TESTING STOCK MARKET EFFICIENCY IN EMERGING FINANCIAL MARKETS: A COMPARATIVE TEST OF RANDOM WALK BEHAVIOUR (RWB) IN HIGH AND LOW VOLATILITY REGIMES

Dr. D.A.I. Dayaratne[1] and Mr. T.U.I. Peiris[2]

Abstract

One of the most contentious issues in finance is possibly whether the financial markets are efficient or not. When determining the market efficiency, Efficient Market Hypothesis (EMH) has attracted the interest of greater number of academics and practitioners in empirical finance literature. However, empirical studies of the market efficiency in the two regimes of high and low volatility are still unexplored. Thus, this study attempts to identify the random work behaviour in high and low volatility regimes in emerging financial markets namely, India, China, Indonesia, Korea, Malaysia, Taiwan and Philippine. Returns of daily, weekly and monthly of the market portfolios from 2000 to 2010 are used for the investigation. Primarily, the Iterated Cumulative Sums of Squares (ICSS) algorithm and GARCH regression are used to identify the volatility breaks and for the purpose of sub-dividing the original series in to low volatile and high volatile regimes. Subsequently, popular econometric models of Autocorrelation Function (ACF), Runs Test, and Augmented Dickey-Fuller (ADF) test and Phillip and Perron (P-P) test are employed for the empirical analysis of randomness. The empirical results indicate that the random work behaviour in most of the emerging markets is relatively similar in the two regimes. However, results highly depend on the nature of econometric model applied and on the type (daily, weekly and monthly) of data series.

Keywords: Efficient Market Hypothesis, Random work, Volatility regimes and Emerging markets.

1 Introduction

The efficiency of capital market is one of the popular concepts in the field of finance that evolved with the pioneering work of Fama (1970). During the last four decades several researchers including academics professionals have empirically investigated this concept in several markets. The market efficiency asserts that the securities markets are generally efficient in reflecting information in the stock prices. Fama (1970; 1990) provides the formal definition for the market efficiency. He classifies the market efficiency into three forms namely, *weak form, semi strong from and strong from* efficiency. Weak form efficient market hypothesis (EMH), which is main focus of this paper states that stock returns are serially un-correlated and mean is constant. In other words, the market is weak form efficient if the prices reflect all past information which suggests that no investor can gain abnormal returns beating the market.

There are volumes of previous empirical evidences on efficient market hypothesis focused on developed markets and emerging markets. Among them considerable number of studies are conducted in Asian stock markets. However, the number of studies is comparatively few. The studies were extensively undertaken in late 1980s. For example, Fama (1998), Lo and MacKinlay (1988) and Kiem and Stampbaugh (1986). More, recently

[1]Senior Lecturer, Department of Accountancy & Finance, Sabaragamuwa University of Sri Lanka, Belihuloya
[2]Lecturer, Department of Accountancy & Finance, Sabaragamuwa University of Sri Lanka, Belihuloya.

Worthington and Higgs (2005) examined the random walk behavior of 15 markets of which 10 are emerging (including Sri Lanka market) and 5 are developed markets. They concluded that the behavior of stock prices in emerging markets is not independent and demonstrate weak form efficient market features; however, finding for some developed markets were characterized by a random walk behavior.

