ARTHAVAAN
Volume 1, Number 1, 2015 pp. 51-57

http://www.bharaticollege.com

Empirical Test of the Random Walk Characteristics of the Stock Returns of Select South Asian Markets

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Abstract: **The present study is an attempt to test Random Walk Hypothesis on three prominent South Asian Markets viz. India, Pakistan and Sri Lanka. The monthly log returns data for these markets has been analyzed for a ten year period viz. April 1, 2005 to March 31, 2015 to test the hypothesis. Both Parametric and Non Parametric tests have been employed for testing this hypothesis, these include the Augmented Dickey Fuller test which checks for the stationarity of time series, the Box Pierce 'Q' statistics, Ljung – Box (LB) test, turning point test & the difference of the runs test. The results of these techniques give a mixed picture about the randomness of the stock indices i.e. whereas the parametric tests like the Unit root test reject the random character of the indices, the non-parametric tests like difference of the runs test or the turning point test could prove two of the three markets as random.**

Keywords: **ADF test, Random Walk, Turning point, Box Pierce 'Q', Ljung – Box (LB) Statistics**

1. INTRODUCTION

The concept of randomness or Random Walk has been of interest to researchers in different fields including physics, chemistry, psychology, economics, finance etc. Whereas researchers in science may be interested in knowing path traced by a molecule, those in economics and finance are more concerned with the movement of the stock prices. Perhaps the simplest definition of a Random Walk is the absence of serial correlation between stock prices of two time intervals. This is also what the market efficiency means and the two terms are often used interchangeably.

Amongst the earliest works which laid the foundation of market efficiency could easily be dedicated to Bachelier (1900) who recognized this aspect by using Brownian Motion. Thus his dissertation in Mathematics was one of the earliest research works to have recognized the concept that stock prices reflect all available information, however the world could only know of his contribution sixty years later when his works were translated in English & published in Paul Cootner's ; *The Random Character of Stock Market Prices* (1964). The concept of Random Walk also got a big boostwhen the theory of Efficient Market Hypothesis was formulated by Fama (1970), Fama also discussed the three layers of this hypothesis i.e. the weak, semi strong and strong forms. It is important to mention that the term Random Walk Hypothesis was actually given by Kendall (1953); this was however eventually confirmed by Fama (1965) through a comprehensive study of stock prices.

2. NEED & SCOPE OF STUDY

The present study is an attempt to test random walk hypothesis of three major South Asian Markets namely India, Pakistan & Sri Lanka.We have chosen the three major indices Bombay Stock Exchange's Sensex , Karachi Stock Exchange's KSE 100 & and Colombo's CSE ASPI Index.

The Time Period of our study is ten years, April 1, 2005 – March 31, 2015. The month-wise closing data has been collected for the aboveindices for the sampled period. To test the hypothesis of random walk, both Parametric and Non Parametric tests have been employed. For applying the various tests, the data on monthly closing prices has been converted to log returns by applying the following formula $\ln (P_t/ P_{t-1})$, where P_t is the index at time t &P_{t-1} is the index at time t-1. The sources of data from where information has been collected include the websites: *www.bseindia.com, in.finance.yahoo.com,,www.kse.com,www.cse.lk.*

3. LITERATURE REVIEW

Random Walk Hypothesis is one of the most extensively research areas in the field of finance. Research in this area has been carried out on most of the developed as well as emerging markets for which data is available over a period of time *Sunal G et.al (2014)* tested weak form market efficiency of Indian Stock Markets using unit root testing, the runs test & the day of the week effect. The results gave mixed picture on weak form of market efficiency; the hypothesis was rejected when Unit root test was employed but the Day of the week test was however not proved i.e. return for none of the days was

