Jurnal Pengurusan 17(1998) 31-40

The Stochastic Behavior of Stock Indices: A Test of Long Memory in the Kuala Lumpur Stock Exchange

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ABSTRACT

Characterization of the stochastic process of stock market indices is vital in understanding the behavior of stock prices. Conventional share valuation models are subject to the nature of inter-temporal dependence between current and past movements. This paper studies the stochastic process of four KLSE indices (Composite Index, Industrial Index, Finance Index, and Property Index). In addition to the standard unit root tests, the ARFIMA (Autoregressive Fractionally Integrated Moving Average) model which belongs to the class of long memory process is applied in the empirical analysis. The findings indicate that while the level of the indices is non-stationary, its growth rate exhibits stationary properties. Long memory is not supported for the level of the indices but is evidenced in its monthly growth rate. The growth rate of the indices can therefore be characterized as a long memory process that is mean reverting.

ABSTRAK

Penentuan proses stokastik indeks pasaran saham adalah penting dalam memahami gelagat harga saham. Model konvensional penilaian harga saham adalah tertakluk kepada ciri kebergantungan antara masa antara pergerakan harga semasa dan yang lepas. Kajian ini menyelidik proses stokastik empat indeks KLSE (Indeks Komposit, Indeks Industri, Indeks Kewangan, dan Indeks Harta). Disamping ujian "unit root" yang lazim, model ARFIMA (Autoregressive Fractionally Integrated Moving Average) yang berciri proses "long memory" diaplikasikan dalam analisa empirikal. Penemuan penyelidikan menunjukkan paras indeks adalah tidak pegun tetapi kadar pertumbuhannya menunjukkan ciri-ciri pegun. "Long memory" tidak dapat disokong untuk paras indeks tetapi terbukti pada pertumbuhan bulanan indeks. Oleh itu kadar pertumbuhan indeks boleh disifatkan sebagai satu proses "long memory" yang "mean reverting".

INTRODUCTION

Numerous efforts have been made to understand the behavior of stock market prices. Knowledge of time series properties of stock market prices is critical as traditional share valuation models such as the capital asset pricing model and arbitrage pricing model are subject to the inference made on the stochastic process of share prices. In addition, conclusion regarding the efficiency of stock market, i.e. the speed at which the market absorbs the available information, is largely influence by the presence or absence of the martingale process in stock prices. Efficiency in stock prices is evidenced when stock prices exhibit a random walk behavior that can be characterized by a unit root process that displays no significant dependence between current and past price movement.

Early attempts that investigate the dependence in assets returns generally conclude in favor of persistence effect. Greene and Fielitz (1977) analyze the daily returns of securities listed in the New York Stock Exchange and support a long-range dependence hypothesis consistent with Mandelbort (1971). More recent attempts, however, generated mixed findings on the issue. In general many supports the persistence dependence in the stock returns. Fama and French (1988) evaluate the permanent and transitory components in the stock prices and support a mean reverting process for long horizon returns. Large negative autocorrelations for returns horizon beyond one year is consistent with the mean reverting process. Poterba and Summers (1988) analyze mean reversion properties of the securities listed in the New York Stock Exchange using a variance-ratio estimates. The results support the presence of transitory components in stock prices, with returns showing positive autocorrelation in the short run but negative autocorrelation in the long run. The analysis confirms mean reversion behavior for the stock prices. Jegadeesh (1990) provides the evidence of predictability in stock return. The negative first-order serial correlation in monthly stock returns is highly significant. The results also indicate the presence of significant positive serial correlation at longer lag and twelve months interval. The evidence supports the predictability of stock returns.

Lo and MacKinlay (1988) reject the presence of predictable components in the weekly holding period returns. Their estimates indicate insignificant serial correlation in stock returns. Kim et al. (1991) suggests that mean reversion behavior was a pre-war phenomenon. Post-war evidence based on the variance-ratio analysis does not support mean reversion properties. Lo (1991) modifies the range over standard deviation or R/S statistics developed by Hurst (1951) in his hydrology studies. It is argued that the conventional R/S statistics is sensitive to short range dependence and fail to accurately isolate the long memory process. Applying the modified R/S statistics on the daily and monthly stocks return, he fails to identify evidence of long memory. Thus, allowing him to characterize the stochastic process of stock prices as short-range dependence process.