Moreover, studies on the behavior of stock prices limited in emerging markets when compared to developed markets. However, significant number of studies has tested RWB in the emerging markets. Urrutia (1995) examined the RWB in Latin American emerging markets of Argentina, Brazil, Chile and Mexico using the variance ratio (VR) and reject the existence of RWB in these markets whereas the runs test confirm the existence of weak form efficiency of these markets. Another similar study of Grieb and Reyes (1999) examined the properties of random walk in Brazil and Mexico applying the variance ratio test and conclude that the Mexico exhibits mean reversion and a tendency towards random walk in Brazil. Subsequently, Abraham, Seyyed and Alsakran (2002) investigated the RWB in three Gulf stock markets Kuwait, Saudi Arabia and Bahrain and they attempted to minimize the issue of thin trading by decomposing the log of the observed index into its random and stationary components. They rejected the both RWB and weak form efficiency for these markets. Conversely, the corrected indexes show that successive price changes are independent for all three markets implying weak form efficiency. However, in their findings the Kuwaiti market fails to follow random walk even after the correction. Al Khazali, Ding and Pyun (2007) came up with contradictory results to Abraham, Seyyed and Alsakran (2002) in their study on eight emerging markets, Baharain, Egypt, Jordan, Kuwait, Morocco, Oman, Soudi Arabia, and Tunisia. They conclude that weak form efficiency not seen in these markets. Also, they conclude that Saudi and Bahraini markets are much more robust, statistically; Kuwaiti market is weak form efficient.

The current study examines the weak from efficiency and random walk behavior of seven Asian stock markets. The novel contribution of this study is that it divides the original market return series of seven markets into two regimes as high volatile and low volatile and several specification tests are separately conducted for both regimes. This is important because under the high volatile situation, in the market the stocks are traded beyond the fundamentals. Therefore, there is a high possibility of getting different results from the predictions made by applying these pricing data into the statistical models. Looking at weak form efficiency test and random walk test in two regimes will bring new perspective to the available empirical evidences in this area.

The section 2 of this explains the data and methodology adopted for various tests for randomness. This section also explains the ICSS and its steps. Diagnostic test of autocorrelation is explained in section 3. Sections 4, 5, and 6 explain Runs Test, Augmented Dickey Fuller Test and Philips and Perron Test respectively including the results. Section 7 concludes the paper.

2 Data and Methodology

As stated before, this study attempts to identify the random work behaviour in high and low volatility regimes in emerging financial markets namely, India, China, Indonesia, Korea, Malaysia, Taiwan and Philippine. Returns of daily, weekly and monthly of the market portfolios from 2000 to 2010 are used for the investigation. The market indexes of all the seven countries gathered from the database of yahoo finance and obtained the first differences of all daily, weekly and monthly series. For the purpose of splitting data into high volatile and low volatile periods the Iterated Cumulative sums of Squires Algorithm (ICSS) of Inclan and Tiao (1994) is applied.

2.1 Identification of High Volatile and Low Volatile Regimes

Inclan and Tiao (1994) introduce and refine a test for the detection of multiple changes in volatility of a time series. The test, which will be identified as ICSS because it uses Iterated Cumulative Sum of Squares method, is applied here for the market index series. The advantage of this method is that the data can be used to reveal crisis periods without human intervention, which is what makes it an objective approach. This section mainly focus on the Centered Cumulative Sum Squares Function, D_k, and outlines the how ICSS use it iteratively identify multiple volatility breaks.

Iterated Cumulative sum of squares (ICSS) Algorithm

The ICSS algorithm according to Inclan and Tiao (1994) compares well against alternative approaches available in the literature to detect changes in volatility. Inclan and Tiao (1994) make this comparison using monte carlo simulation methods which revealed that ICSS algorithm was the best for analyzing long time series with potentially multiple change points of variance in a series. Inclan and Tiao (1994: 913) define a long time series as on with 200 or more observations. These conditions are satisfied for the daily, weekly and monthly return processes that are studied here. In other words, they are long time series with potentially multiple volatility breaks.