significantly different from other days which suggested some form of efficiency in Indian Markets.*Surbhi et.al (2014)* made an attempt to investigate to test the market efficiency of BSE Sensex by using the 'day of the week 'effect & followed Dummy Variable Approach. The results showed insignificant difference in the 'day-wise' returns thereby making a somewhat case for market efficiency.*Arora H (2013)* carried out the unit root test to test weak form of efficiency of Indian Markets.The results gave some positive signals that Indian Markets did behave randomly *Nikunj R. Patel, Nitesh Radadiaand Juhi Dhawan (2012)* tested the market efficiency in weak-form for 11 year period. The markets chosen were select Asian markets (BSE, HANGSENG, NIKKEI and SSE), the tests used were unit root, auto-correlation and variance ratio test. The results showed mixed picture in terms of observation of weak-form of efficiency for all the markets under study. *Chiwira Oscar and Brian Muyambiri (2012)* studied random walk in the Botswana Stock Exchange; the results however rejected the random walk hypothesis**.** *Gupta, R., & Basu, P. K. (2011).* Used Unit root, PP & KPSS tests on two major indices of India to test the weak formefficiency. The results of all the tests were quite similar in terms of the results of markets not being efficient, thus random walk was rejected*Nikunj R. Patel, Bhavesh K. Pate& Darshan Ranpura (2011)* could not get a correct picture about the random walk hypothesis and were getting contradictory results during different time frames for which the study was conducted. The markets under study were NSE & BSE of India and the period of study was 1998-2010.

The test used were Unit Root, runs test & autocorrelation tests. *Gimba Victor K (2011)* carried out his study for a smaller three year period Jan 2007 to Dec 2009 (daily data) & again on weekly data for the period June 2005-Dec 2009. The market chosen by him was Nigerian Stock Exchange & the results proved that this market was not efficient in weak form or the random walk was rejected. *Worthington Andrew C. and Helen Higgs (2004)*carried out their research on European and Emerging Markets and found that only one emerging market was weak form efficient. *Charles A and O. Darne (2009)*applied different variance ration tests to test the Random Walk of two Chinese indices and the results showed that Class A shares only followed random walk , however the Class B Shares which were less efficient were showing some improvement in efficiency after the re-entry of domestic investors and banks *Madhusoodanan (1998)* used variance ratios to test the mean reversion behaviour of the Indian Markets The results showed positive autocorrelations at different lags indicating long-term mean reversion , further the variance ratio could not prove the random walk of the market , the same result was proved at the individual stocks levels which also showed significant autocorrelations *Liu Bin (2003)*carried out his study on Shanghai Stock Exchange (1996-2002) & concluded that unsystematic risk affected the returns .Moreover he could not find any linear relation between stock betas and their returns. *Smith Graham and Hyun-Jung Ryoo (2003)*tested the hypothesis of Random Walk on five different European emerging markets & the methodology applied was multiple variance ratio test. The hypothesis could not be accepted in four of these five markets which were studied. *ChaudhuriKausik& Yangru Wu (2003*) studied seventeen emerging markets for this hypothesis; however their hypothesis also incorporatedstructural breaks from linearity in time series for these markets. The results (ten of the 14 markets were rejected for Random Walk) were considered superior to those studies which could not incorporate this aspect. *Abraham A, J, Seyyed and S.K.Alsakaran (2002)* tried to apply the RWH in three Gulf Markets the Saudi, Kuwait and the Bahrain exchanges using Variance ratio and non-parametric tests, however the in frequent trading in these markets could not justify the conclusions drawn that the markets were inefficient . Once the corrective steps were taken by using Beveridge Nelson (1981) decomposition of index returns into permanent and cyclical movements, superior results emerged from these markets *Ayadi, O. F and C.S. Pyun (1994)* applied the Lo & Mac Kinlay Variance Ratio test (1988) to Korean Markets. Since the test has two parts, one which assumes homoscedasticity of residuals and second which does not, their results showed the hypothesis of Random Walk was rejected for daily stock prices but for the second part the RWH was not rejected for daily data. Also the hypothesis could reflect the randomness for a longer time horizon (longer than the daily data).*Lo & Mac Kinlay (1988)* used volatility based specification test (popularly known as the variance ratio test) and applied it to weekly data from US NYSE and found that correlations of returns were positive, however the opposite picture was also not found to be absolutely true i.e. the mean reversion seen in case of a pure stationary process could also not be proved through their study.

