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MARKET EFFICIENCY OF THE MALAYSIAN STOCK EXCHANGE: FURTHER EVIDENCE

CHIN WEN CHEONG
Faculty of Information Technology
Multimedia University, Malaysia

ABU HASSAN SHAARI MOHD NOR
Faculty of Economic and Business
National University Malaysia

ZAIDI ISA
Faculty of Science and Technology
National University Malaysia

ABSTRACT

This paper investigates the weak-form of market efficiency using the Malaysian Stock Exchange over a period of January 1991 to December 2006. The long-spanning data set enabled us to study piecewise before and after the economic crisis encountered by the Malaysian stock market. Using the daily price index, the weak-form efficiency is examined according to the price, return, and volatility. The unit root test was performed for both the price level and price changes to verify the presence of random walk processes. In order to account the characteristics of emerging markets, the daily returns are adjusted for infrequent trading and non-linearity behaviour. The non-linearities are further examined by the exponential GARCH-M to ensure that the observed return predictability is not resulted by time-variation in the market risk premium. Besides the clustering volatility, the predictability of the long-range dependence volatility was also checked. The empirical results evidenced the mixtures of efficient and inefficient markets in the Malaysian stock exchange for the studied sub-periods.

Keywords: *Random walk hypothesis; market efficiency; long-range dependence.*

ABSTRAK

Penyelidikan ini mengkaji keberkesanan pasaran Bursa Malaysia bagi tempoh tahun 1991 sehingga 2006. Penggunaan jangka masa yang panjang *membolehkan kajian terhadap krisis ekonomi yang menimpa Bursa Malaysia ini dijalankan. Pengajian ini berdasarkan analisa terhadap harga, pulangan dan kemeruapan bursa saham. Ujian unit root terhadap harga dan pulangan pasaran dijalankan untuk menentukan kewujudan proses 'random walk'. Untuk merangkumi karekteristik pasaran, pulangan harian diubahsuaikan terhadap 'infrequent trading' dan ketaklineran. Ketaklineran diuji dengan EGARCH-M supaya pengganggaran pulangan tidak disebabkan oleh risiko premium. Selain daripada kemeruapan, kajian ini juga menganalisa anggaran terhadap kemeruapan jangka panjang. Keputusan membuktikan wujud keberkesanan dan juga ketidakberkesanan di dalam Bursa Malaysia.*

Kata kunci: *Hipotesis random walk; efisiensi pasaran; bersandaran jangka panjang.*

INTRODUCTION

The Efficient Market Hypothesis (EMH) initiated by Bachelier and Cootner (1900) assumed that the markets are efficient if all available information is reflected in the current market prices. Fama (1970) summarised this concept into three categories according to the information efficiency degree, namely the weak-from efficiency (history of prices/returns), semi-strong efficiency (publicly available information), and strong efficiency (private information), respectively. Campbell, LD, and MacKinlay (1997) furthered this study by distinguishing the random walk model into three sub-hypotheses. The random walk 1 (RW1) is the most restrictive model which requires independent and identically distributed increments in the price changes. In random walk 2 (RW2), the restriction of identically distributed condition is not imposed. Finally, by relaxing the independence restriction of RW2, the RW3 model is obtained. The implication of random walk hypothesis (RWH) sometimes can provide insight and understanding of EMH. However, RWH can only be treated as equivalent to EMH (Merton, 1990) under the risk neutrality condition. Risk and expected return trade-off are nature phenomena in financial markets where, if an asset's expected return is positive, the investor is dealt with greater risk of holding it. Moreover, the nature of the increment may show non-linear dependency in their higher conditional moments, such as conditional variances.

The traditional definition of market efficiency assumed that the market is composed of homogeneous participants who react according to the rational expectation framework, regardless of the amount of available information. This assumption is not reasonable in the real financial market because not all market participants are provided with equivalent information. Consequently, improved definitions of market efficiency have been proposed such as fractal market hypothesis by Peters (1994), heterogeneous market hypothesis by Mullier, Dacorogna, Dav, Pictet, Olsen, and Ward (1993), and mixture of distribution hypothesis by Andersen and Bollerslev (1997). According to Shiller (2000), most participants in the stock market are not expert investors, but rather followers of market trends and fashions. Dacorogna, Ulrich, Richard, and Oliveier (2001) suggested that the market is composed of heterogeneous agents. They also proposed that in the quantitative measurement of market efficiency, the extreme price changes within short time intervals should be considered. Mandelbrot (1997) suggested that the weak form market efficiency is rejected if the stock returns present long-range dependence behaviour. Generally, the above studies found the presence of long-range dependence behaviour in the heterogeneous equity markets and this fractal scaling behaviour is important in measuring volatility, market efficiency, and market risk.

This study focused on the Kuala Lumpur Stock Exchange (KLSE) index which consisted of the composite index (CI). As an emerging stock market, the KLSE has received great attention from researchers and investors as a source of case studies and potential investment alternatives. In the early studies of the KLSE efficiency, Barnes (1986) examined the monthly price data of 30 companies and six sector indices for the six years ended at 30 June 1980 and found that the results are statistically serially correlated, thus supported that the KLSE is weak-form inefficient. Othman (1989, 1990) randomly selected 30 KLSE industrial indices and 170 stocks traded on all sectors of the KLSE, and supported that the KLSE is weak-form inefficient. Nassir and Mohammad (1993) studied the 1975 to 1989 market reaction of earning and dividend announcements and concluded that new information is almost fully reflected in price by the end of the announcement month. Annuar, Ariff, and Shamser (1994) found that about 87% of the 82 stocks posed unit roots and suggested that the market is inefficient over the 15 year period. These studies had concentrated mainly on the linear statistical test by using the unit root test, serial correlation and multiple variance ratio test across the selected periods. However, less research has focused on the non-linearity and long-range dependence behaviour of the Malaysian stock market.

Under the regulation of International Finance Corporation (IFC) and the World Bank, Malaysia is categorised as a developing country and emerging market. As an emerging market, the nature of the Malaysian stock market is characterised by low liquidity, infrequent trading, low quality of information and rapid changes in regulatory framework. According to Antoniou, Ergul, and Holmes (1997), the market participants are irrational with loss aversion, over self-confidence in own forecasts, and do not always respond instantaneously to information. All the mentioned behaviours of market participants are in contradiction to the assumption of efficiency market hypothesis. Therefore, the failure to account for all these conditions may lead to spurious statistical conclusion on market efficiency.