Present study, for above reasons, uses the ICSS to detect structural shifts in volatility in daily, weekly market and monthly returns series from the seven markets. The ICSS mainly asserts that the variable D_k is more sensitive to the changes in volatility than the alternatives available. Here Dk is defined as

$$D_k = \frac{C_k}{C_T} - \frac{k}{T},\ k = 1,\ldots,T, \qquad \textbf{(1)}$$

with $D_0 = D_T = 0$ where $C_k = \sum_{t=1}^{k} R_{m,t}^2$ and $R_{m,t}$ is the market return series at week t. Thus the ICSS tracks the changes in D_k to detect changes in volatility. The algorithm involves several iterative steps which are followed in this paper. These steps given below closely follow the explanation by Inclan and Tiao (1994: 916). Here the notation $R[t_1 : t_2]$ represents $R_{m,t_1}, R_{m,t_1+1}, R_{m,t_1+2},\ldots,R_{m,t_2}$, $t_1 > t_2$ and notation $D_k(R[t_1 : t_2])$ represents the range over which cumulative sum of squares are sought.

Step 1. Let $t_1 = 1$,

Step 2. Calculate $D_k(R[t_1 : T])$. Let $k^*(R[t_1 : T])$ be the point at which $\max_k |D_k(R[t_1 : T])|$ is obtained and let

$M(t_1 : T) = \max_{t_1 \le k \le T} \sqrt{(T - t_1 + 1/2} |D_k(R[t_1 : T])|$

If $M(t_1 : T) > D^*$, where D^* is the critical value, consider that there is a change point at $k^*(R[t_1 : T])$ and proceed to Step 2a.

Step 2a. Let $t_2 = k^*(R[t_1 : T])$. Evaluate $D_k(R[t_1 : t_2])$; that is the centered cumulative sum of squares applied only to the beginning of the series up to t_2. If $M(t_1 : t_2) > D^*$, then there will be a new point of change and repeat Step 2a until $M(t_1 : t_2) > D^*$, When this occurs it can be concluded that there is no evidence of change in $t = t_1,\ldots t_2$ and therefore the first point of change is $k_{first} = t_2$.

Step 2b. Now do a similar search starting from the first change point found in step 1 , towards the end of the series. Define a new value for t_1: let $t_1 = k^*(R[t_1 : T]) + 1$. Evaluate $D_k\left(R[t_1 : T]\right)$, and repeat Step 2b until $M\left(t_1 : T\right) > D^*$. Let $K_{last} = t_1 - 1$

Step 2c. If $K_{first} = K_{large,}$ then there is just one change point. The algorithm steps there. If $K_{first} = K_{large,}$ keep both values as possible change points and repeat steps 1 and 2 on the middle part of the series; that is $t_1 = K_{first} + 1$ and $T = K_{last}$. Each time that steps 1 and 2 are repeated then result can be one or two more points. Call N_T the number of change points found so far.

Step 3. If there are two or more possible change points, make sure they are in increasing order. Let cp be the vector of all the possible change points, found so far. Define the two extreme values $cp_0 = 0$ and $cp_{NT+1} = T$. Check each possible change point by calculating $D_k(R[cp_{j-1} + 1 : cp_{j+1}]),\ j = 1, \ldots N_T$. If $m(cp_{j-1} + 1 : cp_{j+1}) > D^*$, then keep the point; otherwise eliminate it. The retained points constitute the multiple volatility change points in the $R_{m,t}$ series.

2.2 Hypothesis

Mainly this study focuses on two hypotheses.

1. The alternative hypothesis is that market indexes on seven stock markets follow random walk in high volatile and low volatile regimes.
2. That the seven stock markets are weak form efficient

3 Autocorrelation Diagnostic Test

In testing the EMH the Autocorrelation test is widely used by researchers. Particularly, this test is widely used in testing the weak form efficient hypothesis which suggests that the prices only reflect the past information. The autocorrelation coefficient measures the relationship between the values of a random variable at time *t* and its value in the previous period. Autocorrelation is reliable measure for testing of dependence/independence of random variable in a series. If no autocorrelations are found in a series then the series is considered random. In this study the daily, weekly and monthly prices of market indices of seven countries transformed into return series and computed the autocorrelation. Based on the results the markets are divided into random markets and non-random markets. Owing to space limitations the statistics are not reported here. However, the Table 1 summarizes the final judgments of the results of the test in brief.

