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Random Walk in Emerging Asian Stock Markets

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Abstract

The random walk hypothesis is an important area of research in finance and many tools have been proposed to investigate the behaviour of the fluctuations in stock prices. However, a detail study on emerging Asian stock markets which employ the various unit root tests has not been done. In this paper, we employ six different unit root tests such as the Augmented Dickey and Fuller test (1979), Phillips and Perron test (1988), Kwiatkowski-Phillips-Schmidt-Shin test(1992), Dickey-Fuller GLS (ERS) test (1996), Elliot-Rothenberg-Stock Point-Optimal test (1996) and Ng and Perron (2001) unit root tests on 10 emerging Asian stock markets to detect for the presence of a random walk in stock prices. We have conducted the unit root tests during different sub-sample time periods of global financial crisis to check for robustness. To be specific, we have found that during the overall sample period (2001-2015) 8 out of 10 Asian stock markets and during the pre-crisis period (2001-2007) all the 10 Asian stock market prices do follow random walk according to the unit root tests under consideration. However, during the crisis & post-crisis period (2008-2015) we have found only 5 out of 10 Asian markets follow the random walk movement based on unit root tests.

Keywords: unit root tests, random walk, weak-form efficiency, stock indices, emerging asian markets, global financial crisis

1. Introduction

The random walk hypothesis has been an important area of research in the academic literature and is well known that stock prices move uncertainly in an efficient market. The origins of efficient market can be traced back to the pioneering work of Bachelier (1900) and the empirical research work of Cowles (1933). In an efficient market, the prices will completely reflect all the available information. Fama (1970) classified the markets into three categories namely weak form, semi-strong form and strong form of market efficiency. In weak form market efficiency, the information set consists of only the history of past prices. In semi-strong form, the information set consists of all publicly available data whereas in strong form market efficiency, the information set incorporates all private data i.e. it includes all information known to any market participant.

The tests on market efficiency have important implications on trading strategies and in the development phase of the market. Hence it is very much essential for the investors and the policy makers to understand the efficiency of the stock markets. In a weak form efficient market, stock prices do follow random walks due to which it becomes impossible to predict the future stock prices based on the past stock price information set due to which no individual can outperform the market.

First, we contribute to the existing literature on detecting the presence of random walks in the movement of stock prices in the most important emerging Asian stock markets. Most of the studies have dealt on few Asian markets but in this paper we do an extensive empirical analysis by undertaking 10 emerging Asian stock markets namely {India, China, Hong Kong, Taiwan, Malaysia, Thailand, Pakistan, Srilanka, Indonesia & Philippines}. Second, we employ six different unit root tests such as the Augmented Dickey-Fuller test (1979), Phillips-Perron test (1988), Kwiatkowski-Phillips-Schmidt-Shin (1992) test, Dickey-Fuller GLS (ERS) test, Elliot-Rothenberg-Stock Point-Optimal test (1996) and Ng and Perron (2001) unit root tests to detect for the presence of a random walk in stock prices. We conducted the tests by considering the intercept and also by including trend & intercept in the test equation for 10 emerging Asian stock markets. Third, in order to check for robustness, we have also implemented the unit root tests for the emerging Asian stock markets during different sub-sample time periods.

We have performed the analysis during pre-crisis period (2001-2007), crisis & post-crisis period (2008-2015) and overall sample period (2001-2015). The period of study is most relevant to understand the impact of Asian stock markets with regards to the global financial crisis 2008.

The remainder of the paper is discussed as follows. Section 2 contains the literature review on the efficiency of the major Asian stock markets. Section 3 provides a description of the data and Section 4 discusses the methodology used in our paper. The results are dealt with in Section 5. The paper ends with some concluding remarks in Section 6.

2. Literature Review

We find an extensive literature on the study of random walk hypothesis or tests for weak form efficiency in the major developed markets. However, the available literature on the movement of random walk in the emerging Asian stock markets is scarce. Most of the studies have concentrated on a single Asian market than performing tests on the overall emerging markets as a whole. Chaudhuri (1991) finds Indian market does not seem to be efficient even in its weak form by undertaking serial correlation, Runs test for the period 1988-1990. Poshakwale (1996) studies Indian market from the period 1987-1994 by performing serial correlation, Runs test, KS test and found evidence of weak form efficiency. Laurence et al. (1997) studied China Market for the period 1993-1996 and found evidence of weak form efficiency by conducting the unit root tests.

Balkiz (2003) investigates Kuala Lumpur stock market weak-form efficient and finds that the market is not efficient in a weak form. Ashutosh (2005) finds evidence of weak form efficiency in the Indian market during the period 1996-2001 by doing serial correlation test. Worthington & Higgs (2006) for both developed and Asian markets by using serial correlation, Runs test, Unit root tests (ADF, PP & KPSS) and multiple variance ratio tests. Cooray et al. (2007) studied SAARC countries namely India, Srilanka, Pakistan and Bangladesh by using the unit root tests for the period 1996-2005 and supports weak form efficiency by ADF & PP unit root tests while DF-GLS and ERS tests do not support. Islam et al. (2007) examine Thailand Stock market with data from 1975 to 2001 and find that the market is not efficient. Asma *et.al* (2008) conducted studies on Bangladesh market for the period 1988-2000 by autocorrelation test and indicates that daily returns are not random.

Gupta and Basu (2007) performed ADF, PP and KPSS unit root tests on Indian stock markets and results found that market is not weak form efficient for the period from 1991-2006. Mishra (2009) used ADF, PP unit root tests on Indian stock market for the period from 2001-2009 and find weak form inefficiency. Hamid et al. (2010) performed analysis on Asia-Pacific markets for the period from 2004-2009 and found that monthly prices do not follow random walks in all the markets. Nisar et al. (2012) studied four South Asian markets and found that none of the markets follow random-walk and hence are not weak form efficient for the period 1997-2011. Mishra (2012) performed analysis on five South Asian markets for the period 2005-2010 by using ADF, PP unit root tests and provide evidence that these markets are not weak form efficient. Paulo (2013) studied 9 Asian markets by using the daily data and performed unit root tests like ADF, PP and KPSS along with variance ratio test and finds evidence that the analyzed markets are not weak form efficient. Amer et al. (2014) studied 3 south Asian markets for the period from 2003-2011 on monthly & weekly return indices and finds evidence that the markets are not weak form efficient by using ADF, PP unit root tests.

