Intra Day Behaviours of the STI Stock Index and SiMSCI Index Futures in the Singapore Exchange

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Abstract

Following the evolvement of technology in the trading and reporting systems of financial markets in the recent past, the abundance of high frequency data made available for analysis has opened up the scope for more insightful research work on the intra day behaviour of financial market data. Using high frequency intra day data from 1st January 2004 to 31st December 2004, this paper examines the patterns of the intra day returns of the Singapore Straits Times Index (STI) and the MSCI Singapore Free (SiMSCI) Index futures contract. The popular Variance Ratio framework together with other commonly employed tests will be used as comparison in our inference of the serial correlation in the returns series. Interestingly, our empirical findings report no evidence of asynchronous trading effect present in the observed STI stock index returns while the unusual phenomenon of strong significant positive serial correlation is observed in the SiMSCI futures returns.

Keywords: Stock Index Futures, High Frequency Data & Variance Ratio Test
I. Introduction

High frequency finance is a relatively new field (Goodhart and O’Hara (1997)). Tailing the enhanced technological development in the trading and reporting system of financial markets, intra day financial market data has become available for analysis. This high frequency data constitutes prices and volumes data that can be observed at interval as small as a second. The first high frequency data made available was the time series of every single traded price on the New York Stock Exchange (NYSE). While the first study of high frequency data began on the foreign exchange markets with data made available by Olsen and Associates. In particular, high frequency data have the potential to uncover many interesting insights on the behaviour of intra day financial market data. Not surprisingly, studies on the time series patterns of intra day returns and volatility have proliferated rapidly into one of the few controversial topics in the finance literature over the last decade. Since then, a huge literature that focused on characterizing the behaviour of intra day prices, returns and volumes of financial market data has emerged.

The random walk theory asserts that price movement will not follow any pattern or trend and that past price movement cannot be used to predict future price movement in financial assets. Many empirical tests on the Efficient Market Hypothesis \(^1\) (EMH) focused on the presence of serial correlation in the financial market data where significant serial correlation will hence indicate that prices could be forecasted. Most of

\(^1\) An efficient market is defined as a market where there are large numbers of rational, profit-maximizers actively competing, with each trying to predict future market values of individual securities, and where important current information is almost freely available to all participants. In an efficient market, competition among the many intelligent participants leads to a situation where, at any point in time, the actual price of a security will be a good estimate of its intrinsic value. Hence, under the null of the EMH, serial correlation ought to be negligible.
the empirical literatures on market efficiency documented that serial correlation in daily
returns are very small. On the other hand, empirical studies on the intra day behaviour of
financial market data in the high frequency regime are still by far very limited. In
consideration of all these developments in the finance literature, this paper attempts to
examine the intra day behaviours of both the stock index and index futures in the high
frequency regime using an advanced econometrical technique.

Most of the research done until now relate to the U.S. market. Only a limited number of
recent studies tackled the U.K. market while very few empirical works were performed
on other countries, especially the emerging market economies. The past twenty years
have seen substantial changes in the degree of openness and stability in most of Asia’s
emerging markets. Especially after the onset of the Asian Financial Crisis, numerous
capital markets in Asia went through intensive reforms leading to the accelerated pace of
financial integration in the region. On account of the rising significance of Asia’s
emerging financial markets, our motivation to employ an advanced econometrical
technique to examine and characterize the intra day behaviours of the stock index and
index futures contract in these markets is judiciously justified. Emerging markets, unlike
the mature U.S. market, might paint a completely different conclusion from the existing
literature; together with the possibility of unique findings along the way, our study will
be pertinent to both industry practitioners and academics by giving them an overall
outlook of the intra day behaviour of the emerging financial market data. We will confine
our analysis to Singapore in this paper.
The remaining part of the paper is organized as follows: Section 2 presents the background of the literature that has revolved around this area of research over the past decades and also states the hypotheses. Section 3 gives a brief description of both the market and the data, together with the framework of the empirical methodology employed in our analysis. Section 4 discusses the empirical findings, and finally, section 5 gives the conclusion for the study and also the scope for further research regarding this area.

II. Literature Review and Hypotheses

A. Literature Review

Since many decades ago, there has been an extensive literature in finance to examine the univariate time series behaviour of the prices, returns and volumes of financial market data. One of the widely discussed topics in this area of research is whether stock prices deviate from a random walk. The random walk theory in stock prices has a long history in finance. In addressing this issue, both academic researchers and industry practitioners have employed different empirical techniques which have led to different conclusions. Much of this controversy seems to be due to the particular choice of test statistics employed in the empirical analysis. The study of serial correlation in financial time series is particularly important in financial economics since it can reveal basic features of the trading process. Some of the more popular univariate test statistics include the t statistic, Q statistic, J statistic and the Variance Ratio (VR) statistic. However, the studies of these various test statistics are mainly concentrated on inter day and inter month prices and returns of financial market data.
Over the years, numerous empirical studies have worked on the high frequency financial market data from the New York Stock Exchange (NYSE). Wood, McNish and Ord (1985) studied the behaviour of minute by minute average market return series in NYSE using the t statistic for the estimated serial correlation coefficients. Their paper reported significant positive serial correlation in the market return series that include overnight trades. However, no significant serial correlation is observed for the entire trading day when overnight returns are excluded. Their empirical findings showed that a majority of days report significant t statistics for one to nine minutes lags for the period 1971 to 1972 and for one to fifteen minutes lags for the 1982 period at the 5% confidence level. They attributed the causes of such observed serial correlation to the effects of infrequent trading and large overnight trades.