The aim of this paper is to study the weak-form market efficiency through the stock price index, returns, and volatility in the KLSE. This study included the infrequent trading, and non-linearity in the conditional mean specification, while the common stylised facts such as clustering volatility, leverage effects, and risk premium were taken into account in a conditional variance modelling. A battery of statistical tests were employed to diagnose the model specifications.

Lastly, the long-range dependence volatility was studied and the results allowed us to rank the sub-period inefficiency based on the strength of the Hurst's parameter. In addition, the presence of long-range dependence also implied that the markets are composed of heterogeneous agents with various interests and responses to new information. Based on our empirical studies, we claim that the equity market of the Malaysian stock market is categorised as weak-form efficient before the implantation of currency control and it is inefficient after the implementation. The return and volatility are, to some extent, predictable in all sub-periods, hence this violates the random walk hypothesis.

DATA SOURCE

The daily closing prices of the KLSE were obtained from the DATASTREAM. The selection guidelines of the Kuala Lumpur composite index (KLCI) components can be found in the official website of the previously the KLSE. The continuously compounded daily return at time t is defined as:

$$return_t = log(index_t) - log(index_{t-1}) \tag{1}$$

In this paper, the sample period starting from 1 January 1991 to 31 November 2006, comprised 3779 observations. The 15 years long-spanning data set enabled us to run various tests with reliable statistical results. This was suggested by Taylor (1986) that a large sample size of stock prices series may improve the error variance and increase the power of random walk tests. The KLSE traded five days a week, starting from Monday through Friday.

METHODOLOGY

Sub-Periods Determination

In this study, we selected the Andrews (1993) test by deriving the asymptotic distribution of the LR-like test for one shift based on the first order autoregressive model. Similar tests based on OLS can be found in Perron and Vogelsang (1989), and Perron (1998). We extended the m-multiple-structural changes under a selected time interval (four years of trading days, etc.):

$$p_{1,t} = \rho_1 p_{t-1} + \varepsilon_{1t}, \qquad t = 1,\ldots,B_{1,t}. \tag{2}$$

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$$p_{k,t} = \rho_k p_{t-1} + \varepsilon_{kt}, \qquad t = B_{k,t}+1,\ldots,B_{k+1,t}.$$

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$$p_{m,t} = \rho_m p_{t-1} + \varepsilon_{mt}, \qquad t = B_{m,t}+1,\ldots,T. \tag{3}$$

where $\varepsilon_t \sim N(0, \sigma_t^2)$. We allowed the heteroscedasticity OLS estimations based on the White's (1980) covariance matrix:

$$var(\hat{\rho}) = (p'p)^{-1}\left(\sum_{t=1}^{T} \hat{\varepsilon}_t^2 p_t p_t'\right)(p'p)^{-1} \tag{4}$$

where the square roots of the diagonal components are White standard errors. For every time interval, we performed a single Chow's test at every observation between $t = 1,\ldots,B_{k,t}$ and the maximum Chow's F-statistic was selected as the most possible location of structural change as follows:

$$Sup\ \text{LR-F} = \max_{1 \le t \le B_{k,t}} \frac{\left(\hat{\varepsilon}'\hat{\varepsilon} - (\hat{\varepsilon}_I'\hat{\varepsilon}_I + \hat{\varepsilon}_{II}'\hat{\varepsilon}_{II})\right)/k}{(\hat{\varepsilon}_I'\hat{\varepsilon}_I + \hat{\varepsilon}_{II}'\hat{\varepsilon}_{II})/(B_{k,t} - 2k)} \tag{5}$$

$$Exp\ \text{LR-F} = \log\left(\frac{1}{k}\sum_{t=1}^{B_{k,t}} \exp\frac{\left(\hat{\varepsilon}'\hat{\varepsilon} - (\hat{\varepsilon}_I'\hat{\varepsilon}_I + \hat{\varepsilon}_{II}'\hat{\varepsilon}_{II})\right)/k}{(\hat{\varepsilon}_I'\hat{\varepsilon}_I + \hat{\varepsilon}_{II}'\hat{\varepsilon}_{II})/(B_{t,k} - 2k)}\right) \tag{6}$$

To avoid the distribution degeneration of these statistics, it is customary to trim out the 7.5% of the first and last of the overall observations. Andrews suggested 15% trimming to obtain a reliable statistical inference. However, the trimming may vary depending on the sample size. Therefore, to be more precise, the null hypothesis indicated no breakpoints within the trimmed observations. We calculated both the Sup LR-F and exponential LR-F for comparison purposes. The details of the numerical approximations of these asymptotic distributions p-values can be found in Hansen (1995) where p-values are more preferable than the predefined significance tests.

Random Walk Hypothesis Tests for Price Level and Returns

In random walk hypothesis test, we considered a random walk (RW1) model with drift of logarithm price:

price : $p_t = \mu + p_{t-1} + e_t$

price changes/return : $r_t = \ p_t = \mu + e_t$ (7)

where logarithm price index, $p_t = \log P_t$, $\mu = E[p_t - p_{t-1}]$ and a_t is a random disturbance term satisfying $E[e_t]=0$ and $E[e_t e_{t-s}] = 0$, $s \neq 0$ for all t. The random walk model hypothesises the unity coefficient of p_{t-1}. Without considering the risk, this hypothesis suggested that a market is weak-form efficient if the stock prices reflect all available information and therefore the best predictor of future prices is the most recent price. We employed the Augmented Dickey-Fuller (ADF) test with the null hypothesis of non-stationarity to estimate their respective regression models. The ADF test is represented by the following equation:

$$\Delta p_t = \beta_1 + \beta_2 t + \delta p_{t-1} + \sum_{i=1}^{K} \alpha_i \Delta p_{t-i} + e_t \quad (8)$$

where β_1 is a constant, β_2 is the estimated drift parameter, δ is the estimated unit root parameter, k is the number of lagged terms, and e_t is a random disturbance. The test statistics were based on MacKinnon critical *tau* values. If the stock price variable is trend stationary, the effects of a shock would be transitory and permanent if it is difference stationary. One of the important issues in implementing the ADF test is the lag length determination. Ng and Perron (1995) and Schwert (1989) had independently introduced two approaches in lag length selection. The former method sets an upper bound (maximum lags) for p and estimated the t-statistic. If the absolute t-statistic is greater than 1.6 (5% critical value), then preserve this lag and practise the unit root test. Otherwise, decrease the maximum lag by one, and repeat the procedures until the condition is fulfilled. On the other hand, the latter approach is based on the following equation:

$$p_{\max} \approx \left[3.7947\sqrt[4]{T} \right] \tag{9}$$

where the [ ] represented the integer part. In our analysis, we set the maximum lags based on integer [$3.7947\sqrt[4]{T}$] and reduced the lag according to the Ng and Perron procedures. With this lag determination, the ADF test can run under the unknown order of general ARMA process.