Table 1: Autocorrelation Diagnostic Test Results.

ACF	LOW VOLATILE			HIGH VOLATILE		
	Daily	Weekly	Monthly	Daily	Weekly	Monthly
China	Not Random	Random	Random	Random	Random	Not Random
India	Random	Not Random	Random	Random	Random	Random
Indonesia	Not Random	Random	Not Random	Not Random	Random	Not Random
Korea	Random	Random	Random	Random	Not Random	Random
Malaysia	Not Random	Not Random	Random	Random	Random	Random
Philippines	Not Random	Random	Random	Not Random	Random	Random
Taiwan	Not Random	Random	Random	Not Random	Random	Random

As shown in Table 1 ACF test is applied for daily, weekly and monthly data for seven counties. It shows that out of 42 (3x7x2) possible outcomes 28 outcomes indicate random process and the balance 14 indicate non-random process. Interestingly, some significant differences are found among different series. In case of daily data out of 14 possible outcomes 6 are random and when it comes to weekly data 11 processes are random. On the other hand with monthly data it is similar to weekly result. This result suggest that higher time intervals of the data series pertinent to higher the randomness of the series. Importantly, during low volatile period out of 21 outcomes 13 processes are random and for high volatile period it is 15 processes. Based on this result it can be concluded that the ACF results more pertinent to randomness during high volatile periods.

Finally, the evidence of presence of autocorrelation in the transform series on several lags suggests that there is a serial dependence between values. Therefore, the hull hypothesis that there is no first order autocorrelations present in the series is rejected in most cases in several markets.

4 Test for Serial Dependence –Runs Test

This paper applies the Runs Test to investigate the randomness of the seven index series. Runs test is reliable test for investigating serial correlation in share price movements and compares the expected number of runs from a random process with observed number of runs. A run is defined as a series of identical signs (negative or positive) that are preceded that follows by a different sign or are followed by a different sign or no sign at all. In nutshell, the runs test examines whether the value of one observation influences the values taken by subsequent observations. If the observations are independent the data series is considered random. The total numbers of runs are the measure of randomness, while too many or too few observations suggest dependence between observations.

Table 2 summarizes the results of the Runs Test for the seven markets. According to the table out of 42 outcomes of the test for seven countries 31 cases are random and only 11 cases are non random. This suggests that the test results of runs test more bias towards randomness when compared with the ACF. The results relating to the monthly data report that 13 occasion of randomness and only one occasion of non randomness. Here also as in the ACF the monthly series is more susceptible to be random than daily and weekly data. It seems that majority of the markets are random with monthly data during high volatile period.

Table 2: Results of Runs Test

RUNS TEST	LOW VOLATILE			HIGH VOLATILE		
	Daily	Weekly	Monthly	Daily	Weekly	Monthly
China	Not Random	Random	Random	Random	Random	Random
India	Random	Random	Random	Random	Not Random	Random
Indonesia	Not Random	Random	Not Random	Not Random	Random	Random
Korea	Random	Random	Random	Random	Random	Random
Malaysia	Not Random	Not Random	Random	Not Random	Random	Random
Philippines	Not Random	Not Random	Random	Not Random	Random	Random
Taiwan	Random	Random	Random	Random	Random	Random

5 Augmented Dickey-Fuller (ADF) test

The simple Dickey-Fuller unit root test is valid only if the series is an AR(1) process. If the series is correlated at higher order lags, the assumption of white noise disturbances $\epsilon_t$is violated. The Augmented Dickey-Fuller (ADF) test constructs a parametric correction for higher-order correlation by assuming that the Y series follows an AR(p) process and adding *p* lagged difference terms of the dependent variable Y to the right hand side of the test regression:

$$\Delta Y_t = \alpha Y_{t-1} + \delta X_t' + \beta_1 \Delta Y_{t-1} + \beta_2 \Delta Y_{t-2} + \cdots \ldots + \beta_p \Delta Y_{t-p} + \epsilon_t \quad \textbf{(2)}$$

This augmented specification is then used to test.