The Variance Ratio (VR) test is also a popular test used in many empirical literatures to test for serial correlation in financial market data (Lo and MacKinlay (1988), Poterba and Summers (1988), Malliaropulos and Priestley (1990), Kim et al. (1991), Frennberg and Hansson (1993) and Felix Ayadi and Pyun (1994)). Surprisingly, the use of the Variance Ratio test in the high frequency data literature has been relatively limited so far. Among the empirical literatures, Lo and MacKinlay (1988) heteroskedasticity consistent Variance Ratio statistic is the most commonly employed form used to test for serial correlation in financial time series. Thomas and Patnaik (2003) used the non overlapping heteroskedasticity consistent Variance Ratio statistic on high frequency data to examine the behaviour of serial correlation in the NSE Nifty 50 stock index returns from the National Stock Exchange of India for the period March 1999 to February 2001. Their
paper reported no evidence of significant serial correlation even at the five minute interval for the NSE Nifty 50 market index returns. However, significant negative serial correlation is observed at the ten and fifteen minute intervals for the returns of individual stock in the constituent index.

There have been several papers extending and improving the tests of Variance Ratio and a number of alternatives have been proposed in the literature. Apart from the original Variance Ratio test statistic proposed by Lo and MacKinlay (1988), there is the subsampling test of Whang and Kim (2003) and the non-parametric test of Wright (2000) which proposed the exact test of Variance Ratio statistic based on the ranks and signs of time series. In addition, Richardson and Smith (1991) developed the Wald test which takes into account serial correlation induced by overlapping observations when the Variance Ratio statistic is calculated. Cecchetti and Sang Lam (1994) proposed a Monte Carlo method for exact inference when using a joint test of multiple Variance Ratio statistics for small samples. Chow and Denning (1993) extended the original form to test multiple Variance Ratio statistics jointly and Pan et al. (1997) used a bootstrap scheme to obtain an empirical distribution of the Variance Ratio at each period.

Most of the empirical literatures which examine the serial correlation of stock index returns in the high frequency regime documented evidence of significant strong positive serial correlation (Wood, McNish and Ord (1985), Stoll and Whaley (1990), Grunbichler, Longstaff and Schwartz (1994) and Jong and Nijman (1997)). Significant negative serial correlation is sometimes observed in the index returns especially if the index is narrowly
based (Stoll and Whaley (1990), Chan (1992), Grunbichler, Longstaff and Schwartz (1994) and Jong and Nijman (1997)). For individual stock returns, no significant positive serial correlation is however observed but significant negative serial correlation is observed most of the time (Stoll and Whaley (1990), Jong and Nijman (1997) and Thomas and Patnaik (2003)). Many studies have hence been done to explain the results of these empirical findings on the intra day patterns of the observed returns. Two well known explanations put forth to reconcile the documented intra day patterns of serial correlation observed in the market index returns are the theories of infrequent trading and bid-ask bounce effect.

Different stocks have different trading frequencies, and even for a single stock the trading intensities varies from hour to hour and from day to day. This non synchronous trading will tend to lead to a stock that is being traded more actively to react to news or shocks faster than another stock that is traded at a lesser intensity. Hence, the former stock will appear to be leading the latter and this lead lag cross correlation between these two stocks will introduce significant positive serial correlation in the stock index level, and hence index returns. This is the well known infrequent trading effect put forth to explain the significant strong positive serial correlation observed in many empirical literatures. Before the introduction of high frequency data literature, Fama (1965) has observed positive serial correlation in the daily returns of the index calculated from infrequently traded stocks. This is due to the fact that the prices of some illiquid stocks may reflect in the index calculated in the next period and result in positive correlation with the previous index. Many other empirical studies on the behaviour of inter day and inter week
financial time series also produced similar results (Lo and MacKinlay (1988)). Therefore, we can expect the erroneous positive serial correlation induced from non synchronous trading to be much stronger for studies of intra day behaviour based on high frequency data.

The presence of market makers in stock exchanges provides adequate market liquidity\(^2\) by standing ready to buy or sell whenever investors wish to sell or buy. Hence, market makers play an important role in facilitating trades in many stock exchanges. In return for providing liquidity, market makers are granted monopoly rights by the exchange to post different prices for the purchases and sales of a security. They buy at the bid price and sell at the higher ask price where the bid price is the sale price and the ask price is the purchase price for the public respectively. The difference between the bid and ask prices is called the bid-ask spread, which is also the primary source of compensation for market makers. The existence of bid-ask spread has several important consequences in the intra day times series patterns of stock returns and often introduces negative serial correlation in the stock returns (Ruey S. Tsay (2001)). This is the well known bid-ask bounce effect discussed by Roll (1984), MacKinlay and Ramaswamy (1988) and Campbell, Lo and MacKinlay (1997). Hence, non synchronous trading, in a more complicated manner, can also induce erroneous negative serial correlation for individual stock which will in turn introduce negative serial correlation to the stock index, especially if the index is narrowly based. This effect, however, is mitigated for stock indexes because of the averaging of stock prices.

\(^2\) By market liquidity, we mean the ability to buy or sell significant quantities of a security quickly, anonymously, and with little price impact.
Ever since the introduction of the stock index futures in the financial markets in the 1980s, there have been extensive studies on the financial market data of index futures. More recently, empirical studies on the intra day behaviour of the futures markets in the high frequency regime are blooming rapidly with the availability and easy accessibility of high frequency data on futures markets. However, most of the studies done so far are more focused on the causal relationship between the index futures and their underlying indexes. Surprisingly, little attention has been given to the intra day behaviour of index futures returns. Most of the empirical studies done on the futures markets used the simple t statistics of the estimated serial correlation coefficients to examine for serial correlation in the observed futures returns, very few studies have employed more advanced test statistics to check for serial correlation in the intra day patterns of index futures (Reno and Bianco (2005)). Since index futures is a single financial instrument, the erroneous positive serial correlation induced by non synchronous trading should not exist in the observed futures returns. However, the negative serial correlation induced by the bid-ask bounce effect observed in many of the individual stock returns is likely to be observed in the index futures returns as well. Hence, we would expect empirical evidence of either no serial correlation or significant negative serial correlation to be reported in the studies of intra day time series behaviour of index futures returns. Most of the empirical works done so far to examine the serial correlation of index futures are consistent with the literature.