Infrequent Trading and Non-Linearity Corrections for Returns

Emerging markets are often related to the infrequently traded share activities. This phenomenon occur when stock markets do not trade at every consecutive interval. One of the impacts of infrequent trading (Antoniou *et al.*, 1997; Miller, Muthuswamy, & Whaley 1994) is triggering a serial correlation in the time series of returns. To overcome this drawback, we adopted the method proposed by Miller *et al.* (1994) using an estimated moving average that reflects the number of non-trading days and later adjust the returns accordingly. Due to the difficulties in identifying the infrequent trading periods, the moving average can be estimated by an autoregressive model. However, this infrequent trading adjustment is an approximate correction which does not fully capture the complex infrequent trading impact. The procedures of the adjusted returns are stated as follows:

$$\textit{estimated model: } r_t = a_0 + a_{1i} r_{t-1} + e_t \tag{10}$$

$$\textit{adjusted return: } r_{t(adj)} = \frac{e_t}{(1 - a_{1i})} \tag{11}$$

where i represents the selected period (i=1,2,3). The model assumed that the non-trading adjustment required for adjusted-returns is constant throughout the periods in most of the high traded markets. In this study, the adjustments were varied in the three sub-periods according to Equation 10.

Besides the thin trading, non-linearity is also often observed in worldwide emerging markets, such as the evidences shown in Antoniou *et al.* (1997), Crato and deLima (1994), and Karemera, Ojah, and Cole (1999). The non-linearity maybe caused by the self-regulatory market, transaction costs, risk lovers and irrational market participants. The non-linearity is captured by a logistic map where a series has evolved according to the function:

$$r_t = ar_{t-1}(1 \copyright r_{t-1}) = a\, r_{t-1} \copyright a\, r^2_{t-1} \tag{12}$$

The function mapped the returns at time $t \copyright 1$ into its value of time t. The negative non-linear feedback term featured the self-regulatory markets. If the deviations of returns are not proportional to the initial value, then the feedback mechanism exhibited the non-linear self-regulation. The causes of this mechanism are discussed in DeBondt and Thaler (1985) and Costa *et al.*(1994).

The aim of the adjusted return and logistic map approach are to ascertain the presence of non-linearity under the correction of infrequent trading. The non-linear and adjusted returns are estimated by using Equation 4, 5, and 6:

$$r_{t(adj)} = a_0 + a_1 r_{t-1(adj)} + a_2 r^h_{t-1(adj)} + e_t \tag{13}$$

where h is either two or three. The model would follow the efficient market hypothesis if all the coefficients are equal to zero and the ε_t is a white noise process.

Clustering Volatility and Risk Premium Analysis

The financial asset returns often exhibited time-varying heteroskedasticity, volatility clustering, asymmetry effects, and non-normality. In order to account all these conditions, an EGARCH (Nelson, 1991) is fitted to the conditional variance equation. The EGARCH model is selected due to the robustness of parameter determination (less restriction compared to the GARCH model) and its capability to model the positive and negative shocks in the conditional variance equation. Merton (1980) and French, Schwert, and Stambaugh (1987) suggested that the non-linearity maybe caused by the time-variation in the market risk premium. To validate this, the non-linearity of the returns series is examined by including the time variation of market risk premium in the EGARCH-mean model. The risk premium of the market can be estimated by using the GARCH-mean model. The EGARCH-mean model can be expressed as follows:

$$r_{t(adj)} = a_0 + a_1 r_{t-1(adj)} + a_2 r^2_{t-1(adj)} + a_4 \sigma^2_t + e_t,$$
$$e_t = \sigma_t z_t \text{ where } z_t \sim \text{student-}t(v) \tag{14}$$

$$\log \sigma_t^2 = \alpha_0 + \alpha_1 \log \sigma_{t-1}^2 + \alpha_2 \frac{\varepsilon_{t-1}}{\sigma_{t-1}} + \alpha_3 \left| \frac{\varepsilon_{t-1}}{\sigma_{t-1}} \right| \quad (15)$$

where σ^2_t is the conditional variance, a_4 is the relative risk aversion coefficient, and $a_4\sigma^2_t$ is the time-varying risk premium of a representative investor. The absence of time-varying risk premium should result in statistically significant a_2 and a_3 coefficients, which would indicate the non-linearity.

Long-Range Dependence Volatility

We chose two unconditional volatility proxies, namely the squared-return and absolute-return, for the long-range dependence examination. Absolute-return and squared-return are the two volatility proxies commonly used in empirical financial time series analysis. Ding, Granger, and Engle (1993) claimed that absolute-return exhibited consistently higher long memory behaviour than squared-return in S & P 500. Ding and Granger (1996) further examined worldwide stock markets and foreign exchange and found similar results. The presence of long-range dependence volatility in the stock market would suggest that future volatilities are predictable by using past information. Barkoulas and Baum and (1996), and Cajueiro and Tabak (2004) tested the emerging market efficiency by using long-range dependence analysis. Some studies (Dacorogna *et al.* 2001; Mullier, 1993) believed that non-homogeneous market participants with different expectations according to their time dimension (e.g. short and long term trading) have caused the long persistence volatility clustering.

In this study, the long-range dependence is measured by the value of global Hurst's parameter, H (Hurst, 1951). In this paper, we implemented two time-domain approaches, namely the variance-time plot and R/S plots. Others common estimations such as absolute value method, periodogram, and Whittle's estimator can be found in Mandelbrot (1997) and Beran (1994).