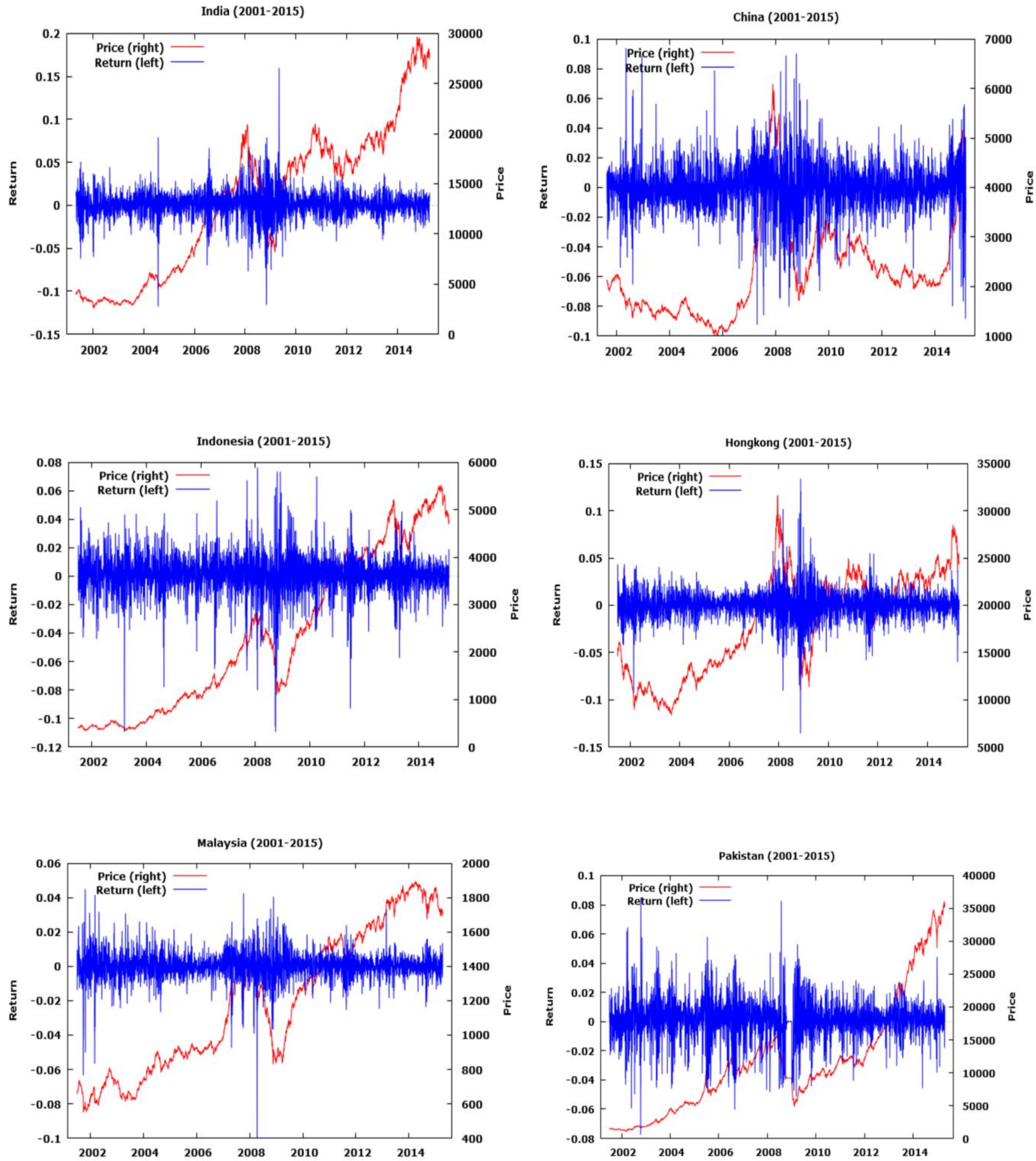
3. Data Description

The study is conducted empirically by using the daily data of stock market prices of major Asian stock indexes namely India, China, Hongkong, Malaysia, Taiwan, Thailand, Pakistan, Srilanka, Indonesia and Philippines. The closing prices of the daily stock market index data is collected from the source Bloomberg for three different sample period's i.e. the overall period (Jan2001-Mar2015), the pre-crisis period (Jan2001-Dec2007) and the crisis & post-crisis period (Jan2008-Mar2015). The continuously compounded annual rate of return is measured using, $r_t = \ln(p_t/p_{t-1})$ where r_t the return, ln is is the natural log, p_t is the current price and p_{t-1} is the previous price.

Figure 1 displays the time plots of the return and price series for 10 emerging Asian stock markets. Table 1, Panel A: shows the results for the overall sample period from Jan 2001 to Mar 2015. During this period, we find the lowest mean returns are in Hongkong (0.0001), whereas the highest mean returns are in Pakistan (0.0009). The lowest minimum returns are in Thailand (-0.1723), as are the highest maximum returns in Srilanka (0.1829). The standard deviations of returns range from 0.0080 (Malaysia) to 0.0164 (China). We find the returns in Taiwan, Pakistan and China are the least volatile, with Srilanka, Philippines and Malaysia being the most volatile. Finally, The Jarque-Bera statistic and the corresponding p-values reject the null hypothesis that the daily distributions of 10 Asian market returns are normally distributed.

Table 1, Panel B: shows the results for the sub-sample pre-crisis period from Jan 2001 to Dec 2007. During the pre-crisis period, we find the lowest mean returns are in Taiwan (0.0003), whereas the highest mean returns are for Pakistan (0.0013). The standard deviations of returns range from 0.0084 (Malaysia) to 0.0152 (China). We find Taiwan, Pakistan and Hongkong to be least volatile, with Srilanka, Philippines and Thailand being the most volatile. The Jarque-Bera statistic and the corresponding p-values reject the null hypothesis that the daily distributions of 10 Asian market returns are normally distributed.

Table 1, Panel C: shows the results for the sub-sample crisis & post-crisis period from Jan 2008 to Mar 2015. During this period, we find the lowest mean returns are in China (-0.0002), whereas the highest mean returns are for Srilanka (0.0006). The standard deviations of returns range from 0.0076 (Malaysia) to 0.0174 (China). We find the returns in Taiwan, China and Pakistan are the least volatile, with Malaysia, India and Philippines being the most volatile. The Jarque-Bera statistic and the corresponding p-values reject the null hypothesis that the daily distributions of 10 Asian market returns are normally distributed.