The recent paper by Reno and Bianco (2005) is one of the few studies on futures markets which used a more advanced test statistics apart from the commonly employed t statistics to test for serial correlation in the intra day financial time series of index futures. In their
paper, they employed the variance ratio test to examine the serial correlation pattern of
the Italian stock index futures (FIB30) for the period January 2000 to December 2002, a
total of 751 trading days. Their empirical findings reported evidence of serial correlation
in high frequency prices of the Italian stock index futures and the serial correlation is
mainly negative and it is non negligible for periods smaller than 20 minutes. They also
showed in their paper that the observed negative serial correlation in their empirical
findings is due to the well known bid-ask bounce effect.

Stoll and Whaley (1990) investigated the intra day time series behaviour for the U.S
indexes using observations on all transactions of the S&P 500 index and the Major
Market index (MMI) together with the futures on these indexes. In their paper, each
trading day is partitioned into fixed 5 minute intervals where the first prices observed in
these intervals are then used to compute the 5 minute returns. Using the simple t statistics
test on the estimated serial correlation coefficients of the observed returns, their findings
reported strong and significantly positive serial correlation in the S&P 500 index returns
in the first few lags for both their sample periods from July 1984 to December 1986 and
April 1982 to March 1987. On the other hand, significant negative serial correlation is
observed in the returns of the Major Market (MMI) index which is attributed mainly to
the bid-ask bounce effect since the MM index is narrowly based. The observed S&P 500
futures returns are almost serially uncorrelated, exhibiting lingering negative serial
correlation in lag 2 and 3 due to the bid-ask bounce effect. Similarly, individual stock
returns of IBM also tend to be significantly negatively serially correlated due to the bid–
ask bounce effect.
Jong and Nijman (1997) investigated the serial correlation pattern of intra day high frequency spot and futures prices of the S&P 500 index using a covariance estimator developed to deal with intervals without new observations on the index or futures prices. Their analysis can therefore be performed on a higher frequency than the common five minute practice without non trading bias. Using a sampling period of the last quarter of 1993, their empirical findings reported little serial correlation on the ten minute interval but significant positive first order correlation is observed on the five minute interval. The serial correlation is significantly positive up to order eight on the one minute interval. For the S&P futures returns, their paper documented no evidence of any significant serial correlation on both the five and ten minute intervals. However, significant negative serial correlation of order one is observed on the one minute interval which is again attributed to the bid-ask bounce effect.

On concluding, high frequency data analysis is a relatively new field in the finance literature and most empirical works till now report strong positive serial correlation observed in the intra day stock index returns while no evidence of any positive serial correlation is observed on the intra day behaviour of index futures returns. Hence, we can see that the empirical studies on the high frequency regime are consistent with the existing literatures that expect stronger erroneous effect from non synchronous trading to be observed in the intra day patterns of stock index returns. On the other hand, negative serial correlation induced by the bid-ask bounce effect can be observed in both the intra day returns of individual stocks and index futures. Though the Variance Ratio test is a popular test used to test for serial correlation of financial time series, the application of
this test in the high frequency regime is still very limited, especially on the analysis of the intra day behaviour of index futures financial time series.

**B. Hypotheses**

Most prior empirical works on the intra day patterns of stock index and index futures returns in the high frequency regime employed the t statistics of the estimated serial correlation coefficients to test for the presence of serial interdependence. One issue that arises when analyzing the serial correlation in the observed returns series is the U shaped patterns in volatility documented for markets all over the world (Wood et al. (1985); Stoll and Whaley (1990); Lockwood and Linn (1990); McNish and Wood (1990a, 1990b, 1991, 1992); Andersen and Bollerslev (1997)). Such heteroskedasticity in the observed returns could cause problems with our inference of the serial correlation. To accommodate the conditional heteroskedasticity in the observed returns, we will employ the heteroskedasticity robust Variance Ratio test statistic proposed by Lo and MacKinlay (1988) in our analysis.

We will examine the serial correlation of the observed returns series using a comparison of both the commonly employed t statistic test on the estimated serial correlation coefficients and the popular Variance Ratio test. Hence, we will test our hypotheses according to the empirical findings of the existing literatures in the following forms:

*Hypothesis 1: There is evidence of significant positive serial correlation observed in the STI stock index returns series due to the infrequent trading effect.*
Hypothesis 2: The observed returns of the SiMSCI index futures are negatively correlated due to the bid-ask bounce effect.

III. Market and Data and Methodology

A. Market

Singapore Exchange (SGX) is Asia-Pacific's first demutualised and integrated securities and derivatives exchange. SGX was inaugurated on 1 December 1999, following the merger of two established and well-respected financial institutions - the Stock Exchange of Singapore (SES) and the Singapore International Monetary Exchange (SIMEX). On 23 November 2000, SGX became the first exchange in Asia-Pacific to be listed via a public offer and a private placement. Listed on the bourse, their stock is a component of benchmark indexes such as the MSCI Singapore Free Index and the Straits Times Index (STI). As a pioneer in Asian equity futures and options, the SGX was the first market in Asia to list equity index futures which include Japan, Taiwan, India, Hong Kong and Singapore. The SGX derivatives market is a pioneer in global alliances, having been a partner with the Chicago Mercantile Exchange (CME) in a mutual offset arrangement since 1984. SGX's Mutual Offset System (MOS) with CME is the world's 1st and most successful futures trading link. This truly fungible facility provides round-the-clock trading of Eurodollar and Euroyen futures and options.