Variance-time Plot

For stationary time series y, the n-aggregated time series $y(n)=\{r_k^{(n)}, k=0,1,2,3,\ldots\}$ is obtained by summing the original time series over a non-overlapping, adjacent blocks of size m. The expression is:

$$r_k^{(n)} = \frac{1}{n} \sum_{i=kn-(n-1)}^{kn} y_i \quad (16)$$

For the aggregated time series $y(n)$ of a self-similar process, the variance obeys the following large sample property:

$$V[y^{(n)}] \sim \frac{V[y]}{n^{\beta}}$$, where the self-similarity parameter is $H = 1 - (\beta/2)$. (17)

By taking the logarithm on both sides, this can be written as:

$$\log(V[y^{(n)}]) \sim \log(V[y]) - \beta \log(n) \tag{18}$$

Since $\log(V[y])$ is a constant independent of n, therefore the plot $\log(V[y^{(n)}])$ versus n on a log-log graph should be a straight line with a slope of β. Slope values between −1 and 0 suggest self-similarity and conclude that the existence of long memory effect in that series.

R/S plot

Given a stochastic process y_t at discrete time instances $\{y_t, t = 0, 1, 2, \ldots\}$, the rescaled range of y_t over a time interval M as defined by Hurst, is the ratio of R/S:

$$\frac{R}{S} = \frac{\max_{1\le j\le N}\left[\sum_{k=1}^{j}(y_k - M(L))\right] - \min_{1\le j\le N}\left[\sum_{k=1}^{j}(y_k - M(L))\right]}{\sqrt{\frac{1}{N}\left[\sum_{k=1}^{N}(y_k - M(L))^2\right]}} \tag{19}$$

where $M(L)$ is the sample mean over the time period L. Mandelbrot (1997) showed that the R/S statistic converged to a random variable at rate L^H when the long-range dependence exists. In the self-similar process, the ratio would exceed 0.5 with the following characteristic: $R/S \sim (L/2)^H$, where $H > 0.5$.

In Figure 1, the movement of the index prices are illustrated over approximately 15 years. The minimum index is 262.7 points on 1 September 1998 and maximum at 1314.46 points on 5 January 1994. The market price index increased from approximately 500 points in 1991 to 1300 points in 1994. After that, the price index fluctuated around 900 to 1300 points until December 1996. It then slid massively to around 300 points over a two year periods due to drastic depreciation of the Malaysian Ringgit (RM) and consequently, investors continued to flee from the Malaysian market. The currency crisis had a deep impact on the RM where the first half of 1997, the RM was maintained at a stable exchange rate of approximately RM2.50 to one US dollar and depreciated to the weakest rate recorded against USD as RM4.88 on 9 January, 1998. The RM traded in the range of RM3.50 to RM4.50 for the first half of 1998.

Empirical Studies of Malaysian Stock Market

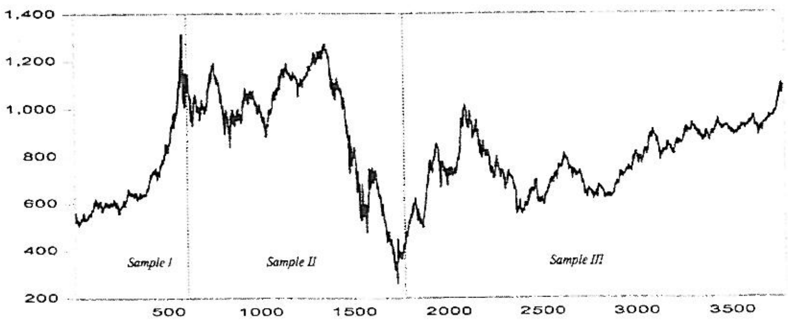

Figure 1: Kuala Lumpur composite index

Due to the weak performance of RM and high interest rates, the Malaysian government had implemented the one USD pegged to RM3.80 on 1 September 1998, and it was non-convertible outside the country. Besides, the fixed currency control also required the foreign investors to retain their principle capital in Malaysia for at least one year and the capital gain is repatriated. This implementation had stabilised the RM and protected it from currency speculation. After the USD was pegged, the price index showed positive increment and reached 1000 points in year 2000. However, the currency control policy had caused the direct foreign investors to flee from the Malaysian market. Despite this, the RM being pegged has successfully boosted the growth in exports due to the low exchange rate. This has led to the recovery of the price index in Malaysia stock market over a two year period (November 2000) and fluctuating around 700 points until year 2005. The selected annual statistics of the values, volumes, and market capitalisation are illustrated in Table 1.

In the early 90s, Malaysian government was in its ongoing effort to enhance the transparency in the stock market. The quality of information is improved by the introduction of information and communication technology (ICT) applications in the exchange trading system, such as semi-automated SCORE in 1989 and fully automated WinSCORE in 1995. In addition, the clearing service for stockbroking are provided by the Securities Clearing Automated Network Services Sdn. Bhd. (SCANS) and a Fixed Delivery and Settlement System

(FDSS) established in 1990. In October 1999, the KLSE introduced the Listing Information Network (LINK), as an internet-based facility. These efforts have improved the availability and reliability of information in the stock market.

Table 1: Selected Annual Statistics of KLSE Stock Prices Index

Period (end of year)	1990	1996	1997	1998	1999	2000	2004
Index	505.92	1237.96	594.44	586.13	812.33	679.64	907.43
Listed company	285	621	708	736	757	795	963
Trading value (RM Million)	29521	463264	408558	115180	185249	244054	215622
Trading unit (Million Unit)	13137	66461	72799	58287	85156	75408	107610
Market Capitalisation (RM billion)	131.66	806.77	375.80	374.52	552.69	444.35	722.04

Table 2: Andrews Break-Point Identification

Index	Break point	statistic	Test statistic	p-value
KLCI	5th Jan 1994	LR SupF	21.40142*	0.0008
		Exp LR-F	4.943786*	0.0089
	2nd Sep 1998	LR SupF	18.99686*	0.0024
		Exp LR-F	2.548476*	0.0128

Notes: Asymptotic distributions p-values are based on Hansen
* denotes 5% level of significance

Using the break-point identification in Table 2, we were able to separate the KLCI into three sub-periods as follows:

(i) Sample I (1 January 1991 until 5 January 1994) – economic boom;

(ii) Sample II (6 January 1994 until 2 Septhember 1998) – important events such as the Asian financial crisis and implementation of currency control; and

(iii) Sample III (3 September 1998 until 31 December 2006) – economic recovery.

We also included the overall data set for comparison purpose.