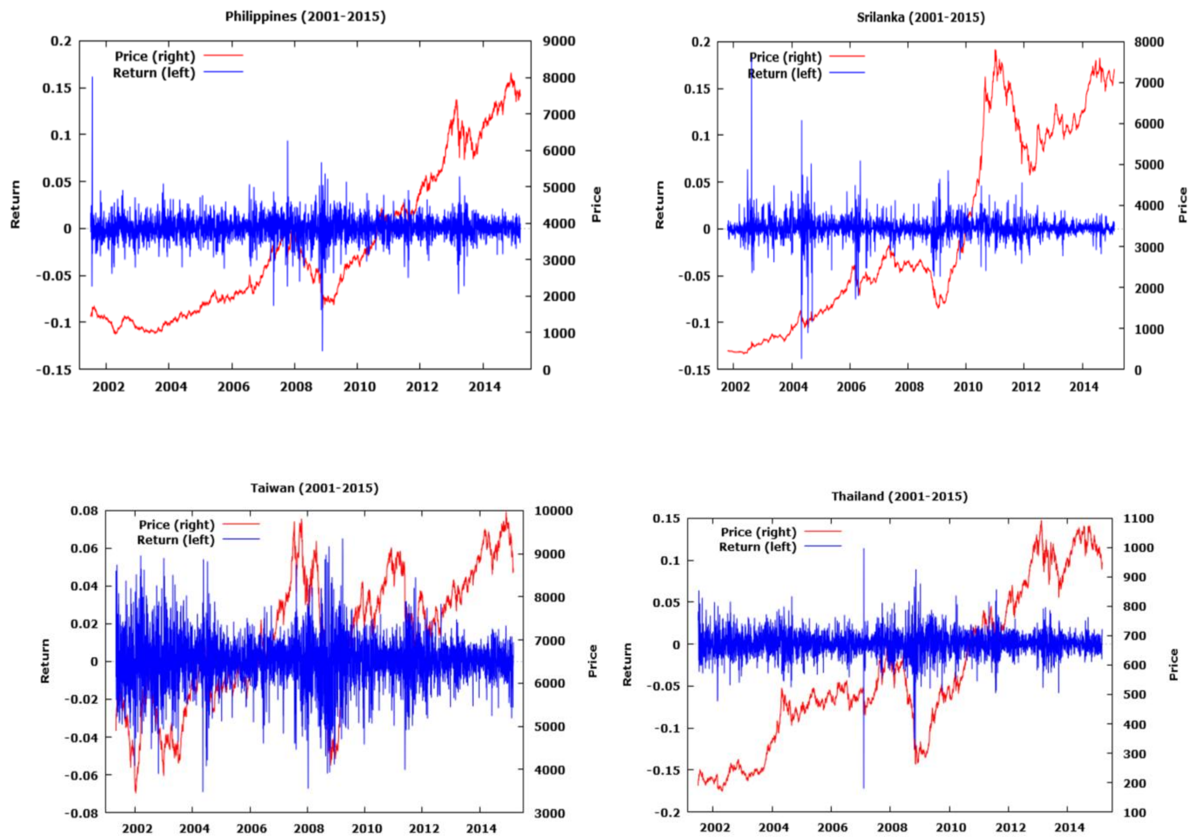


Figure 1. Time plot for return & price series of Asian stock indices

Table 1. Descriptive statistics of Asian stock market index returns

Panel A: Overall Sample Period (2001-2015)

	India	China	Hongkong	Taiwan	Malaysia	Thailand	Pakistan	Srilanka	Indonesia	Philippines
Mean	0.0005	0.0002	0.0001	0.0002	0.0003	0.0005	0.0009	0.0008	0.0007	0.0005
Median	0.0010	0.0006	0.0004	0.0005	0.0005	0.0005	0.0013	0.0005	0.0013	0.0005
Maximum	0.1599	0.0940	0.1341	0.0652	0.0450	0.1143	0.0851	0.1829	0.0762	0.1618
Minimum	-0.1181	-0.0926	-0.1358	-0.0691	-0.0998	-0.1723	-0.0774	-0.1390	-0.1095	-0.1309
Std. Dev.	0.0151	0.0164	0.0151	0.0136	0.0080	0.0152	0.0136	0.0121	0.0141	0.0131
Skewness	-0.1252	-0.2532	-0.0209	-0.1917	-0.9700	-0.5779	-0.3001	0.3211	-0.6807	-0.0424
Kurtosis	11.0044	7.1818	11.8501	5.6657	15.1137	12.7316	6.3845	32.6616	9.6916	15.6079
Jarque-Bera	9713.56	2609.14	11735.90	1091.59	22531.93	14262.08	1773.19	127375.80	6899.46	23666.14
Probability	0.0000*	0.0000*	0.0000*	0.0000*	0.0000*	0.0000*	0.0000*	0.0000*	0.0000*	0.0000*
Observations	3635	3529	3596	3612	3593	3564	3602	3473	3551	3573

Panel B: Pre Crisis Period (2001-2007)

	India	China	Hongkong	Taiwan	Malaysia	Thailand	Pakistan	Srilanka	Indonesia	Philippines
Mean	0.0009	0.0005	0.0004	0.0003	0.0004	0.0007	0.0013	0.0010	0.0011	0.0005
Median	0.0016	0.0006	0.0005	0.0002	0.0006	0.0003	0.0022	0.0008	0.0015	0.0001
Maximum	0.0793	0.0940	0.0576	0.0561	0.0450	0.1143	0.0851	0.1829	0.0673	0.1618
Minimum	-0.1181	-0.0926	-0.0929	-0.0691	-0.0634	-0.1723	-0.0774	-0.1390	-0.1093	-0.0825
Std. Dev.	0.0143	0.0152	0.0125	0.0144	0.0084	0.0152	0.0151	0.0144	0.0136	0.0132
Skewness	-0.6293	-0.0060	-0.2436	-0.0982	-0.6588	-0.6253	-0.3542	0.2936	-0.6994	0.9409
Kurtosis	8.0635	7.4860	6.2006	4.9292	10.0258	15.2525	5.6689	32.3722	8.0642	18.7767
Jarque-Bera	1991.85	1412.89	753.77	271.38	3672.69	10832.92	547.42	59623.65	1959.75	18123.40
Probability	0.0000*	0.0000*	0.0000*	0.0000*	0.0000*	0.0000*	0.0000*	0.0000*	0.0000*	0.0000*
Observations	1756	1685	1726	1732	1725	1714	1723	1658	1704	1723