Since its first equity futures launched in 1986, the Singapore Exchange Derivative Trading (SGX-DT) has developed to become the trading centre of Asian equity indexes.
SGX-DT has two stock index futures contracts based on the Singapore stock market, namely the MSCI Singapore Free (SiMSCI) Index futures contract and the Singapore Straits Times Index (STI) futures contract. Both of these contracts are being traded on the SGX Electronic Trading System (ETS). However, the SiMSCI futures contract is more popular with investors and traders and is traded more actively compared to the STI futures contracts. SGX SiMSCI futures contract, based on the MSCI Singapore Free Index, began trading on Singapore Exchange Derivatives Trading (SGX-DT) on September 7, 1998. The MSCI Singapore Free Index is a market-capitalization equity index, which currently contains 36 securities listed on the Singapore Exchange Securities Trading (SGX-ST). Compiled fully and independently by Morgan Stanley Capital International (MSCI), the market capitalization-weighted index tracks the prices of stocks listed on Singapore Exchange representing a sampling of large, medium and small-capitalized companies. It currently represents about 60% of the total market capitalization of Singapore and has been calculated since January 1, 1998. Hence, the MSCI Singapore Free Index is often widely used as a performance benchmark of the Singapore stock market. In addition, the MSCI Singapore Free index has a high correlation of about 95% with the Straits Times Index (STI). On the contrary, STI futures contract consists of only 45 market-representative stocks listed on the Singapore Exchange Securities Trading Ltd at a mere fraction – about 5-10% - of the total STI value.

Unlike continuous trading throughout the day as in the US and UK markets, the Singapore stock and futures markets have two trading sessions, the morning session and the afternoon session. The underlying Singapore stock market trades from 9.00am -
12.30pm and 2.00pm - 5.00pm (Monday - Friday) while the trading hours of the Singapore Exchange Derivative Trading (SGX-DT) starts from 8.45am – 12.35pm and 2.00pm – 5.15pm (Monday – Friday). The value of each SiMSCI contract is S$200 multiplied by the value of the MSCI Singapore Index Futures Price. The types of contracts offered include the 2 nearest serial months and 4 quarterly months on March, June, September and December cycle, with expiration date on the second last trading day of the contract month.

B. Data

Time stamped transaction data of the MSCI Singapore Free (SiMSCI) Index futures contracts are obtained from the Singapore Exchange Derivative Trading (SGX-DT). While an interval as short as one minute is feasible, the 5 minute interval will be our choice of focus since it is concise and able to convey all the findings effectively. Our sampling period covers from 1 January 2004 to 31 December 2004 and each trading day is partitioned into 5-minute intervals. Only the spot month contract is used for the entire analysis since it is the most actively traded contracts. Comparatively, the contract for the 2nd serial month is only traded on slightly more than half of the 253 total trading days available in our sampling period and the number of transactions each day is significantly lesser than that of the spot month contract. Hence, there are not enough transactions to create a meaningful data set for our analysis. Similarly, the market for the other expiration contracts is very thin. Following common practice, the nearby future contract is followed until the second last trading day of the expiration month, at which point the series switches to the next nearby contract. The last 2 trading days before expiration are
also discarded to avoid the influence of unusual trading activities as the contracts approach maturity. The closing prices for the Straits Time Index (STI) are retrieved from the financial databases of the Bloomberg’s Archive.

Returns of the SiMSCI futures contract and the STI stock index in interval t are defined as $R_{F,t} = 100 \times \ln\left(\frac{F_{t}^m}{F_{t-1}^m}\right)$ and $R_{S,t} = 100 \times \ln\left(\frac{S_{t}^c}{S_{t-1}^c}\right)$, where $F_{t}^m$ is the mean traded price of the futures contract and $S_{t}^c$ is the closing price of the stock index in interval t respectively. Overnight returns are discarded since we focus only on intra day behaviour. The first 2 returns each day for the STI stock index are also excluded from our analysis because the index value at the beginning of the day are computed using closing stock prices from the previous day. Since closing prices are inaccurate reflections of opening values, there may be noise in the index level and, hence, in index returns, until all stocks within the index have traded.

C. Methodology

Serial correlations are estimated for lags 1 through 12, that is, up to one hour of trading time for both the STI stock index and SiMSCI index futures returns series. Since we are focusing on intra day series, 43 and 39 return observations are lost respectively for the STI stock index and SiMSCI futures contracts each time the order of the serial correlation k increases and hence the serial correlation estimates will not be contaminated by returns from adjacent days.
Two approaches are employed to test for serial correlation in the returns series. The first approach is the serial correlation coefficient test which is a widely employed procedure that tests the relationship between returns in the current period and those in the previous periods. If no significant autocorrelations are found then the series are assumed to follow a random walk. Since we are focusing on intra day behaviour, we will also examine the proportion of trading days showing significant serial correlation coefficients for all the lags. This can provide us more insights on the intra day behaviour of the returns series.

The second approach is the Variance Ratio (VR) test which was first applied to financial data in Nelson and Plosser (1982). Lo and MacKinlay’s Variance Ratio Statistics (VRs) will be employed in our analysis to test for the serial correlation in the observed returns series. VRs have been often used to test for serial correlations in stock market prices (Lo and MacKinlay (1988) and Poterba and Summers (1988)). The VR statistic measures the serial correlation over k period as given by:

\[
VR(q) = \frac{Var[r_t(q)]}{Var[r_t]}, \quad \text{where } r_t(q) = \sum_{k=1}^{q} r_t
\]

(3)

\[
= 1 + \sum_{k=1}^{q-1} \left(1 - \frac{k}{q}\right) \rho_k
\]

(4)

where \( r_t(q) \) is the q-period return, and \( \rho_k \) is the k-period autocorrelation. For a random walk, \( \rho_k \equiv 0 \quad \forall k \). Hence the null of market efficiency is defined as,
Following the formula given by Wright (2000), the VR statistic can be written as

\[ VR(R; k) = \left\{ \frac{1}{Tk} \sum_{t=k}^{T} \left( R_t + R_{t-1} + \ldots + R_{t-k+1} - k\bar{R} \right) \right\} \div \left\{ \frac{1}{T} \sum_{t=1}^{T} (R_t - \bar{R})^2 \right\} \]

where \( \bar{R} = T^{-1} \sum_{t=1}^{T} R_t \).