Table 3: Descriptive Statistics of Stock Returns

Sub-sample period	overall	Sample I	Sample II	Sample III
Mean	0.007670	0.059610	-0.054637	0.027852
Std. Dev.	0.666333	0.400829	0.859831	0.596604
Skewness	0.536090	-0.014275	1.077464	-0.197182
Kurtosis	46.54729	6.187220	21.34485	82.38900
Jarque-Bera	298700*	245*	16319*	538098*
p-value	(0.000)	(0.000)	(0.000)	(0.000)

Note: * denotes 5% level of significance.

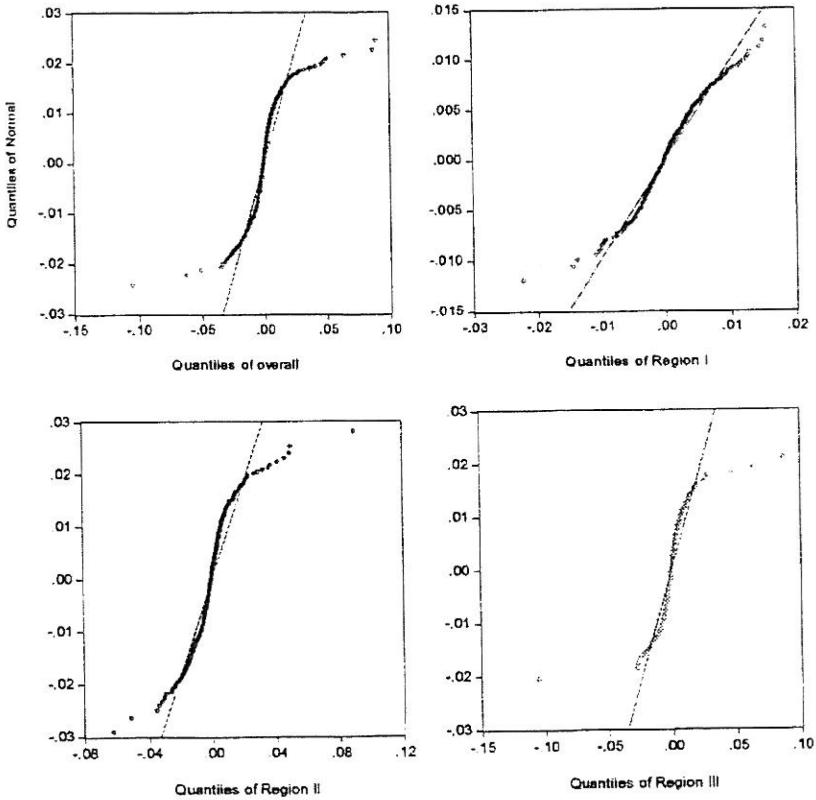

Figure 2: Quantile-quantile plots

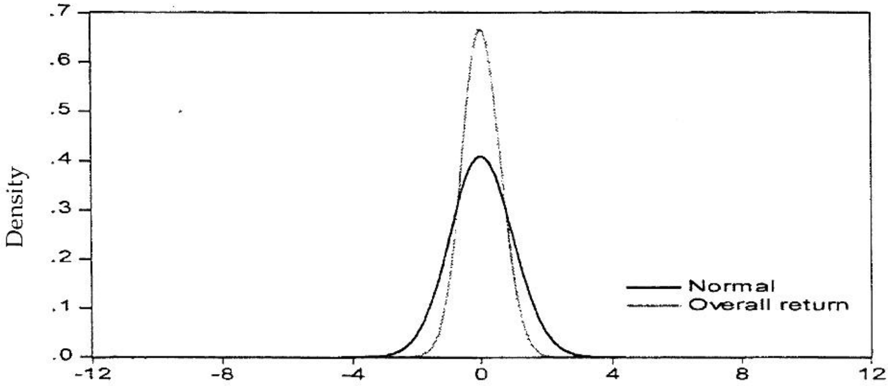

Figure 3: Kernel density plots for overall return

A graphical view of the descriptive statistics is illustrated in Table 3. The descriptive statistics measured the moments, skewness, kurtosis, and normality of the return series. The return series shown highest standard deviation and volatility in Sample II where, the Asian financial and currency crises hit the Malaysian stock market, among other regional countries. The excess kurtosis was observed in all the samples with the largest value in Sample III. For graphical illustrations, we compared the kernel density estimates (adjusted histogram) of the probability distribution (for overall KLCI only) and QQ plot for all the samples with a simulated normal distribution. Figure 2 and Figure 3 evidenced the high peak, heavy tail, and slightly asymmetric behaviour compared to a standardised normal distribution. In addition, the Jarque-Bera statistics in all samples enabled us to reject the returns series as being normally distributed. This finding implied that a non-normal distribution is in favour in the model specification.

Unit Root Test for Unadjusted Return

Table 4 reports the analysis of random walk hypothesis for the logarithm of price index (p_t) and the first difference price or return index (p_t) in each respected samples. When we applied the test to the logarithm price, the results indicated that the null hypothesis of a unit root cannot be rejected in the first two samples (I and II). However, the non-stationarity was not observed in *Sample III*. For the first difference price index, all the null hypotheses were rejected at the 1% level of significance. Based on the results, we concluded that the price series were non-stationary for sample I and II, whereas stationary in the price level of *Sample III* as well as all the first difference forms.

Although this preliminary tests were only able to identify the presence of random walk process in the price level of *Sample I* and *Sample II*, nevertheless RWH can only be treated as equivalent to EMH under the risk neutrality condition. Moreover, the nature of the increment may shown non-linear dependency in their higher conditional moments such as conditional variances.

Table 4: Unit Root Test in the Daily Price Index

	Level (p_t)			First difference (p_t)		
overall	*t-statistic*	*p-value*	Lag	*t-statistic*	*p-value*	Lag
p_{max} =29	-2.0254	0.5866	5	-27.0027	0.0000*	4
Sample-I	*t-statistic*	*p-value*	Lag	*t-statistic*	*p-value*	Lag
p_{max} =18	0.0065	0.9963	1	-18.1090	0.0000*	0
Sample-II	*t-statistic*	*p-value*	Lag	*t-statistic*	*p-value*	Lag
p_{max} =22	0.4775	0.9993	h1	-29.8710	0.0000*	0
Sample-III	*t-statistic*	*p-value*	Lag	*t-statistic*	*p-value*	Lag
p_{max} =25	-4.7447*	0.0006	15	-19.9173	0.0000*	4

Notes: t-statistics in ADF regression allowed the existence of constant and trend
* means significant at level 5%

Thin Trading and Non-Linearity in Return Results

Table 5 shows the results of the random walk test without adjusted returns by excluding the non-linear components for all the periods. The coefficients a_1 are statistically significant at 1% level for overall, *Sample I*, and *Sample II*. However, the coefficient is not statistically different from zero in the *Sample III*. This inferred that the return series in *Sample I* and *Sample II* contained predictability components and were inefficient. However, the diagnostic tests for error terms showed an unconditional heteroscedastic effect (RW2) and serial correlation across all the samples and led to the rejection of white noise process for the error term.

