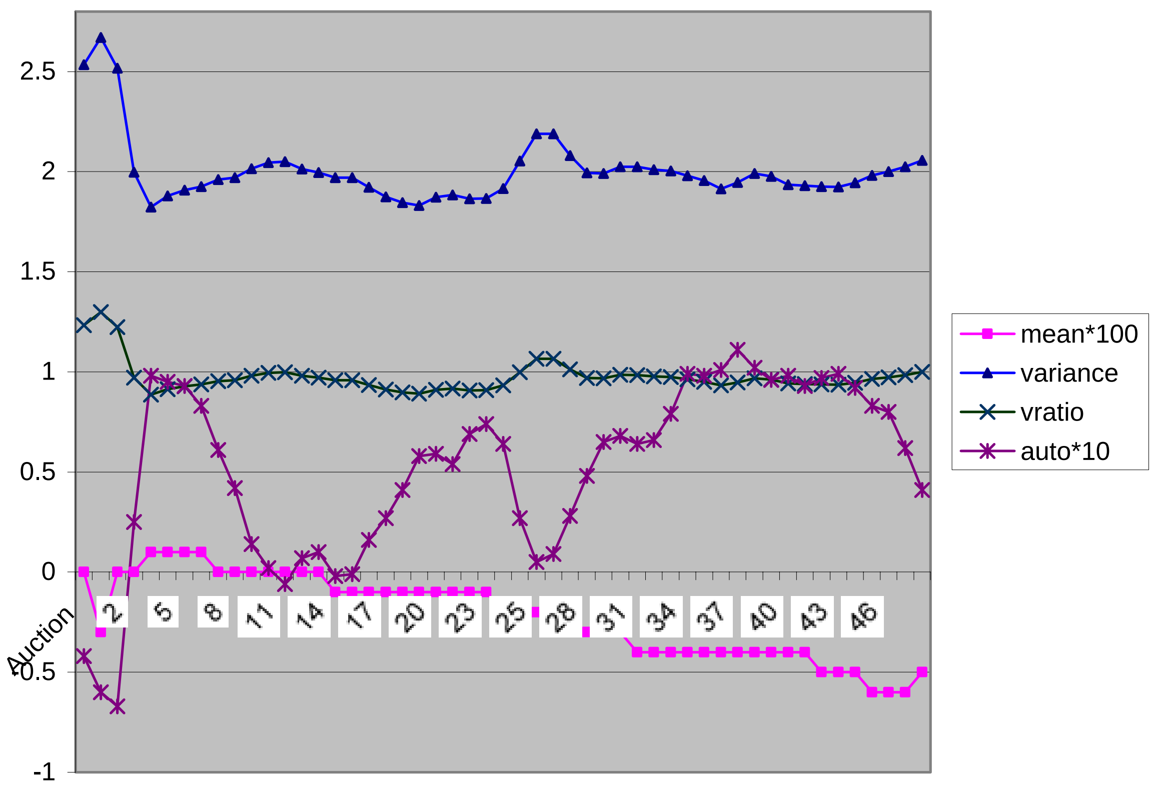
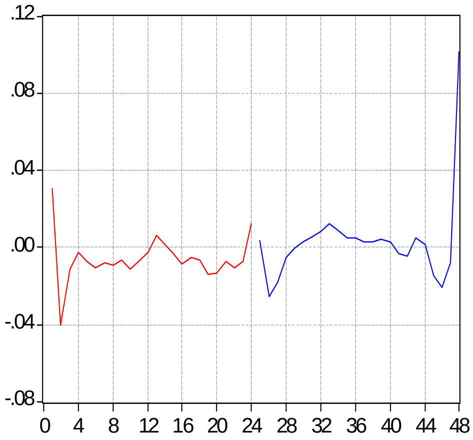
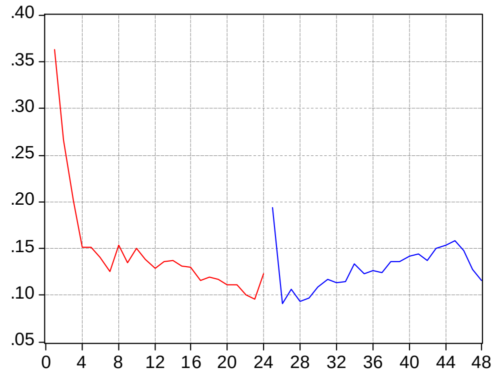


Figure 2 The mean 5-minute intraday returns in percentage and return volatility based on standard deviations of Shanghai Composite Index, 2000 - 2002.



Mean 5-minute intraday return of Shanghai Index



Volatility of 5-minute intraday return of Shanghai Index