This is an estimator for the unknown population \( VR(k) \), which is the ratio of 1/k times the variance of k-period return to the variance of one-period return. To accommodate conditional heteroskedasticity in the observed returns, Lo and MacKinlay (1988) proposed a heteroskedasticity robust test statistic \( M(R; k) \) and showed that if \( R_t \) is independent and identically distributed, then under the null hypothesis that \( VR(k) \equiv 1 \),

\[ M(R; k) = (VR(R; k) - 1) \left( \sum_{j=1}^{k-1} \frac{2(k-j)}{k} \delta_j \right)^{-1/2} \]

where \( \delta_j = \left\{ \sum_{t=j+1}^{T} (R_t - \bar{R})^2 (R_{t-j} - \bar{R})^2 \right\} \div \left\{ \sum_{t=1}^{T} (R_t - \bar{R})^2 \right\} \) follows the standard normal distribution asymptotically.
The VR test has more power than the other tests for serial correlation, such as the Ljung-Box Q statistics and the Dickey-Fuller test (Lo and MacKinlay 1989). On top of that, it does not require the normality assumption and is quite robust.

VI. Empirical Results

A. Serial Correlation in Observed STI Stock Index Returns

The estimated serial correlation coefficients of the observed returns for the STI stock index together with their respective t statistics are computed and shown in Table 1.

In Table 1, we can observe that the lag one serial correlation coefficient, -0.174, is reasonably large and significantly negative at the 0.05 significance level. Similarly, the serial correlation coefficients at lag two (-0.044), lag three (-0.063) and lag seven (-0.049) though smaller as compared to lag one, are also significantly negative. The serial correlation coefficients for the other remaining lags are all negligible and insignificant. Comparatively, Stoll and Whaley (1990) reported that there is no evidence of significant negative serial correlation observed in the U.S S&P 500 index returns series. Since S&P 500 index has a large base of 500 stocks, any bid-ask bounce effect in the individual stock returns will tend to disappear in the index portfolio returns as a result of diversification. However, Singapore’s STI stock index has a relatively small base of only 40 stocks since 1998 and hence any bid-ask bounce effect in the individual stock returns will be easily reflected in the index returns as well.
Therefore, our empirical finding suggests that many of the individual stocks in the STI stock index do not trade for period as long as five minutes but occasionally as long as fifteen minutes or more. The observed negative serial correlation is also consistent with the empirical study done on the Major Market (MM) index which consists of only 20 active stocks reported in Stoll and Whaley (1990) paper. However, the bid-ask bounce effect observed in the STI return series, though less significant, are stronger than those reported in the observed returns of the MMI despite that STI stock index consists of twice the number of stocks contained in the Major Market (MM) index.

Surprisingly, STI stock index returns exhibit an interesting feature which differs from the serial correlation patterns reported in many earlier empirical literatures. We can observe from our empirical finding that STI stock index returns, in contrast to models of infrequent trading, does not show any evidence of significant positive serial correlation.

This is an interesting paradox to the typical rationale that is given to explain the behaviour of intra day stock index returns, which is the asynchronous trading of the constituent stock. Since negative correlation is observed, this gives rise to the possibility that there is so much negative correlation from the bid-ask bounce effect that it beats the positive aspect we expect from asynchronous trading. However, the observed magnitudes of the negative serial correlation coefficients to account for the bid-ask bounce effect are comparably large, hence it is unlikely that the bid-ask bounce effect strongly overrides any positive effect of infrequent trading and leads to the observed negative serial correlation in the returns series.
TABLE 1

Estimated Serial Correlation Coefficients of Observed Returns of STI Stock Index ($R_{S,t}$)

<table>
<thead>
<tr>
<th>Lag k</th>
<th>No of Obs</th>
<th>$\hat{\rho}_k$</th>
<th>$t(\hat{\rho}_k)$</th>
<th>Positive Significance</th>
<th>Negative Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>19987</td>
<td>-0.174</td>
<td>-7.111*</td>
<td>2.8%</td>
<td>13.8%</td>
</tr>
<tr>
<td>2</td>
<td>19734</td>
<td>-0.044</td>
<td>-2.028*</td>
<td>5.9%</td>
<td>8.3%</td>
</tr>
<tr>
<td>3</td>
<td>19481</td>
<td>-0.063</td>
<td>-2.481*</td>
<td>6.7%</td>
<td>9.5%</td>
</tr>
<tr>
<td>4</td>
<td>19228</td>
<td>0.014</td>
<td>1.161</td>
<td>1.6%</td>
<td>6.3%</td>
</tr>
<tr>
<td>5</td>
<td>18975</td>
<td>0.001</td>
<td>0.149</td>
<td>0.0%</td>
<td>2.0%</td>
</tr>
<tr>
<td>6</td>
<td>18722</td>
<td>0.012</td>
<td>0.333</td>
<td>3.2%</td>
<td>0.4%</td>
</tr>
<tr>
<td>7</td>
<td>18469</td>
<td>-0.049</td>
<td>-2.437*</td>
<td>1.2%</td>
<td>0.8%</td>
</tr>
<tr>
<td>8</td>
<td>18216</td>
<td>0.008</td>
<td>0.555</td>
<td>1.6%</td>
<td>0.4%</td>
</tr>
<tr>
<td>9</td>
<td>17963</td>
<td>-0.003</td>
<td>-0.077</td>
<td>2.8%</td>
<td>4.3%</td>
</tr>
<tr>
<td>10</td>
<td>17710</td>
<td>-0.006</td>
<td>-0.101</td>
<td>0.4%</td>
<td>4.7%</td>
</tr>
<tr>
<td>11</td>
<td>17457</td>
<td>-0.011</td>
<td>-0.425</td>
<td>1.2%</td>
<td>1.2%</td>
</tr>
<tr>
<td>12</td>
<td>17204</td>
<td>-0.003</td>
<td>-0.131</td>
<td>0.4%</td>
<td>2.0%</td>
</tr>
</tbody>
</table>