Table 5: Random Walk Model without Adjusted Return

Period	a_0	a_1	$Q(12)$	White's statistics
Overall	0.0071 (0.5060)	0.0755* (0.0000)	1897.9* (0.0000)	793.1896* (0.0000)
Sample-I	0.0436* (0.0077)	0.2629* (0.0000)	51.08* (0.0000)	5.2566* (0.0055)
Sample-II	-0.0475 (0.0601)	0.1155* (0.0001)	143.6* (0.0000)	27.6349* (0.0000)
Sample-III	0.0278* (0.0351)	0.0005 (0.9786)	1227.9* (0.0000)	1398.9640* (0.0000)

Notes: Model: $r_t = a_0 + a_1 r_{t-1} + \varepsilon_t$
Figures in parentheses are p-values
Q(m): Ljung-Box Q-statistics for serial correlation squared-residual with lag-m
White's statistics: unconditional heteroscedasticity test
* denotes 1% level of significance

In Table 6, an inclusion of a non-linear term for lag-one return indicated that the linear and non-linear coefficients, a_1, a_2, and a_3 are alternately statistically significant. The negative non-linear coefficients in *Sample I* and *Sample II* implies that the markets are self-regulatory. This would explain why the market participants over-react to bad news and under-react to good news, as discussed by DeBondt and Thaler (1985). Contradicting results are shown in the overall and *Sample* III un-adjusted return series. The error terms remained with conditional heteroscedastic effect for all the samples under the squared-residual, White, and LM ARCH tests.

In order to check that the non-linearities were not due to the volatility effects, an EGARCH model is fitted to all the samples. The student-t distributed increment EGARCH models showed that the non-linear terms remained statistically significant for *Sample I* and *Sample III* periods. This implies that the non-linearities were not caused by the clustering volatility in the two periods. However, contradicting results were indicated in the overall and *Sample II* periods with the linear coefficients, a_1, staying statistically significant. Due to the possibility of predictions for linear and non-linear components in the return series, we again suggested that the return series are predictable and inefficient in all the periods.

Table 6: Non-Linear Random Walk Model without Adjusted Return

Period	a_0	a_1	a_2	a_3	$Q(12)$	White's stat.	ARCH test
Overall	0.0033	0.0723*	0.0087*		1511.9*	497.9924*	88.4655*
Non-linear model	(0.7612)	(0.0000)	(0.0153)		(0.0000)	(0.0000)	(0.0000)
Non-linear model fitted	0.0061	0.1526*	0.0088		15.845		1.3144
by E-GARCH(1,1)	(0.2592)	(0.0000)	(0.3001)		(0.198)		(0.2024)
Sample-I	0.0434*	0.3456*		-0.1071*	52.764*	3.8465*	5.7908*
Non-linear model	(0.0079)	(0.0000)		(0.0680)	(0.0000)	(0.0019)	(0.0000)
Non-linear model fitted	0.0358*	0.3177*		-0.1315*	18.754*		1.6648
by E-GARCH(1,2)	(0.0095)	(0.0000)		(0.0384)	(0.095)		(0.0709)
Sample-II	-0.0411	0.2079*		-0.0060*	145.69*	14.4241*	8.4847*
Non-linear model	(0.1017)	(0.0000)		(0.0000)	(0.0000)	(0.0000)	(0.0000)
Non-linear model fitted	-0.0196	0.1624*		-0.00354	5.1113		0.4217
by E-GARCH(1,1)	(0.1204)	(0.0000)		(0.1740)	(0.954)		(0.9555)
Sample-III	0.0246*	-0.0002	0.00866*		919.10*	3122.255*	19.9920*
Non-linear model	(0.0632)	(0.9895)	(0.0325)		(0.0000)	(0.0000)	(0.0000)
Non-linear model fitted	0.0086		0.04275*		19.715*		1.5228
by E-GARCH(1,1)	(0.2056)		(0.0264)		(0.073)		(0.1087)

Note: Model: $r_t = a_0 + a_1 r_{t-1} + a_2 r^h_{t-1} + \varepsilon_t$
Figures in parentheses are p-values.
Q(m): Ljung-Box Q-statistics for serial correlation squared-residual with lag-m
White's statistics: unconditional heteroscedasticity test
Lagrange Multiplier ARCH test: conditional heteroscedasticity test
* denotes 10% level of significance

Table 7: Random Walk Model with Adjusted Return

Period	a_0	a_1	*Q(12)*	*White's statistics*
Overall	-3.34×10^{-5} (0.9977)	-0.0014 (0.9270)	1897.00* (0.000)	644.163* (0.000)
Sample-I	-0.0004 (0.9850)	0.01302 (0.7617)	51.32* (0.000)	5.166* (0.0060)
Sample-II	0.0017 (0.9516)	-0.0006 (0.9838)	142.65* (0.000)	23.581* (0.0000)
Sample-III	0.02783 (0.03510)	0.000584 (0.9786)	1227.90* (0.000)	1398.964 (0.0000)

Notes: Model: $r_{t(adj)} = a_0 + a_1 r_{t-1(adj)} + \varepsilon_t$
Q(m): Ljung-Box Q-statistics for serial correlation with lag-m
White's statistics: unconditional heteroscedasticity test
Figures in parentheses are p-values
* denotes 1% level of significance

We repeated the previous analysis using adjusted returns. Table 7 shows that after the correction of thin trading effect, the adjustments appeared to have eliminated the apparent serial correlation of the linear model across all the periods. The coefficient a_1 is insignificantly different from zero at the 1% level for all the periods. Across all the periods, the diagnostic tests indicated the presence of conditional heteroscedasticity effect. This again, led to the conclusion of a less stringent random walk process (RW2 or RW3) with the relaxation of *i.i.d.* conditions in all the periods. In Table 8, after the thin trading adjustment, the non-linear property indicated in all the periods except in *Sample* I. However, after the inclusion of non-linear EGARCH, the non-linearity in *Sample II* disappeared while it remained in the two samples. As a result, only the *Sample III* adjusted return series contained non-linearity which was not caused by the time-varying volatility. Until this point, after the thin trading adjustment, only the return series in overall and *Sample III* consisted of predictability components in the non-linear form. On the hand, the volatility also showed dependence on the lag value, as indicated by the EGARCH models. Although the return series in *Sample I* and *Sample II* do not consist of predictable components, nevertheless the volatilities have shown dependent property in their lag values.