Studies on the behavior of stock prices in the Far East countries generally focus on the efficient market hypothesis (see Ibrahim & Yong (1993) for review). Earlier findings on the issue discussed in Ang and Pohlman (1978) show that the Far Eastern markets (Australia, Hong Kong, Japan, Phillipines, and Singapore) can be categorized as weakly efficient. The conclusion is substantiated by serial correlation, run tests and spectral analysis. In addition to the serial and run tests, Hong (1978) performed the Theil-Leenders Test of proportion of advancing-declining for the exchanges studied by Ang and Pohlman except Phillipines. The efficiency hypothesis is supported for Japan but not the other three. Evidence supporting weak form efficiency in the Kuala Lumpur Stock Exchange (KLSE) can be found in Lanjong (1983), Lawrence (1986), and Barnes (1988). Using monthly and daily observations, these authors indicate that despite being thinly traded market, the KLSE is subject to the weak form efficiency hypothesis. However, in a series of studies Yong (1987,1988a, 1988b, 1989) has rejected the weak form efficiency for KLSE. Studies on market efficiency are of critical interest because it implies the predictability of stocks prices. Evidence of random walk dismisses the usefulness of historical information in predicting future price movement. It also indicates the stochastic process of the stock prices, which is non-mean reverting. Parallel to these studies the objective of this study is to investigate the stochastic process of the KLSE indices. As discussed in the following section evidence of long memory rejects the random walk hypothesis and can also be interpreted as invalidate the efficiency of stocks markets.

THE LONG MEMORY PROCESS

Findings related to the developed markets mentioned earlier mostly applied serial correlation analysis and refinement of the rescaled range statistic (the R/S statistics) initially developed by Hurst (1951) to study river discharge in hydrology research. Significant serial correlations are interpreted as supporting the intertemporal dependence in stock returns. The R/S statistic is the range of partial sums of deviations of a time series from its mean, rescaled by its standard deviation. Mandelbort (1972) argues that the R/S analysis can effectively capture the long-range dependence that exists in a time series. Studies on the Far East markets generally based on the common efficiency test such as serial correlation, run-test, spectral analysis and several other methods. Efficiency of markets is supported by rejecting the random walk hypothesis tested in the studies.

Another approach that can be used to examine temporal dependence of a time series is to investigate the stationarity of the series. Series that exhibits mean reversion in that it fluctuates around constant long run mean and has a finite time-invariant variance are classified as stationary series. Shocks on a stationary time series are necessarily transitory and dissipate over a period of time, thus, fulfilling the mean reversion process. The opposite process to stationary, i.e. non-stationary is commonly known as a unit root process. The mean and variance of a unit root process are time-dependent. Movements in the series are influence by a permanent shock that prevents mean reverting process. Conventional analysis of the stochastic process of a time series normally relies on the standard integrated autoregressive moving average (ARIMA (p, d, q)) representation:

$$\Phi(L)(1-L)^d Y_t = \Theta(L)\varepsilon_t, \quad \varepsilon \sim \left(0, \sigma^2\right) \tag{1}$$

where $\Phi(L)=1-\phi_1(L)-\ldots-\phi_p L_p$ is the autoregressive polynomials in the lag operator, $\Theta(L)=1+\theta_1 L+\ldots+\theta_q L_q$ is the moving average polynomials in the lag operator, and all roots of $\Phi(L)$ and $\Theta(L)$ lie outside the unit circle.

Standard tests for unit roots (e.g. the Dickey-Fuller and Phillips-Perron Tests) typically have considered only integer values of d; i.e. 0 or 1. Unit root (non-stationary) is supported when $d = 1$ and rejected when $d = 0$. This forced choice between $I(0)$ and $I(1)$ process has been subject to criticism in recent literature. Theoretically the value of d is not limited to an integer. A more general modeling of the ARIMA process that allows non-integer d values has been proposed and is known as ARFIMA (Autoregressive Fractionally Integrated Moving Average). The ARFIMA model belongs to the class of long-memory process due to its ability to display significant dependence between distance observations. Hosking (1981) shows that the autocorrelation, ρ (k), of an ARFIMA process have a slower hyperbolic decay pattern; for large k the decay can be approximated by