*Significant at the 0.05 level

1. The last two columns report percentage of trading days with significant positive and negative estimated serial correlation coefficients respectively at the 0.05 significance level.
2. The number of observations used in the computation of the serial correlation coefficient. Note that as the lag k is incremented by one, the number of observations lost equals the number of days in the sample period. This reflects the loss of one return each day of the sample. The serial correlation coefficient estimates, therefore, are not contaminated by using returns from adjacent days.
3. The estimated lag k serial correlation coefficient across all 5 minute returns in all days of the period excluding overnight returns. The first two returns each day are also excluded.

Another possible explanation lies in the selection of our choice of interval. If the width of the interval is too high, then information about the temporal pattern in the returns may be lost. On the other hand, a thin interval may lead to high incidence of “non-trading” which is associated with spurious positive serial correlation in the returns. Therefore, the choice of interval must be chosen to minimize the information loss while avoiding the problem of spurious autocorrelation. Hence, we might need to examine the STI index returns at higher frequencies, in order to find evidence of asynchronous trading in the index.
Interestingly, our findings suggest the possibility of an unusual scenario where most of the stocks in the STI stock index are generally traded at the same intensity and react to shocks simultaneously; and hence little or no infrequent trading effect is present in the observed STI returns series.

However, the empirical result from the estimated serial correlation coefficients might be misleading. A detailed investigation on the proportions of trading days showing significant serial correlation coefficients at each of the lags reports no sign of any serial interdependence among the STI stock index returns. From the last two columns in Table 1, we can observe that less than 10% of the trading days display significant positive serial correlation coefficients for all the lags, hence indicating no evidence of infrequent trading effect in the observed STI stock index returns. Similarly, the highest proportion of trading days showing significant negative serial correlation coefficients is for lag one but the reported percentage of 13.8% is still too low to conclude any negative significance. Hence, there is little evidence of any significant serial interdependence among the observed intra day STI stock index returns.

We will employ Lo and MacKinlay proposed heteroskedasticity robust test statistic $M(R;k)$ to investigate the serial correlation patterns in the observed STI stock index returns. Table 2 reports the percentages of trading days in our sample period that show significant serial correlation for the various lags.
Our empirical result shows that none of the trading days displays positive serial correlation at any lag at all the 3 significance levels. This is consistent with our empirical results derived from the t statistics test on the estimated serial correlation coefficients earlier; and hence our finding is again contrary to what was documented in earlier literatures where stock market indexes exhibit positive serial correlation in their observed returns.

### TABLE 2

Percentage of Trading Days that shows Significant Serial Correlation for the Observed Returns of STI Stock Index ($R_{S,t}$)

<table>
<thead>
<tr>
<th>Lag</th>
<th>90% Level (0.05)</th>
<th>95% Level (0.025)</th>
<th>99% Level (0.005)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Positive</td>
<td>Negative</td>
<td>Positive</td>
</tr>
<tr>
<td>1</td>
<td>0.0%</td>
<td>43.9%</td>
<td>0.0%</td>
</tr>
<tr>
<td>2</td>
<td>0.0%</td>
<td>48.6%</td>
<td>0.0%</td>
</tr>
<tr>
<td>3</td>
<td>0.0%</td>
<td>42.7%</td>
<td>0.0%</td>
</tr>
<tr>
<td>4</td>
<td>0.0%</td>
<td>44.3%</td>
<td>0.0%</td>
</tr>
<tr>
<td>5</td>
<td>0.0%</td>
<td>39.5%</td>
<td>0.0%</td>
</tr>
<tr>
<td>6</td>
<td>0.0%</td>
<td>36.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>7</td>
<td>0.0%</td>
<td>35.2%</td>
<td>0.0%</td>
</tr>
<tr>
<td>8</td>
<td>0.0%</td>
<td>34.4%</td>
<td>0.0%</td>
</tr>
<tr>
<td>9</td>
<td>0.0%</td>
<td>33.2%</td>
<td>0.0%</td>
</tr>
<tr>
<td>10</td>
<td>0.0%</td>
<td>32.4%</td>
<td>0.0%</td>
</tr>
<tr>
<td>11</td>
<td>0.0%</td>
<td>31.2%</td>
<td>0.0%</td>
</tr>
<tr>
<td>12</td>
<td>0.0%</td>
<td>31.6%</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

At the 0.005 significance level, we can observe that negative serial correlation is most prominent in the first 2 lags where 13.4% and 15.0% of the trading days in our sample period show significant negative serial correlation respectively. However, this percentage is relatively small, hence suggesting the low significance of negative serial correlation in the first 2 lags. Since the empirical result from the estimated serial correlation coefficients might be misleading, the empirical finding from the study of the proportion
of trading days showing significant estimated serial correlation coefficients will be used instead for comparison between the two tests. In comparison, heteroskedasticity patterns in the observed STI returns series do not induce any significant erroneous effect on the inference of serial correlation in the observed returns. Therefore, when the effect of heteroskedasticity is accommodated using Lo and MacKinlay heteroskedasticity robust variance ratio test, the empirical findings from both tests are consistent.

At the 0.025 significance level, lag 3 reports the highest percentage of trading days showing significant negative serial correlation. We can observe that approximately 20% of the trading days display significant negative serial correlation for the first 5 lags which is over a time interval of 25 minutes. Though the proportion of trading days with significant negative serial correlation for the first few lags are much higher than at the 0.005 significance level, the observed percentages are still too low to accurately conclude that there is significant negative serial correlation present in these lags. Lastly, above 30% of the trading days show significant negative serial correlation for all the lags at the 0.05 significance level. Hence, this indicates the inadequacy of the 0.05 significance level to test for serial correlation in the observed STI returns.