Table 8: Non-Linear Random Walk Model without Adjusted Return

Period	a_0	a_2	a_3	*Q(12)*	White's stat.	ARCH test
Overall						
Non-linear model	-0.0057 (0.6232)	0.0111* (0.0006)		1385.1 * (0.0000)	406.4913* (0.000)	79.9417 * (0.000)
Non-linear model fitted by E-GARCH(1,1)	0.00083 (0.8878)	0.01555* (0.0622)		16.922 (0.153)		1.3871 (0.1640)
Sample-I						
Non-linear model	0.0041 (0.8664)	-0.0172 (0.6930)		50.751 * (0.000)	5.7766* (0.0033)	5.6471* (0.000)
Non-linear model fitted by E-GARCH(1,2)						
Sample-II						
Non-linear model	0.0043 (0.8779)[a]		-0.0032* (0.0001)	135.04* (0.000)	8.4400 * (0.0002)	8.1282 * (0.000)
Non-linear model fitted by E-GARCH(1,1)	0.0330* (0.0209)		-0.0021 (0.3845)	4.9968 (0.958)		0.4120 (0.9595)
Sample-III						
Non-linear model	0.02466 (0.0629)	0.0086* (0.0325)		918.68* (0.000)	1206.87* (0.0000)	19.9965* (0.0000)
Non-linear model fitted by E-GARCH(1,1)	0.00861 (0.2056)	0.0427 * (0.0264)		19.715 * (0.073)		1.5228 (0.1087)

Notes: Model: $r_t = a_0 + a_1 r_{t-1} + a_2 r^2_{t-1} + a_3 r^3_{t-1} + \varepsilon_t$
Figures in parentheses are p-values
Q(m): Ljung-Box Q-statistics for serial correlation squared-residual with lag-m
White's statistics: unconditional heteroscedasticity test
Lagrange Multiplier ARCH test: conditional heteroscedasticity test
* denotes 10% level of significance

Table 9: Egarch-M Non-Linear Random Walk Model with Adjusted Return

Period	a_0	a_2	a_3	a_4	α_1	α_2	*Q(12)*	*ARCH test*
Overall	0.0080 (0.2628)	0.0275* (0.0041)		-0.0560* (0.0709)	0.9871* (0.0000)	0.0227 * (0.0000)	17.993 (0.116)	1.4749 (0.1257)
Sample-I	-0.0504 (0.2839)			0.1912 (0.3115)	0.9709 * (0.0000)	0.02689* (0.4683)	17.576 (0.129)	1.6372* (0.0776)
Sample-II	0.0530* (0.0020)		-0.0019 (0.4156)	-0.0729* (0.0458)	0.99030 * (0.0000)^c	-0.1076* (0.0000)	5.8102 (0.925)	0.4789 (0.9278)
Sample-III	0.0046 (0.7901)	0.04204* (0.0576)		0.01292 (0.8171)	0.9761 * (0.0000)	-0.0239 * (0.0994)	19.949* (0.068)	1.5398 (0.1030)

Notes: Model: $r_{t(adj)} = a_0 + a_3 r^h_{t-1(adj)} + a_4\sigma^2_t + \varepsilon_t$, $\log\sigma_t^2 = \alpha_0 + \alpha_1 \log\sigma_{t-1}^2 + \alpha_2 \frac{\varepsilon_{t-1}}{\sigma_{t-1}} + \alpha_3 \left|\frac{\varepsilon_{t-1}}{\sigma_{t-1}}\right|$
Figures in parentheses are p-values
Q(m): Ljung-Box Q-statistics for serial correlation squared-residual with lag-m
White's statistics: unconditional heteroscedasticity test
Lagrange Multiplier ARCH test: conditional heteroscedasticity test
* denotes 10% level of significance

Volatility and Risk Premium

In the previous ARCH tests, all the periods indicated the presence of conditional heteroscedasticity. This indicated that the non-linearity might be caused by the time-variation in the market risk premium. For the EGARCH-m modeling, the negative and significantly different from zero asymmetry coefficients α_2 in all the samples except *Sample-III* suggested that negative shocks have a greater influence of future volatility as compared to the positive shocks. The heavy-tailed property was also indicated in the disturbance term with the degree of freedom from the range four to six. The diagnostic tests for the specifications in GARCH models indicated no serial correlation and ARCH effect in the variance equations.

To validate the presence of risk premium, an EGARCH-mean model is fitted in each respective return series. In Table 9, only the *Sample-II* and overall period estimates are negative and significantly different from zero at 10%. The estimated risk premium coefficient was a_4 indicated to be insignificant from zero for *Sample-III* period and this implies that the predictability of non-linear term is outside the risk-return relationship. It was concluded that only the predictability identified from *Sample-III* is due to inefficient pricing.

Long-Range Dependence Behaviour

The predictability of long-range dependence volatility was examined using two discrete-time approaches. Two volatility proxies namely the squared-return and absolute-return were used in the empirical analysis. For the preliminary test, we plotted the sample autocorrelation function (SACF) in Figure 4. As expected, the SACF of the absolute returns$\{|r_t|\}$ and $\{r_t^2\}$ for the overall sample exhibited hyperbolic decay with significant spikes up to more than 200 and 20 lags, respectively.

The Hurst's parameter is determined by calculating the slope of the regression analysis with the estimation of 0.720 for overall squared-return with correlation coefficient 99.5%. Long-range dependence would occur if the Hurst's parameter is between 0.5 to 1.0 with the strongest dependence when H nears unity. Table 10 reports the rest of the regression ordinary least square estimations where, in general the R/S methodology provided better sample correlation coefficients as compared to Variance-time plots. From absolute return R/S analysis in Table 10, *Sample I* showed the weakest dependence (0.551), followed by *Sample III* (0.695), and finally, *Sample II* (0.751). Overall, the samples' volatilities indicated long-range dependence and hence, provided predictability components in the pricing indices.