$H_0{:}-\quad \alpha = 0$ & $H_1{:}-\quad \alpha < 0$

and; evaluated using the conventional t-ratio for α.

$$t_\alpha = \frac{\acute{\alpha}}{se(\acute{\alpha})} \quad \textbf{(3)}$$

Where $\acute{\alpha}$ = the estimate of α. $se(\acute{\alpha})$ = Coefficient standard error.

6 Phillips and Perron (P-P) Test

Phillips and Perron (1988) propose an alternative (nonparametric) method of controlling for serial correlation when testing for a unit root. The P-P method estimates the non-augmented DF test and modifies the t-ratio of the α coefficient so that serial correlation does not affect the asymptotic distribution of the test statistic. The P-P test is based on the statistic:

$$\tau_\alpha = t_\alpha \left(\frac{\gamma_0}{f_0}\right)^{1/2} - \frac{T(f_0 - \gamma_0)(Se(\acute{\alpha}))}{2 f_0^{1/2} s} \quad \textbf{(4)}$$

Where = the estimate, and t_α = t-ratio of α, $se()$ = coefficient standard error, and s = standard error of the test regression. In addition, γ_0 = consistent estimate of the error variance in equation (3). The null and alternative hypotheses may be written as;

$H_0{:}-\quad \alpha = 0$ & $H_1{:}-\quad \alpha < 0$

The asymptotic distribution of the P-P modified t-ratio is the same as that of the ADF statistic. If calculated t-value > critical (table) t-value then H_0 is rejected otherwise H_0 is accepted. However, in this study the probability value (p-value) method used at 95% confidence level as the decisions criteria. Hence, the decision criterion will be; If p-value is < 0.05 then, H_0 is rejected otherwise, H_0 is accepted.

In case, H_0 is accepted, the tested data series has a unit root indicating that the series is not stationary.

Table 3 presents the summary of the results of ADF and P-P test. The reported results indicate that in both tests all the p-values are significant at 95% level. Therefore, the null hypothesis is accepted. In other words the hypothesis the series are random is accepted.

Table 3: Summary of Results – ADF Test, P-P Test.

		ADF Test			P-P Test		
		D	W	M	D	W	M
China	Low Volatile	-43.74 (0.00)	-18.20 (0.00)	-7.68 (0.00)	-43.73 (0.00)	-18.25 (0.00)	-7.86 (0.00)
	High Volatile	-28.52 (0.00)	-13.40 (0.00)	-3.88 (0.00)	-28.48 (0.00)	-13.59 (0.00)	-8.21 (0.00)
India	Low Volatile	-32.67 (0.00)	-10.71 (0.00)	-7.24 (0.00)	-32.68 (0.00)	-18.31 (0.00)	-7.24 (0.00)
	High Volatile	-37.69 (0.00)	-15.30 (0.00)	-7.35 (0.00)	-37.69 (0.00)	-15.32 (0.00)	-7.36 (0.00)
Indonesia	Low Volatile	-31.24 (0.00)	-16.46 (0.00)	-5.36 (0.00)	-31.25 (0.00)	-16.75 (0.00)	-5.31 (0.00)
	High Volatile	-32.43 (0.00)	-10.00 (0.00)	-7.98 (0.00)	-32.45 (0.00)	-16.89 (0.00)	-7.98 (0.00)
Korea	Low Volatile	-38.83 (0.00)	-20.72 (0.00)	-9.84 (0.00)	-39.16 (0.00)	-20.66 (0.00)	-9.95 (0.00)
	High Volatile	-35.40 (0.00)	-17.69 (0.00)	-4.94 (0.00)	-35.40 (0.00)	-17.54 (0.00)	-5.14 (0.00)
Malaysia	Low Volatile	-31.84 (0.00)	-19.60 (0.00)	-8.97 (0.00)	-56.19 (0.00)	-20.00 (0.00)	-8.98 (0.00)
	High Volatile	-18.92 (0.00)	-8.03 (0.00)	-5.30 (0.00)	-18.81 (0.00)	-8.03 (0.00)	-5.28 (0.00)
Philippines	Low Volatile	-42.73 (0.00)	-10.83 (0.00)	-5.38 (0.00)	-42.78 (0.00)	-11.00 (0.00)	-5.40 (0.00)
	High Volatile	-22.72 (0.00)	-19.95 (0.00)	-9.43 (0.00)	-22.72 (0.00)	-20.08 (0.00)	-9.40 (0.00)
Taiwan	Low Volatile	-43.04 (0.00)	-21.69 (0.00)	-6.43 (0.00)	-43.05 (0.00)	-21.74 (0.00)	-6.47 (0.00)
	High Volatile	-26.57 (0.00)	-9.85 (0.00)	-8.98 (0.00)	-26.57 (0.00)	-9.89 (0.00)	-8.98 (0.00)