4. METHODOLOGY ADOPTED

We test the Random Walk Hypothesis using parametric and non-parametric tests. Whereas the parametric tests would assume a standard model structure or probability distribution, the non-parametric tests are distribution free tests or make no assumptions about the underlying distributions.

5. PARAMETRIC TEST: METHODOLOGY ADOPTED

Augmented Dickey Fuller Test

The Unit root Dickey Fuller stationarity tests is one of the most celebrated tests and commonly applied to test whether our time series follows a random walk.

Steps

First the monthly natural log return on the chosen index is computed for the entire period of study (April 1, 2005 – March 31, 2015)

i.e. $r_t = (\ln p_t - \ln p_{t-1})$ .....eq(i)

Random walk Hypothesis tracksthe following model

$$lnP_t = ln\ P_{t-1} + u_t \quad \ldots\ldots \quad eq\ (ii)$$

to test this hypothesis we usually employ ADF test by transforming the linear model to first difference model and the three indices for which we are testing this model are given as under (eq iii to v):-

$$\Delta\ Ret\ Sensex_t = \beta_1 + (\beta_2 - 1)\ Ret\ Sensex_{t-1} + \beta_3\ \Delta\ Ret\ Sensex_{t-1} + u_{1t} \ldots\ldots \quad eq(iii)$$

$$\Delta\ Ret\ KSE_t = \delta_1 + (\delta_2 - 1)\ Ret\ KSE_{t-1} + \delta_3\ \Delta\ Ret\ KSE_{t-1} + u_{2t} \ldots\ldots \quad eq(iv)$$

$$\Delta\ Ret\ CSE\ ASPI_t = \gamma_1 + (\gamma_2 - 1)\ Ret\ CSE\ ASPI_{t-1} + \gamma_3\ \Delta\ CSE\ ASPI_{t-1} + u_{3t} \ldots \quad eq(v)$$

(Δ Ret Sensex $_t$ is change in Sensex return in time t, Δ Ret KSE $_t$ is change in Ret on KSE 100 in time t & Δ Ret CSE ASPI $_t$ is change in return of CSE ASPI in time t, Δ Ret Sensex $_{t-1}$ is change in Sensex return in time t-1 is the augmented variable which has been added to take care of autocorrelation.Similarly Δ Ret KSE $_{t-1}$ is change in Ret on KSE 100 in time t-1 & Δ Ret CSE ASPI $_{t-1}$, u $_t$ is random error term.)

The testable hypothesis (H_0) would be

$\beta_2 - 1 = 0$ 0r $\beta_2 = 1$ (the stock returns follow a random walk)

Alt Hyp (H_a): $\beta_2 - 1 \neq 0$, (stock returns do not follow random walk)

2. Box Pierce 'Q' statistics (or the Autocorrelation Test)

We use the Box Pierce 'Q' statistics (1970) and its modified version Ljung – Box (LB) (1978) statistics to test whether our returns are randomly distributed or not.It simply is a test which checks whether autocorrelation between return residuals and lag return residuals (upto certain lag) is zero. If proved then series is random.

Null Hypothesis (H_0): Time series is random.

Alt Hypothesis (H_a): Non Random time series

2. Box Pierce 'Q' statistics has the following formula:

$\mathbf{Q_m = n\sum_{k=1}^{m} \rho_k^2}$ follows Chi Square Statistics with 'm' degrees of freedom.

3. Ljung – Box (LB) Statistics:

This is a Modified Version of 'Q' Statistics and is given by

$\mathbf{LB = (n+2)\ n\ \sum_{k=1}^{m}(\rho_k^2/\ n-k)}$, also follows Chi Square with 'm' degrees of freedom.