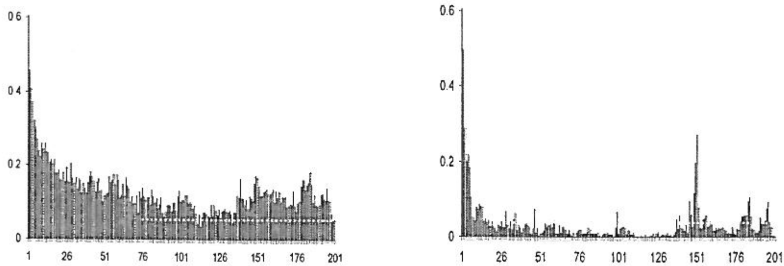

Figure 4: Sacf of absolute and squared returns (lagged 200) of overall period

Note: The dotted line represented the $1.96(1/\sqrt{T})$

Table 10: The Hurst's Estimation

$\{r_t^2\}$	Overall	Sample-I	Sample -II	Sample -III
(a) Variance –Time plot	0.720 (0.995)	0.456 (0.945)	0.707 (0.956)	0.664 (0.993)
(b) R/S analysis	0.725 (0.994)	0.581 (0.997)	0.714 (0.995)	0.675 (0.996)
$\{\lvert r_t \rvert\}$	Overall	Sample-I	Sample -II	Sample -III
(a) Variance –Time plot	0.833 (0.986)	0.476 (0.968)	0.742 (0.803)	0.849 (0.964)
(b) R/S analysis	0.763 (0.987)	0.551 (0.998)	0.751 (0.983)	0.695 (0.986)

Notes: Figures in parentheses are correlation coefficients

DISCUSSION

Sample I (1 January 1991 until 5 January 1994)

During this period, the Malaysian economy encountered a transition into manufacturing, compared to previous mining and agricultural focus with the achievement of more than 7% GDP growth with low inflation. The National Development Policy launched in 1990 also contributed to the economic growth where numerous large infrastructure projects were been implemented all over the country. However, the Malaysian stock market was still in the early developing stages where the KLSE has taken over operations of Kuala Lumpur Stock Exchange Bhd (KLSEB) in 1994. The KLSE was still in the process of impoving the market infrastruture in terms of corporate trasnparency, cost effectiveness, portable information access (Internet-based facility), among others.

Our statistical results evidenced the random walk process for the price level with the presence of heteroscedastic increment (RW3). The randomness of price changes is the result of fast responses from an enormous number of investors seeking greater wealth. Due to the lack of information available, it may be that not many investors have the advantage in manipulating the additional information against others. As a result, these actions would eliminate the possibility of profit opportunities in the financial markets. Similarly, the adjusted return exhibited no non-linear components and risk premium, which again lead to the conclusion that the price changes are unpredictable. At this stage, it is concluded that the price and return series are efficient.

Although the price level and adjusted return are unpredictable, nevertheless the volatility during the economic boom showed short- and long-dependence volatilities under the ARCH modelling and Hurst's parameter estimations. It is believed that heterogeneous market participants with different expectations, which differs with respect to time (e.g. short- and long-term trading), would cause the long-range dependence volatility clustering. This long-range dependence property has improved the definition of market efficiency, where predictable components occur in the underlying asset pricing.

Sample II (6 January 1994 until 2 September 1998)

The Malaysian economy experienced drastic changes due to the Asian financial and currency crises. During the economic crisis beginning early 1997, a sharp drop and precipitous decline occurred in the stock prices and caused a speculative euphoria. This speculation period induced the market participants to become more cautious and react rationally with respect to as much reliable information as possible. This again, led to the hypothesis of randomness if all the market participants are homogenous and react based on the rational expectation model. Inline with this argument, the results indicated that price level follows a random walk process under the heteroscedastic condition. Due to the rationality, precautions, and instantaneous responses to information of market participants, our statistical analysis indicated no non-linearity (after the inclusion of risk premium) in the return series.

On the other hand, the randomness in price and return series do not prevent the dependence property in the volatility which was created by different time horizon investors. As expected, the leverage effect in the EGARCH model indicated that the *bad news* has a deeper impact as compared to *good news* against the return series. The mixture of different time scale volatility has resulted the short- and long-range dependence volatilities.

Sample III (3 September 1998 until 31 December 2006)

In September 1998, the Malaysian government implemented the fixed USD currency to stabilise the RM and protect it from currency speculation. In this recovery period, the Malaysian government improved the market infrastructure in terms of cost effectiveness, competitiveness, corporate transparency, and regulation of investor protection. In October 1999, the KLSE introduced the Listing Information Network (LINK), as an internet-based facility which provided comprehensive, accurate, and timely information of public listed companies' announcements, thus enhanced the corporate disclosure for market participants. The markets provided better quality information with perhaps better informed market participants. However, the Malaysian market participants are still considered less efficient as compared to other mature markets such as S&P500, among others, where investors incorporated their available (even a tiny piece of information) information into the market price to gain any possibility of extra wealth.

These are evidenced from our empirical analyses of price level and return series where predictable components are observed in the lag price level and non-linear returns, respectively. Similar to sub-periods before currency control, the long-range dependence is observed in the market volatility and implied that the volatility is predictable.

CONCLUSION

In this paper, we investigated the weak-form efficiency by considering the price, return, and volatility of the Malaysian stock market. This study included the unit root, non-linear, infrequent trading, clustering volatility, leverage effect, heavy-tailed, and long-range dependence properties in the Malaysian stock exchange. The market efficiency is analysed on the piecewise before and after the economic crisis so that it would be possible to observe the evolution of the market.

The first two samples (*Sample I* and *Sample II*) evidenced the weak-form market efficiency where the price level and return series followed random walk processes. However, after the currency control implementation (*Sample III*), the Malaysian stock market exhibited predictability components in both the price and return series, which led to the violation of efficient market hypothesis.

The significant estimations of EGARCH models implied the presence of dependent conditional heteroscedasticity in the volatility. In addition, the presence of long-range dependence volatilities indicated that the different reaction time horizons (short term, medium term, and long term) by the market participants contributed to different types of volatilities. The combination of all the different time horizon volatility has created a long-range dependence of volatility relationship. This new finding may provide a better implication and insight into the understanding of market efficiency analysis.

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