$$\rho(k) \sim k^{2d-1}, \quad d<0.5,\ k \rightarrow \infty \tag{2}$$

Standard ARIMA processes are short memory because the dependence between distance observations decays rapidly. The decay follows an exponential pattern described by:

$$\rho(k) \sim r^k, \quad 0 < r < 1,\ k \rightarrow \infty \tag{3}$$

Diebold and Rudebusch (1989a, 1989b), Diebold et al. (1991) and Sowell (1990, 1992) conclude that the ARFIMA model is useful in characterizing the stochastic process of a time series and recommended its application against the I(0) versus I(1) paradigm. The memory property of a series depends on the value of d. The existence of long memory can therefore be tested based on the statistical significance of the differencing parameter d.

Denoting the first difference of the series as $\zeta_t = (1 - L)Y_t$, we wish to estimate δ in the model

$$(1 - L)^{\delta} \ X_t = \ \Phi^{-1}(L)\ \Theta(L)\varepsilon_t = u_t \tag{4}$$

As d of the level series equals $1 + \delta$, a value of δ equal to zero corresponds to a unit root in Y_t. Geweke and Porter-Hudak (1983), hereafter abbreviated GPH, introduced a seminonparametric procedure to test for long memory. The differencing parameter δ_{GPH} can be consistently estimated by a least squares regression

$$\ln (I\ (\omega_j)) = c - \delta \ln (4 \sin^2 (\omega_j/2)) + \eta_j,\ j = 1,\ldots\ldots\ldots,n. \tag{5}$$

where $\omega_j = 2\pi/T$ ($j = 1,\ldots..,T\text{-}1$), $n = g(T) << T$, and $I(\omega_j)$ is the periodogram of Y at frequency ω_j defined by

$$I(\omega) = (1/2\pi T)\left|\sum_{t=1}^{T} e^{it\omega}\left(Y_t - \overline{Y}\right)\right|^2 \tag{6}$$

It is suggested to set $n = T^{0.5}$ and to use the known variance of η_j to compute the estimated variance of δ. Long memory hypothesis is supported if the least squares estimate of δ_{GPH} is significantly different from 0. This provides us with a new alternative to examine the stochastic process of a time series in addition to the standard unit root test that is widely applied in current literature. Freeing ourselves from the rigid $I(0)$ and $I(1)$ paradigm allows the identification of the long memory properties.

EVIDENCE OF LONG MEMORY IN THE KLSE INDICES

The stochastic process of the KLSE indices is investigated using three standard unit root test (Augmented Dickey-Fuller (ADF) test, Phillips-Perron (PP) test, and Kwiatkwoski, Phillips, Schmidt and Shin (KPSS) test) and also the ARFIMA long memory test as described above.[3] The null hypothesis of unit root is tested in the first two standard unit root test (ADF and PP) and the KPSS tests the null of stationarity. Rejection of null hypothesis in ADF and PP imply stationarity. Oppositely rejection of null in the KPSS test supports a non-stationary process. Monthly observations of four major indices of the KLSE, i.e. the Composite Index, Industrial Index, Finance Index, and Property Index are tested for a period beginning from January 1980 to December 1991. The tests are conducted for the level and monthly growth rate of the indices. The data set encompasses twelve-year period involving 144 observations, which is sufficient to generate asymptotically efficient estimations. The period chosen is subject to data availability when the paper was initially written. Expanding the data set to recent years are recommended and expected to be insignificant to the findings. Estimations are performed using RATS 4.2.