Note: Values in parenthesis are p-values

7 Conclusion

The results of the autocorrelation test and runs tests indicate non-random nature of index series therefore, this finding is contradict with the weak form efficiency hypothesis in most of the markets. However, ADF and P-P tests confirm a random nature in all the index series. These findings are consistent with the weak form efficient market hypothesis. It is found that the empirical results indicate the random work behaviour in most of the emerging markets is similar in the two regimes. This suggests that results highly depend on the nature of econometric model and the nature of the data series applied.

The implication of the finding of rejection of weak from efficiency is that the well diversified investors will not get a fair return and *vise versa.*

References

Abraham, A., Seyyed, F. J., and Alsakran, S. A., 2002. Testing the Random Walk Behaviour and Efficiency of the Gulf Stock Markets. *Financial Review*. 37(3). pp. 469-480.

Al Khazali, O. M., Ding, D. K., and Pyun, C. S., 2007. A New Variance Ratio Test of Random Walk in Emerging Markets: A Revisit. *Financial Review*. 42(2). pp. 303-317.

Fama, E. F., 1970. Efficient Capital Markets: A Review of Theory and Empirical Work. *Journal of Finance*. 25(2). pp. 383-417.

Fama, E. F., 1990. Stock Returns, Expected Returns, and Real Activity. *Journal of Finance*. pp. 1089-1108.

Fama, E. F., 1998. Market Efficiency, Long-Term Returns, and Behavioral Finance. *Journal of Financial Economics*. 49(3). pp. 283-306.

Grieb, T. and Reyes, M. G., 1999. Random Walk Tests for Latin American Equity Indexes and Individual Firms. *Journal of Financial Research*. 22(4). pp. 371-83.

Inclan, C. and Tiao, G. C., 1994. Use of Cumulative Sums of Squares for Retrospective Detection of Changes of Variance. *Journal of the American Statistical Association*. 89(427).

Keim, D. B. and Stambaugh, R. F., 1986. Predicting Returns in the Bond and Stock Markets. *Journal of Financial Economics*. 17. pp. 357-390.

Lo, A. W. and Mackinlay, A. C., 1988. Stock Market Prices Do Not Follow Random Walks: Evidence from a Simple Specification Test. *Review of Financial Studies*. 1(1). pp. 41-66.

Urrutia, J. L., 1995. Tests of Random Walk and Market Efficiency for Latin American Emerging Equity Markets. *Journal of Financial Research*. 18(3). pp. 299-309.

Worthington, A. C. and Higgs, H., 2005. Weak-Form Market Efficiency in Asian Emerging and Developed Equity Markets: Comparative Tests of Random Walk Behaviour. *University of Wollongong Research Online*. Finance Working Paper Series, No. 05/03, 2005.