Panel C: In & Post Crisis Period (2008-2015)

	India	China	Hongkong	Taiwan	Malaysia	Thailand	Pakistan	Srilanka	Indonesia	Philippines
Mean	0.0002	-0.0002	-0.0001	0.0000	0.0001	0.0002	0.0005	0.0006	0.0003	0.0004
Median	0.0005	0.0005	0.0003	0.0007	0.0003	0.0005	0.0005	0.0003	0.0011	0.0010
Maximum	0.1599	0.0903	0.1341	0.0652	0.0406	0.0892	0.0825	0.0626	0.0762	0.0706
Minimum	-0.1160	-0.0886	-0.1358	-0.0674	-0.0998	-0.1256	-0.0513	-0.0511	-0.1095	-0.1309
Std. Dev.	0.0158	0.0174	0.0172	0.0128	0.0076	0.0151	0.0119	0.0095	0.0146	0.0130
Skewness	0.2375	-0.3852	0.0748	-0.3217	-1.3684	-0.5358	-0.2379	0.2460	-0.6560	-1.0038
Kurtosis	12.7525	6.7950	12.0300	6.5671	21.7726	10.3959	7.0758	8.5125	10.7473	12.4082
Jarque-Bera	7460.10	1151.54	6351.72	1028.62	27997.29	4302.63	1317.62	2315.09	4749.00	7129.74
Probability	0.0000*	0.0000*	0.0000*	0.0000*	0.0000*	0.0000*	0.0000*	0.0000*	0.0000*	0.0000*
Observations	1878	1843	1869	1879	1867	1849	1878	1814	1846	1849

* means significant at 1% level of significance**Source:**Developed by authors

4. Methodology

In a stationary time series, the mean and auto-covariance are independent of time. However, for a non-stationary time series, the variance increases over time. *Random walk* is the common example of a non-stationary time series where,

$$z_t = z_{t-1} + \varepsilon_t \tag{1}$$

where ‘ε’ is a stationary random error term. The random walk is a difference stationary series since the first difference of y is stationary:

$$z_t - z_{t-1} = (1-L)z_t = \varepsilon_t \tag{2}$$

A difference stationary series is a random walk and is said to be *integrated* and is represented as I(d) where *d* is the order of integration or the number of unit roots present to make the series stationary. For example, I (0) represent a stationary series with no unit root. I (1) represent stationary series with 1 unit root. Hence unit root is used as a standard method to check the stationary of a time series.

Now let us look at a simple Auto Regressive AR (1) process mentioned as below,

$$z_t = \rho z_{t-1} + y_t'\delta + \varepsilon_t \tag{3}$$

Where ρ and δ are parameters to be estimated, ε_t is random disturbance term and y_t is the independent term which can have a constant, a trend or both constant and a trend. A series *z* is said to be non-stationary if the absolute value of the estimated parameter ρ is greater than or equal to 1. The variance of the non-stationary time series increases with time and nears infinity. Whereas, a series is said to be (trend) stationary, if the absolute value of the estimated parameter ρ is strictly less than 1.

4.1 The Augmented Dickey-Fuller (ADF) Test

In this test, the AR(1) process mentioned in equation (3) is estimated by removing z_{t-1} from both sides of the equation as below.

$$\Delta z_t = \alpha z_{t-1} + y_t'\delta + \varepsilon_t \tag{4}$$

where $\alpha = \rho - 1$. We define the null and alternative hypotheses as,

$$H_O: \alpha = 0,\ H_1: \alpha < 0 \tag{5}$$

and t-ratio for α is measured as:

$$t_\alpha = \hat{\alpha} / (se(\hat{\alpha})) \tag{6}$$

Where $\hat{\alpha}$ is the estimated parameter of α, and $se(\hat{\alpha})$ is the coefficient standard error.

Suppose, if the time series *y* follows an AR (p) process then we test the below regression:

$$\Delta z_t = \alpha z_{t-1} + y_t'\delta + \beta_1 \Delta z_{t-1} + \beta_2 \Delta z_{t-2} + \cdots + \beta_p \Delta z_{t-p} + \vartheta_t \tag{7}$$

4.2 Dickey-Fuller Test with GLS Detrending (DFGLS)

The quasi-difference of z_t conditional on the value of ‘a’ is defined as:

$$d(z_t|\, a) = \begin{cases} z_t & if\ t = 1 \\ z_t - a z_{t-1} & if\ t > 1 \end{cases} \tag{8}$$

The OLS regression of the quasi-differenced data $d(z_t|\, a)$ on the quasi-differenced $d(y_t|\, a)$ is defined as below:

$$d(z_t|\, a) = d(y_t|\, a)'\delta(a) + \eta_t \tag{9}$$

Elliot, Rothenberg, and Stock (ERS) (1996) recommend the value of *a* to be equal to $\bar{a}$ where:

$$\bar{a} = \begin{cases} 1 - \frac{7}{T} & if\ y_t = \{1\} \\ 1 - \frac{13.5}{T} & if\ y_t = \{1, t\} \end{cases} \tag{10}$$

Now the *GLS detrended data*, z_t^d can be defined as :

$$z_t^d = z_t - y_t^{'}\hat{\delta}(\bar{a}) \tag{11}$$

In Dickey Fuller GLS test we substitute the y_t^d for the original y_t as mentioned in equation (7) to get,

$$\Delta z_t^d = \alpha z_{t-1}^d + \beta_1 \Delta z_{t-1}^d + \cdots + \beta_p \Delta z_{t-p}^d + \vartheta_t \tag{12}$$

We further consider the t-ratio for $\hat{\alpha}$ as mentioned in ADF test.

4.3 The Phillips-Perron (PP) Test

The Phillips and Perron (1988) method estimates the equation (4) of the Dickey Fuller test and is based on the test statistic as shown below:

$$\tilde{t}_\alpha = t_\alpha (\frac{\gamma_0}{f_0})^{\frac{1}{2}} - \frac{T(f_0 - \gamma_0)(se(\hat{\alpha}))}{2 f_0^{\frac{1}{2}} s} \tag{13}$$

where $\hat{\alpha}$ is the estimate, and t_α the t-ratio of α, $se(\hat{\alpha})$ is coefficient standard error, and s is the standard error of the test regression. In addition, γ_0 is a estimate of the error variance and f_0, is a residual estimator. It is important to note that the asymptotic distribution of the Phillips-Perron modified t-ratio is the same as that of the ADF statistic.