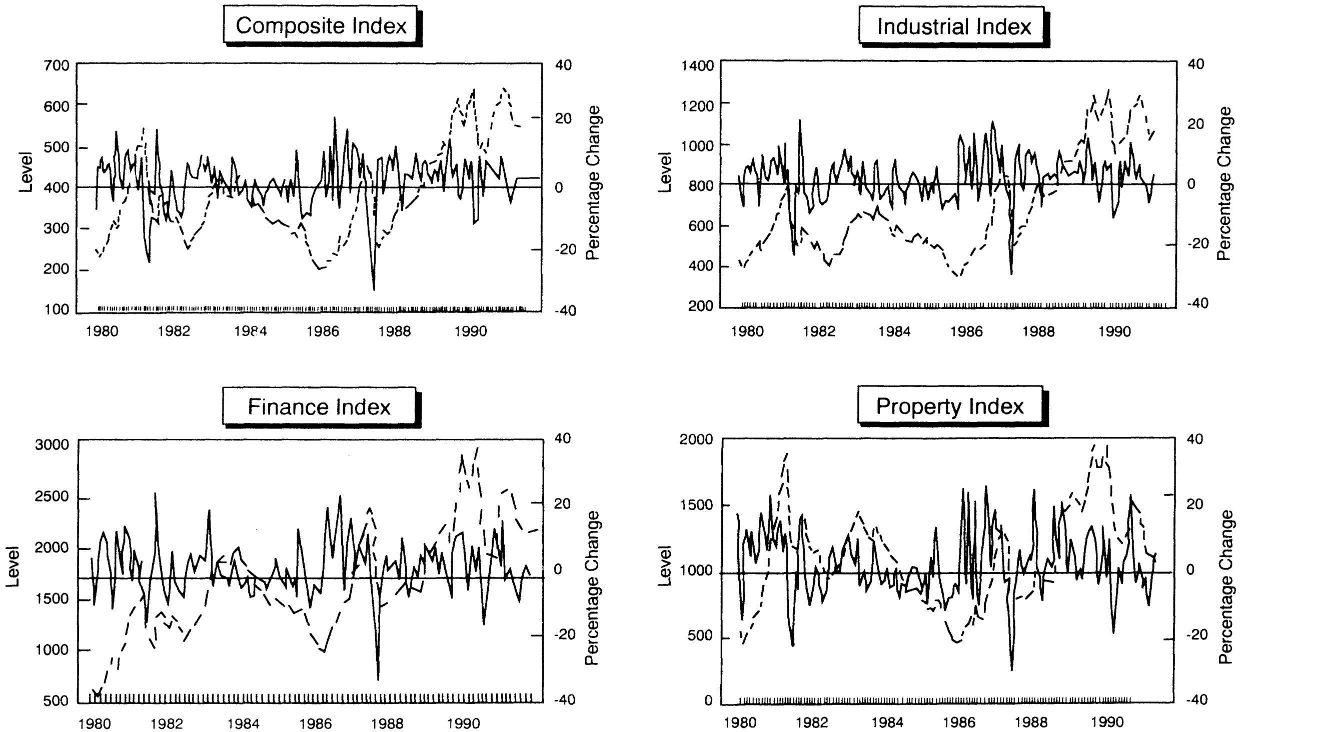

FIGURE 1. Kuala Lumpur Stock Exchange Indices: Level and monthly growth

Notes: (a) The dotted lines are the level and the solid lines are month-to-month change

Initial inference of the stochastic process of these series can be identified from Figure 1. As displayed in Figure 1, the level of all series seems to display a unit root behavior with no tendency of reverting to a common mean. However, the monthly growth of the indices displays a more time dependence stationary process. The month-to-month changes fluctuate within certain bound consistent with a mean reverting process.

Table 1 provides the standard unit root test for the level and monthly growth rate of the indices. Overall the tests indicate that the level of the indices posses a unit root behavior. Both the ADF and PP test cannot reject the null hypothesis of unit root for the level of the indices tested. The KPSS test yields the same conclusion for the Composite and Industrial index but not the Finance and Property index. The null hypothesis of stationarity is rejected for the first two indices. Opposite conclusion is reached for the monthly growth rate of the KLSE indices. All three standard unit root tests indicate a stationary properties for the growth rate of the indices. Unit root hypothesis is rejected by the ADF and PP test. The KPSS test fails to reject the null hypothesis of stationarity. This supports a mean reverting process in the monthly changes.