On concluding, our empirical findings consistently report no evidence of any positive serial correlation observed in the STI stock index returns in contrast to most existing empirical literatures. Hence, we will reject our null Hypothesis 1 that there is evidence of positive serial correlation in the observed STI stock index returns. As mentioned earlier, a choice of interval at higher frequencies may be required to reflect any significant positive
serial correlation induced by the asynchronous trading effect present in the STI stock index returns. Significant negative serial correlation is reported for lag one, two, three and seven at the 0.05 significance level using the commonly employed t statistics test on the estimated serial correlation coefficients; and can be attributed mainly to the bid-ask bounce effect present in many of the individual stocks in the STI index. However, empirical results from both the study of the proportion of trading days showing significant serial correlation coefficients and the variance ratio test report no evidence of any significant serial interdependence in the observed STI returns series.

B. Serial Correlation in Observed SiMSCI Futures Returns

The estimated serial correlation coefficients of the observed returns for the SiMSCI spot month futures contract, together with their respective t statistics are computed and shown in Table 3.

In Table 3, we can observe that the lag one serial correlation coefficient (0.312) is surprisingly large and significantly positive. Similarly, the serial correlation coefficient at lag 2 (-0.083) is relatively large and significantly negative. The serial correlation coefficients are negligible and insignificant for all other lags. Since the futures returns are for a single financial instrument rather than a portfolio of securities, any positive serial correlation caused by the effect of infrequent trading should not appear in the observed return series. Therefore, our empirical finding is a contrary to both the existing literature and empirical studies done on the futures markets. Our finding hence suggests that other factors not documented in the existing literature are at work to cause the significant
positive serial correlation in the observed SiMSCI futures returns. Such factors may well be attributed to certain unique institutional features from the Singapore market and our empirical finding has hence opened up the scope for more theoretical and empirical research works on the Singapore Futures Market.

<table>
<thead>
<tr>
<th>Lag k</th>
<th>No of Obs</th>
<th>( \hat{\rho}_k )</th>
<th>( t(\hat{\rho}_k) )</th>
<th>Positive Significance</th>
<th>Negative Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>19236</td>
<td>0.312</td>
<td>13.971*</td>
<td>39.7%</td>
<td>0.9%</td>
</tr>
<tr>
<td>2</td>
<td>19007</td>
<td>-0.083</td>
<td>-4.115*</td>
<td>1.7%</td>
<td>17.0%</td>
</tr>
<tr>
<td>3</td>
<td>18778</td>
<td>0.004</td>
<td>0.584</td>
<td>6.1%</td>
<td>3.9%</td>
</tr>
<tr>
<td>4</td>
<td>18549</td>
<td>0.017</td>
<td>1.133</td>
<td>4.8%</td>
<td>4.8%</td>
</tr>
<tr>
<td>5</td>
<td>18320</td>
<td>-0.014</td>
<td>-1.081</td>
<td>5.7%</td>
<td>9.2%</td>
</tr>
<tr>
<td>6</td>
<td>18091</td>
<td>0.001</td>
<td>0.416</td>
<td>4.8%</td>
<td>5.2%</td>
</tr>
<tr>
<td>7</td>
<td>17862</td>
<td>0.002</td>
<td>0.401</td>
<td>6.6%</td>
<td>5.7%</td>
</tr>
<tr>
<td>8</td>
<td>17633</td>
<td>-0.011</td>
<td>-1.128</td>
<td>4.8%</td>
<td>6.1%</td>
</tr>
<tr>
<td>9</td>
<td>17404</td>
<td>0.023</td>
<td>1.098</td>
<td>3.9%</td>
<td>7.4%</td>
</tr>
<tr>
<td>10</td>
<td>17175</td>
<td>-0.028</td>
<td>-1.533</td>
<td>3.5%</td>
<td>11.8%</td>
</tr>
<tr>
<td>11</td>
<td>16946</td>
<td>-0.003</td>
<td>-0.423</td>
<td>3.5%</td>
<td>9.6%</td>
</tr>
<tr>
<td>12</td>
<td>16717</td>
<td>-0.010</td>
<td>-0.685</td>
<td>1.7%</td>
<td>5.7%</td>
</tr>
</tbody>
</table>

*Significant at the 0.05 level

1. The last two columns report percentage of trading days with significant positive and negative estimated serial correlation coefficients respectively at the 0.05 significance level.

Not surprisingly, the significant negative serial correlation coefficient observed in lag 2 is due to the bid-ask bounce effect documented in many earlier empirical literatures on the futures markets. However, the magnitude of the negative serial correlation coefficient is relatively larger for the SiMSCI futures returns as compared to those reported in the
observed futures returns from both the U.S. and Germany markets. Chan (1992) reported that the significant negative serial correlation coefficients for the MMI futures returns from August 1984 to June 1985 are -0.047 and -0.035 for lag 3 and 4 respectively. During the same period, the negative serial correlation coefficients for the S&P 500 futures returns that are significant at the 0.001 level are -0.042 (lag 3) and -0.027 (lag 4) respectively. Similarly, Germany’s DAX futures returns showed less significant negative serial correlation for lag 2 and 3 with magnitudes of -0.028 and -0.032 respectively for the sample period from November 1990 to September 1991 (Grunbichler, Longstaff and Schwartz (1994)). Our empirical finding therefore suggests a relatively stronger bid-ask bounce effect present in the SiMSCI futures contracts.