4.4 The Kwiatkowski, Phillips, Schmidt, and Shin (KPSS) Test

The Kwiatkowski et al. (1992) test assumes the series z_t to be (trend-) stationary under the null. The KPSS statistic is defined based on the regression:

$$z_t = y_t^{'}\delta + u_t \tag{14}$$

The LM statistic is defined as:

$$LM = \sum_t S(t)^2 / (T^2 f_0) \tag{15}$$

where f_0, is an estimator of the residual spectrum at frequency zero and S(t) is a cumulative residual function:

$$S(t) = \sum_{r=1}^{t} \hat{u}_r \tag{16}$$

based on the residuals $\hat{u}_t = z_t - y_t'\hat{\delta}(0)$.

4.5 Elliot, Rothenberg, and Stock Point Optimal (ERS) Test

The ERS test is based on the quasi-differencing regression as mentioned in equation (9) in which the residuals are defined as $\hat{\eta}_t = d(z_t|\, a) - d(y_t|\, a)'\hat{\delta}(a)$, and let $SSR(a) = \sum \hat{\eta}_t{}^2(a)$ be the sum-of-squared residuals function. The ERS test statistic of the null that $\alpha = 1$ against the alternative that $\alpha = \bar{a}$, is then defined as:

$$P_T = (SSR(\bar{a}) - \bar{a}SSR(1))/f_0 \tag{17}$$

Where f_0, is an estimator of the residual spectrum at frequency zero.

4.6 Ng and Perron (NP) Tests

Ng and Perron (2001) construct four test statistics that depend upon the GLS detrended data. These test statistics are different forms of Phillips and Perron Z_α and Z_t statistics, the R_1 statistic, and the ERS statistic. First, define the term:

$$k = \sum_{t=2}^{T} (z_{t-1}^d)^2 / T^2 \tag{18}$$

The modified statistics may then be written as,

$$MZ_\alpha^d = (T^{-1}(z_T^d)^2 - f_0)/(2k)$$

$$MZ_t^d = MZ_\alpha * MSB$$

$$MSB = (k/f_0)^{\frac{1}{2}}$$

$$MP_T^d = \begin{cases} (\bar{c}^2 k - \bar{c}\, T^{-1}(z_T^d)^2)/f_0, & if\ y_t = \{1\} \\ (\bar{c}^2 k + (1-\bar{c})T^{-1}(z_T^d)^2)/f_0, & if\ y_t = \{1,t\} \end{cases} \tag{19}$$

where:

$$\bar{c} = \begin{cases} -7, & if\ y_t = \{1\} \\ -13.5, & if\ y_t = \{1,t\} \end{cases} \tag{20}$$

The NP tests require a specification for y_t and a choice of method for estimating f_0.

5. Empirical Results

In this section, we discuss the empirical results of the six different unit root tests that were employed in our paper to detect the random walk behaviour of the stock prices in the 10 emerging Asian stock markets under study. We also check the robustness of the unit root results by conducting the empirical tests during different sub sample periods. We perform the empirical analysis during the pre-crisis (2001-2007), crisis & post crisis (2008-2015) and also during the overall sample period (2001-2015).

5.1 Overall Sample Period (Jan 2001-Mar 2015)

Table 2, Panel A: provides us with the 5 different unit root test results in sections with only Intercept and also with both Trend & Intercept forms. First the Augmented Dickey-Fuller (ADF) Unit root test results shows that the t-test statistic is greater than the critical value at 1% level of significance at intercept level as well as both trend & intercept forms due to which we fail to the reject the null hypothesis of Unit root in the 10 emerging Asian stock markets. Second, we conduct the Phillips & Perron Unit root tests by including only Intercept and also both Trend & Intercept in the test equation. We say that the logarithm of the daily stock prices do follow random walk during overall sample period by employing PP Unit root as we observe the Adjusted t –stat is more than the critical value at 1% level of significance due to which we fail to reject the null hypothesis of Unit root. Third, we employ the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) Unit root test by including only Intercept and also both Trend & Intercept in the test equation. In both the cases we observe that the Lagrange Multiplier (LM) test statistic is more than the critical values due to which we reject the null hypothesis of stationary and conclude that these series are unit root non stationary except the Malaysian market. We find the series in Malaysian market is stationary at 1% level of significance when we include both trend & Intercept in the test equation. Fourth, we have conducted Dickey-Fuller GLS (ERS) test and find that t-stat is more than the asymptotic critical values at 1% and hence we fail to reject the null hypothesis of unit root for all the stock markets except Taiwan market in Trend & Intercept form. We find the series in Taiwan market has no unit root and hence it is stationary at 5% level of significance in the Trend & Intercept form. Fifth, we have performed Elliot-Rothenberg-Stock Point-Optimal (ERSPO) test and find that the calculated P-stat is more than the critical values at 1% level of significance and hence we fail to reject the null hypothesis of unit root for all the Asian stock market series except for Taiwan Market in Trend & Intercept form. We find Taiwan market to be stationary at 5% level of significance in trend& Intercept form by way of ERSPO unit root test similar to the findings of Dickey-Fuller GLS (ERS) unit root test. Table 3, Panel A: shows the Ng-Perron Unit root test results for the overall sample period (2001-2015) and we find that the four MZ_a, MZ_t, MSB, MPT test statistics to be more than the asymptotic critical values at 1% level of significance. We accept the null hypothesis that the series has unit root for all Asian stock markets except for Taiwan Stock market where we find that the series has no unit root at 5% level of significance in Trend & Intercept form. Table 4 & 5 presents the critical values of different unit root tests at 1%, 5% and 10% level of significance.

Hence during the overall sample period (2001-2015), we empirically find that the emerging Asian stock market series has unit root in both the intercept only and trend & intercept forms by six different Unit root tests employed in our analysis except for Malaysian market (KPSS Test in Trend & Intercept form) and Taiwan market (Dickey-Fuller GLS (ERS) test, Elliot-Rothenberg-Stock Point-Optimal test and Ng-Perron unit root in trend & Intercept forms) where we find no unit root. Hence except for Malaysia and Taiwan stock markets, we say that logarithm of daily Asian stock market prices follow random walk and hence are weak form efficient.