TABLE 1. Tests for unit root

	ADF	PP	KPSS
A. Level			
Composite	-2.020	-2.003	0.187*
Industrial	-1.638	-1.551	0.191*
Finance	-2.778	-2.765	0.102
Properties	-2.397	-2.487	0.139
B. Growth Rate			
Composite	-9.948*	-10.029*	0.069
Industrial	-9.827*	-9.852*	0.057
Finance	-10.380*	-10.449*	0.073
Properties	-9.651*	-9.852*	0.090

* null hypothesis can be rejected at 5% level.
Note. The series is entered in log for level and first difference of the log for growth rate. ADF is the Augmented Dickey-Fuller tests, PP is the Phillips-Perron test, and KPSS is the Kwiakowski, Phillips, Schmidt, and Shin test.

The results of the ARFIMA model are presented in Table 2. As described earlier the focus of the analysis centers on the statistical significance of the differencing parameter δ_{GPH}. The long memory hypothesis is supported if δ_{GPH} is significantly different from zero. The δ_{GPH} reported in Table 2 is derived from equation (5). The δ_{GPH} value is estimated for $n = T^{0.5}$ as commonly used and also $n = T^{0.45}$ and $n = T^{0.55}$ for sensitivity of the results. The results of the ARFIMA estimations are consistent with the standard unit root tests

TABLE 2. Results of geweke-porter-hudak test

	D(0.45)	D(0.5)	D(0.55)
A. Level			
Composite	-0.227 (0.270)	-0.034 (0.250)	-0.206 (0.190)
Industrial	-0.235 (0.173)	-0.183 (0.237)	-0.202 (0.238)
Finance	-0.300 (0.272)	-0.318 (0.228)	0.237 (0.237)
Properties	0.127 (0.220)	0.076 (0.197)	-0.036 (0.203)
B. Growth Rate			
Composite	-1.296* (0.229)	-1.228* (0.252)	0.974* (0.187)
Industrial	-1.219* (0.150)	-1.151* (0.215)	1.187* (0.219)
Finance	-1.144* (0.258)	-1.190* (0.206)	-1.078* (0.225)
Properties	-0.729* (0.258)	-0.785* (0.255)	0.914* (0.247)

Note. The series is entered in log for level and first difference of the log for growth rate. D(0.45), D(0.5), and D(0.55) give the δ_{GPH} estimates corresponding to n = $T^{0.45}$, $T^{0.5}$, $T^{0.55}$. The values in the parentheses are the standard errors. Asterisk indicates that the null hypothesis can be rejected at 5% level.

presented earlier. The value of δ_{GPH} is not significantly from zero when the level of the indices is tested. This indicates that the differencing integer d is not significantly different from 1, which supports the unit root process for the level of the indices. However, the long memory hypothesis is supported for the monthly growth rate as the value of δ_{GPH} is significantly different from zero for all indices in all estimations. Thus, the growth rate of these indices can be categorized under a mean reverting process. Intertemporal dependence is supported for the growth rate of the series but not in its level form.

CONCLUSIONS AND IMPLICATIONS

The stochastic process of the KLSE indices is investigated in this paper. Identifying the stochastic process of stock prices is a critical issue as it reflects the predictability of stock prices and the impact of particular shocks on price behaviors. The ARFIMA model that allows non-integer differencing parameter can be classified as a long memory process due to its ability to capture intertemporal dependence of distance observations. The standard ARIMA model that forced the choice between I(0) and I(1) process causes a faster decline in the autocorrelation function and therefore can only capture the short memory process. In addition to three standard unit root tests (ADF, PP, and KPSS), the study also examine the stochastic process of the KLSE indices using the new ARFIMA model. It is shown that while the level of the indices can be described as a unit root process its growth rate is not. Long memory process is evidenced for the growth rate of the indices. We can therefore characterize the month-to-month changes in the KLSE indices as a mean reverting process. The findings support the predictability of stock prices. The random walk hypothesis is rejected in place of the mean reverting process. To the extent that stock prices predictability is dependence on past history this also support the usefulness of studying past behavior of stock prices. It also indicate that shock on prices will not be persistent as over the long run the effect of the shocks disappear since the stock prices possess a long memory.

ACKNOWLEDGEMENT

I would like to thank Professor Benjamin J. C. Kim, Professor Craig Ellis, the participants of the 1997 Fourth Annual Conference of the Asia Pacific Finance Association at Kuala Lumpur, Malaysia, and two anonymous reviewers for their helpful comments.

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