Similarly, the result reported from the estimated serial correlation coefficients might be misleading. The last two columns in Table 3 report the proportion of trading days in the sample period that show significant serial correlation coefficients for all lags. The highest proportion of trading days showing significant negative serial correlation coefficients is reported in lag 2 (17.0%) while the highest proportion showing significant positive serial correlation coefficients is reported in lag 1 (39.7%) at the 0.05 significance level. In comparison, the estimated serial correlation coefficient is negatively significant in lag 2 and positively significant in lag 1. However, the percentage reported in lag 2 is too low to conclude any negative significance in the lag two serial correlation coefficients. On the other hand, an unusually high proportion of trading days are observed with significant positive lag one serial correlation coefficients and hence our finding is again contrary to what was documented in earlier literatures where no significant positive serial correlation
should be observed in the returns of index futures. Nevertheless, it is worthwhile to take note of the presence of unusual characteristics in the intra day patterns of the SiMSCI index futures in the Singapore Exchange.

We will employ Lo and MacKinlay proposed heteroskedasticity robust test statistic $M(R;k)$ to further investigate the serial correlation patterns in the observed SiMSCI futures returns. Table 4 reports the percentages of trading days in our sample period that show significant serial correlation for the various lags in the SiMSCI futures returns series.

\begin{table}
\centering
\begin{tabular}{llllll}
\hline
 & \multicolumn{2}{c}{90\% Level (0.05)} & \multicolumn{2}{c}{95\% Level (0.025)} & \multicolumn{2}{c}{99\% Level (0.005)} \\
Lag & Positive & Negative & Positive & Negative & Positive & Negative \\
\hline
1 & 19.7\% & 0.0\% & 16.6\% & 0.0\% & 7.9\% & 0.0\% \\
2 & 17.9\% & 0.0\% & 12.2\% & 0.0\% & 0.0\% & 0.0\% \\
3 & 17.5\% & 2.6\% & 8.3\% & 0.0\% & 0.0\% & 0.0\% \\
4 & 2.6\% & 0.0\% & 1.3\% & 0.0\% & 0.0\% & 0.0\% \\
5 & 2.6\% & 0.0\% & 1.3\% & 0.0\% & 0.0\% & 0.0\% \\
6 & 2.6\% & 1.7\% & 1.3\% & 0.0\% & 0.0\% & 0.0\% \\
7 & 1.7\% & 1.7\% & 0.9\% & 0.0\% & 0.0\% & 0.0\% \\
8 & 0.9\% & 1.3\% & 0.9\% & 0.0\% & 0.0\% & 0.0\% \\
9 & 0.0\% & 1.3\% & 0.0\% & 0.0\% & 0.0\% & 0.0\% \\
10 & 0.0\% & 1.3\% & 0.0\% & 0.0\% & 0.0\% & 0.0\% \\
11 & 0.0\% & 1.7\% & 0.0\% & 0.0\% & 0.0\% & 0.0\% \\
12 & 0.0\% & 0.9\% & 0.0\% & 0.0\% & 0.0\% & 0.0\% \\
\hline
\end{tabular}
\caption{Percentage of Trading Days that shows Significant Serial Correlation for the Observed Returns of SiMSCI Spot Month Futures Contract ($R_{t+j}$)}
\end{table}

Interestingly, we observe that none of the trading days shows significant negative serial correlation at both the 0.025 and 0.005 significance levels. Though trading days reporting significant negative serial correlation are observed at the 0.05 significance level, the
percentages are too low to conclude any negative significance in the SiMSCI futures returns series. In contrast to our earlier empirical finding from the estimated serial correlation coefficients, our empirical result using the variance ratio test reports no evidence of any significant negative serial correlation in the observed SiMSCI futures returns.

On the other hand, we observe that a number of days, especially in the first few lags, report significant positive serial correlation. At the 0.005 significance level, 7.9% of the trading days report significant positive serial correlation in lag 1 while none of the trading days reports any significant positive serial correlation for the other lags. At the 0.025 significance level, relatively higher percentages of the trading days report significant positive correlation in the first 2 lags, 16.6% and 12.2% for lag 1 and 2 respectively. A larger number of trading days report significant positive correlation in the first 3 lags, 19.7%, 17.9% and 17.5% respectively at the 0.05 significance level. However, all the observed percentages are too small to indicate the presence of any positive serial correlation in the observed futures returns.

On concluding, our empirical findings report that the estimated serial correlation coefficient for lag 1 is strong and significantly positive. Similarly, an unusually high proportion of trading days show significant positive serial correlation coefficients for lag one. Though the variance ratio test reports no evidence of significant positive serial correlation, the presence of a number of trading days with reported significant positive serial correlation at all the significance levels suggests some consistency. On the other
hand, significant negative serial correlation is observed on the estimated serial correlation
coefficient for lag 2. This finding is not surprising and can be attributed to the bid-ask
bounce effect which is documented in many index futures returns. However, empirical
results from both the study of the percentage of trading days showing significant serial
correlation coefficients and the variance ratio test report no evidence of any significant
negative serial correlation in the observed SiMSCI returns series. Hence, we will reject
our null Hypothesis 2 that only significant negative serial correlation is reported in the
observed SiMSCI futures returns.

V. Conclusion

This paper investigates the time series properties of intra day returns of the STI stock
index and the SiMSCI futures contract in the Singapore Exchange and finds several
interesting results. First, there is no significant positive serial correlation observed in the
STI stock index returns and hence indicates no evidence of non synchronous trading as
documented by models of infrequent trading. Second, the lag one serial correlation
coefficient for the intra day returns of SiMSCI futures contract is reported to be
surprisingly strong and significant. Though the variance ratio test reports no serial
interdependence in the intra day returns for both the returns series, a number of trading
days showing significant positive lag one serial correlation for the SiMSCI futures returns
does indicate some unusual behaviour of the futures returns. Hence, our empirical
findings have opened up the scope for more theoretical and empirical research works on
the Singapore Futures Market.
In summary, though the abundance of high frequency data helps to eliminate the problems of weak power of tests and provides us many insights on the intra day patterns of financial time series, the data has to be treated with caution since very high frequency observations bring with it new factors that introduce noise for analysis.
REFERENCES