5.2 Pre-Crisis Period (Jan 2001- Dec 2007)

Table 2, Panel B: provides us with the 5 different unit root test results in sections with only Intercept and also with both Trend & Intercept forms during pre-crisis period. First we employ the Augmented Dickey-Fuller (ADF) Unit root test result, we find that the t-test statistic is greater than the critical value at 1% level of significance due to which we fail to the reject the null hypothesis of Unit root when we include only Intercept and both trend & intercept unit root test equation. We observe that the series has unit root and hence logarithm of stock prices follow random walk in all emerging Asian stock market under consideration as per ADF test. Second, we conduct the Phillips & Perron Unit root tests by including only Intercept and also both Trend & Intercept in the test equation. We say that the logarithm of the daily stock prices do follow random walk during sub sample pre-crisis period by employing PP Unit root as we observe the Adjusted t –stat is more than the critical value at 1% level of significance due to which we fail to reject the null hypothesis of Unit root. We also find the p-values to be insignificant for each Asian stock market under consideration. Third, we employ the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) Unit root test by including only Intercept and also both Trend & Intercept in the test equation. In both the cases we observe that the Lagrange Multiplier (LM) test statistic is more than the critical values due to which we reject the null hypothesis of stationary and conclude that these series are unit root non stationary. Fourth, we have conducted Dickey-Fuller GLS (ERS) test and find that t-stat is more than the asymptotic critical values at 1% and hence we fail to reject the null hypothesis of unit root for all the stock markets. Fifth, we have performed Elliot-Rothenberg-Stock Point-Optimal (ERSPO) test and find that the calculated P-stat is more than the critical values at 1% level of significance and hence we fail to reject the null hypothesis of unit root for all the Asian stock markets. Table 3, Panel B: shows the Ng-Perron Unit root test results for the sub-sample pre-crisis period (2001-2007) and we find the four MZ_a, MZ_t, MSB, MPT test statistics to be more than the asymptotic critical values at 1% level of significance. Hence we accept the null hypothesis that the series has unit root for all Asian stock markets. Table 4 & 5 presents the critical values of unit root tests.

Hence during the sub-sample pre-crisis period (2001-2007), we empirically find that the emerging Asian stock market series has unit root in both the intercept only and trend & intercept forms unanimously by six different Unit root tests employed in our analysis. Our test results show that during pre-crisis period all the Asian stock market prices follow random walk.

5.3 Crisis & Post-Crisis Period (Jan 2008- Mar 2015)

Table 2, Panel C: provides us with the unit root test results in sections with only Intercept and also with both Trend & Intercept forms for crisis & post-crisis period. First, during this sub-sample period, we find that China & Hongkong stock markets do not follow random walk in the Intercept form at 10% level of significance whereas India, Hongkong and Philippines do not follow random walk at 10%, 5%, 5% respectively in Trend & Intercept form of the Augmented Dickey-Fuller (ADF) Unit root test. The rest of the Asian stock markets do follow random walk when we employ the ADF unit root test. Second, we conduct the Phillips & Perron Unit root tests by including only Intercept and also both Trend & Intercept in the test equation. Our test results show that China & Hongkong stock markets do not follow random walk as the series has no unit root at 10% level of significance in Intercept form. Also we find that India, Hongkong and Philippines stock market series has no unit root and hence do not follow random walk at 10%, 5% and 5% level of significance respectively in both Trend& Intercept form. Third, we employ the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) Unit root test by including only Intercept and also both Trend & Intercept in the test equation. In both the cases we observe that the Lagrange Multiplier (LM) test statistic is more than the critical values due to which we reject the null hypothesis of stationary and conclude that these series are unit root non stationary and follow random walks except for China market in Intercept form and Hongkong & Taiwan market in trend & intercept forms where we find series to be stationary at 1% level of significance .Fourth, we have conducted Dickey-Fuller GLS (ERS) test and find that t-stat is more than the asymptotic critical values at 1% and hence we fail to reject the null hypothesis of unit root for all the Asian stock markets. Fifth, we have performed Elliot-Rothenberg-Stock Point-Optimal (ERSPO) test and find that the calculated P-stat is more than the critical values at 1% level of significance and hence we fail to reject the null hypothesis of unit root for all the Asian stock markets. Table 3, Panel C: shows the Ng-Perron Unit root test results for the sub-sample pre-crisis period (2008-2015) and we find the four MZ_a, MZ_t, MSB, MPT test statistics to be more than the asymptotic critical values at 1% level of significance. Hence we accept the null hypothesis that the series has unit root for all Asian stock markets. Table 4 & 5 presents the critical values of different unit root tests at 1%, 5% and 10% level of significance.

Hence during the sub-sample period (2008-2015), we empirically find that the emerging Asian stock market series has unit root in both the intercept only and trend & intercept forms by six different Unit root tests employed in our analysis except for China market (ADF,PP,KPSS Test in Intercept form), Hongkong market (ADF test and PP test in Intercept and both trend & intercept forms, KPSS in Trend & Intercept form), Indian market (ADF test and PP test in trend & intercept form), Philippines market (ADF test and PP test in trend & intercept form) and Taiwan market (KPSS in Trend & Intercept form) where we find no unit root. Hence except for China, Hongkong, India, Philippines and Taiwan, we say that logarithm of daily Asian stock markets under consideration do follow random walk and hence are weak form efficient during the sub-sample period

(2008-2015).

Table 2. Unit root test results of Asian stock market indices

	INTERCEPT FORM					TREND & INTERCEPT FORM				
	ADF (t stat)	PP (Adj t stat)	KPSS (LM stat)	ERS DF GLS (t stat)	ERSPO (P stat)	ADF (t stat)	PP (Adj t stat)	KPSS (LM stat)	ERS DF GLS (t stat)	ERSPO (P stat)
	Panel A: Overall Sample Period (2001-2015)									
India	-0.6686	-0.7071	6.9499	1.2911	113.7101	-1.8303	-1.8075	1.1774	-1.7523	14.7139
China	-0.9057	-1.0096	2.6586	-0.8728	9.6323	-1.6067	-1.6951	0.5044	-1.2379	26.245
Hongkong	-1.2632	-1.2070	5.7984	-0.9068	9.3296	-2.8669	-2.7956	0.5988	-1.9762	11.7412
Taiwan	-2.0373	-2.0101	4.9117	-0.6371	13.2982	-2.9991	-2.9902	0.2477	*-2.9876* **	*5.1345***
Malaysia	-1.0598	-1.0275	7.2341	0.8187	80.9415	-2.4511	-2.5064	0.1821*	-2.4352	7.6952
Thailand	-1.5985	-1.6109	6.2809	0.8731	94.2809	-2.2521	-2.3584	0.4808	-1.8106	13.2938
Pakistan	-1.0775	-1.0857	6.3058	2.5605	296.6413	-1.4316	-1.5834	1.0752	-1.1257	35.5287
Srilanka	-1.7693	-1.7411	6.8613	2.2276	344.1819	-1.5177	-1.5875	0.6859	-0.9962	31.2771
Indonesia	-1.1549	-1.1398	7.4272	1.6192	200.4015	-1.7051	-1.5779	0.8607	-1.8387	12.1544
Philippines	-0.1966	-0.1034	7.2028	1.226	74.0855	-2.8192	-2.6829	0.2911	-1.7256	15.0223
	Panel B: Pre-Crisis Period (2001-2007)									
India	1.3665	1.2655	4.9426	2.6597	122.2662	-2.6494	-2.5425	0.8097	-0.4897	60.4641
China	1.5859	1.5129	1.4039	0.8276	39.7701	0.2784	0.2912	0.9649	0.6143	121.9516
Hongkong	0.7569	0.7221	3.8917	0.4105	25.7995	-2.2281	-2.2311	0.8667	-0.2629	68.5145
Taiwan	-1.1062	-1.2441	3.8062	-0.2091	16.3461	-2.6149	-2.8317	0.3352	-2.3165	8.5275
Malaysia	0.2093	0.3388	4.5508	1.4335	51.7996	-2.1837	-2.1554	0.4318	-1.4979	16.3092
Thailand	-1.0997	-1.1217	4.7145	1.0679	94.8652	-2.0929	-2.1149	0.6739	-2.0504	10.7944
Pakistan	-0.4247	-0.4759	5.2247	2.5974	317.2606	-1.9935	-2.3062	0.7419	-1.5666	18.0582
Srilanka	-1.2592	-1.2627	4.9515	1.6571	227.7765	-1.5525	-1.5651	0.7854	-1.7428	12.5173
Indonesia	0.7979	0.9348	5.0576	2.7781	164.3472	-2.3554	-2.3088	0.6012	-1.1072	26.1121
Philippines	0.3263	0.3891	4.4711	0.9305	39.77405	-2.2741	-2.2296	0.8598	-0.8822	39.3624
	Panel C: Crisis & Post-Crisis Period (2008-2015)									
India	-0.9656	-0.8323	3.6066	-1.0576	8.4014	*-3.2937* ***	*-3.1556****	0.2448	-1.1815	27.9071
China	*-2.8335* ***	*-2.8595****	*0.6298* *	-0.4077	48.7051	-2.4511	-2.4789	0.3851	-0.378	59.5483
Hongkong	*-2.5903* ***	*-2.5779****	1.5141	-1.2283	8.1276	*-3.4782***	*-3.4367***	*0.1539* *	-1.5045	19.3395
Taiwan	-1.6753	-1.6063	2.0622	-1.5903	4.8405	-2.4105	-2.3798	*0.1731**	-1.6018	17.8068
Malaysia	-0.6948	-0.6997	4.4943	-0.6494	18.0261	-2.6114	-2.601	0.3382	-1.0235	44.2122
Thailand	-0.7369	-0.7563	4.533	-0.4931	19.4243	-2.3861	-2.4124	0.3344	-1.2115	31.5152
Pakistan	0.6317	0.4397	4.6636	0.8334	45.9403	-2.5826	-2.7011	0.7641	-0.4842	83.1065
Srilanka	-0.9854	-0.9353	3.7741	0.8509	105.8695	-0.9325	-1.0413	0.7996	-0.9916	42.2566
Indonesia	-0.7814	-0.7003	4.5384	-0.2899	23.9136	-2.2325	-2.1275	0.4437	-1.3656	24.4906
Philippines	-0.2898	-0.1035	5.158	0.1913	33.0413	*-3.5848***	*-3.6846* **	0.2799	-1.1307	35.3803

ADF -Augmented Dickey-Fuller test , PP-Phillips-Perron test, KPSS-Kwiatkowski-Phillips-Schmidt-Shin test, ERS DF GLS - Dickey-Fuller GLS (ERS) test, ERSPO - Elliot-Rothenberg-Stock Point-Optimal test. * means significant at 1 %, ** means significant at 5%, *** means significant at 10% . **Source:**Developed by authors.

Table 3. Ng Perron unit root test results of Asian stock market indices

	INTERCEPT FORM				TREND & INTERCEPT FORM			
Panel A: Overall Sample Period (2001-2015)								
	MZa	MZt	MSB	MPT	MZa	MZt	MSB	MPT
India	1.0000	1.2929	1.2929	112.3080	-6.1922	-1.7526	0.2830	14.7142
China	-2.2508	-0.8727	0.3877	9.6283	-3.3450	-1.2375	0.3700	26.1663
Hongkong	-2.3757	-0.9067	0.3816	9.2919	-7.8143	-1.9744	0.2527	11.6679
Taiwan	-1.3946	-0.6376	0.4572	13.1596	-17.933 **	-2.985 **	0.166 **	5.137 **
Malaysia	0.7332	0.8134	1.1094	79.9309	-12.2027	-2.4294	0.1991	7.6974
Thailand	0.7244	0.8735	1.2059	92.9983	-6.9159	-1.8092	0.2616	13.2467
Pakistan	1.2385	2.5659	2.0717	291.7130	-2.5582	-1.1263	0.4403	35.4456
Srilanka	0.9751	2.2341	2.2911	335.8510	-2.5508	-0.9980	0.3913	31.0746
Indonesia	0.9228	1.6178	1.7533	197.3220	-7.7115	-1.8355	0.2380	12.1549
Philippines	1.2239	1.2262	1.0018	73.3691	-6.1017	-1.7265	0.2830	14.9242
Panel B: Pre-Crisis Period (2001-2007)								
India	2.2608	2.6803	1.1856	120.3320	-0.9180	-0.4880	0.5316	58.4678
China	1.1711	0.8282	0.7072	39.6949	0.8620	0.6151	0.7136	120.0310
Hongkong	0.7291	0.4108	0.5634	25.7888	-0.4707	-0.2623	0.5573	66.8664
Taiwan	-0.4531	-0.2090	0.4613	16.0729	-10.9057	-2.3098	0.2118	8.4881
Malaysia	1.8929	1.4440	0.7628	50.9221	-5.5295	-1.4970	0.2707	16.1031
Thailand	0.9085	1.0691	1.1768	92.4558	-8.4783	-2.0459	0.2413	10.7952
Pakistan	1.2143	2.6000	2.1412	309.5420	-5.0541	-1.5647	0.3096	17.9194
Srilanka	0.8958	1.6640	1.8576	219.3190	-7.5837	-1.7494	0.2307	12.4934
Indonesia	1.9707	2.7940	1.4178	160.9240	-3.1648	-1.1092	0.3505	25.6123
Philippines	1.3589	0.9375	0.6899	39.3655	-2.0024	-0.8808	0.4399	38.5241
Panel C: Crisis & Post-Crisis Period (2008-2015)								
India	-2.8017	-1.0605	0.3785	8.4001	-3.1522	-1.1831	0.3753	27.2940
China	-0.4215	-0.4075	0.9667	47.2739	-0.7253	-0.3775	0.5205	58.1713
Hongkong	-3.0756	-1.2276	0.3991	7.9465	-4.7579	-1.5027	0.3158	18.9156
Taiwan	-5.0816	-1.5900	0.3129	4.8323	-5.1644	-1.6020	0.3102	17.6256
Malaysia	-1.1342	-0.6542	0.5768	18.0165	-2.0976	-1.0239	0.4882	43.4345
Thailand	-0.8544	-0.4931	0.5772	19.3366	-2.9342	-1.2107	0.4126	31.0398
Pakistan	1.0775	0.8369	0.7767	45.6502	-0.7562	-0.4848	0.6411	80.3886
Srilanka	0.6649	0.8513	1.2804	102.5770	-2.0753	-0.9892	0.4767	42.2352
Indonesia	-0.4698	-0.2946	0.6272	23.6836	-3.7523	-1.3659	0.3640	24.2308
Philippines	0.2758	0.1926	0.6982	32.7648	-2.6105	-1.1303	0.4330	34.4741

* means significant at 1 %, ** means significant at 5%, *** means significant at 10% . **Source:** Developed by authors.

Table 4. Critical values of ADF, PP, KPSS, ERS DF GLS, ERSPO Unit tests during different sub sample periods

		INTERCEPT FORM					TREND & INTERCEPT FORM				
		ADF (t stat)	PP (Adj t stat)	KPSS (LM stat)	ERS DF GLS (t stat)	ERSPO (P stat)	ADF (t stat)	PP (Adj t stat)	KPSS (LM stat)	ERS DF GLS (t stat)	ERSPO (P stat)
Overall Sample Period (2001-2015)	1% level	-3.431	-3.433	0.739	-2.565	1.990	-3.960	-3.960	0.216	-3.480	3.960
	5% level	-2.862	-2.862	0.463	-1.940	3.260	-3.411	-3.411	0.146	-2.890	5.620
	10% level	-2.567	-2.567	0.347	-1.616	4.480	-3.127	-3.127	0.119	-2.570	6.890
Pre- Crisis Period (2001-2007)	1% level	-3.433	-3.433	0.739	-2.566	1.990	-3.963	-3.963	0.216	-3.480	3.960
	5% level	-2.862	-2.862	0.463	-1.941	3.260	-3.412	-3.412	0.146	-2.890	5.620
	10% level	-2.567	-2.567	0.347	-1.616	4.480	-3.128	-3.128	0.119	-2.570	6.890
Crisis & Post-Crisis Period (2008-2015)	1% level	-3.433	-3.433	0.739	-2.566	1.990	-3.962	-3.962	0.216	-3.480	3.960
	5% level	-2.862	-2.862	0.463	-1.940	3.260	-3.412	-3.412	0.146	-2.890	5.620
	10% level	-2.567	-2.567	0.347	-1.616	4.480	-3.128	-3.128	0.119	-2.570	6.890

ADF -Augmented Dickey-Fuller test , PP-Phillips-Perron test, KPSS-Kwiatkowski-Phillips-Schmidt-Shin test, ERS DF GLS - Dickey-Fuller GLS (ERS) test, ERSPO - Elliot-Rothenberg-Stock Point-Optimal test.
Source: Developed by authors.

Table 5. Asymptotic critical values of MZa, MZt,MSB,MPT tests of Ng-Perron unit root tests

	INTERCEPT FORM	TREND & INTERCEPT FORM
During all Sample Periods	1% -13.8000, -2.58000, 0.17400, 1.78000	1% -23.8000, -3.42000, 0.14300, 4.03000
	5% -8.10000,-1.98000, 0.23300, 3.17000	5% -17.3000, -2.91000, 0.16800, 5.48000
	10% -5.70000, -1.62000, 0.27500, 4.45000	10% -14.2000, -2.62000, 0.18500, 6.67000

Source: Developed by authors.

6. Conclusion

This paper examines empirically on whether the important emerging Asian stock markets follow random walk or not. A market will be weak form efficient if the stock markets follow random walk. We performed six different unit root tests in intercept as well as trend & intercept forms of unit root equations on 10 emerging Asian stock markets for different time periods to carry out the robustness check in our analysis. The analysis of random walk tests at different time periods before and after the global financial crisis 2008 is particularly relevant to understand how the Asian stock markets movements have been impacted by the crisis.

Our empirical findings show that firstly, during the overall sample period (2001-2015) except for Malaysia and Taiwan stock markets, the test results find the evidence of unit root i.e. random walk movement in 8 Asian stock markets. Hence 8 out of 10 Asian stock markets are weak form efficient during the period 2001-2015. Secondly, during the sub-sample pre-crisis period (2001-2007), our test results show that all the 10 Asian stock markets has unit root in the series. Hence we find all the 10 Asian stock markets are weak form efficient and follow random walk. Thirdly, during the crisis & post-crisis period (2008-2015) except for China, Hongkong, India, Philippines and Taiwan, we find the presence of unit root for the rest of the markets. Hence only 5 out of 10 Asian stock markets are weak form efficient and follow random walk. Thus in our analysis we find evidence that global financial crisis does had an impact on the movement of important Asian stock market prices.

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