Non Parametric tests: Methodology Adopted

1. Runs Test of Successive Differences

A Run (r) is a sequence of alternate signs and in our case we carried out this test on stock returns e.g. if in a return for a week , the return is '+' on Monday, '-' on Tues & Wed , '+' on Thursday & Friday , the total no. of runs (r) is 3

Null Hypothesis (H_0): Observations are Random.
Alt Hypothesis (H_a): Non Random Nature of Observations

We can construct the two critical values of upper and lower limit using normal distribution as

$$(C1) = \mu - 1.96\ \sigma\ \&(C2) = \mu + 1.96\ \sigma,$$

where μ is defined here as ***(2n-1)/3***& σ is defined as $\sqrt{(16n-29)/90}$

(Runs test of successive differences is non parametric test as parameters do not assume that the positive and negative 'runs' have equal probabilities of occurring. However the test does assume that these 'runs' are independent and their distribution is identical) .

2. Turning Point (Trough &Peak) Test for randomness:

Turning Point test is one of the earliest tests to be used for randomness of a variable. It was first published in 1874 and the credit goes to Bienayme Irenee Jules (1874).

A turning Point is a value which is either lower than both preceding and succeeding observations (called trough) or is higher in value than both preceding and succeeding observations (called Peak) . Here sum of the total no. of peaks and trough shall be the turning point ***(p)***.

The Null Hypothesis (H_0): Variation in time series is independent (or Series is random).

Alt Hypothesis (H_a): Non Random time series

For 'n'>30, the turning points are expected to be normally distributed therefore we can easily apply 'Z' test &

'z' statistic shall be $\left|\frac{p-\mu}{\sigma}\right|$

(Mean is defined as $= \frac{2}{3}$ ***(n-2), n is no. of observations and standard deviation defined as*** $= \sqrt{\frac{16n-29}{90}}$ ***)***

(Turning Point Test is non parametric test as parameters have not been defined strictly according to established principles)

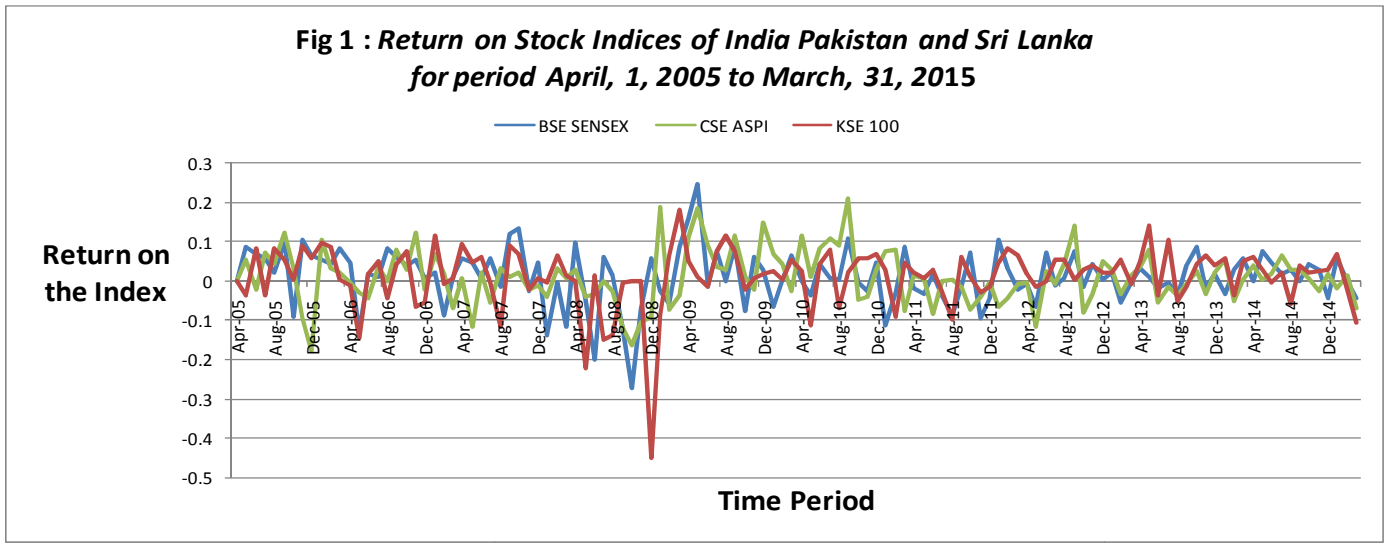
6. RESULTS AND DISCUSSION

The results of our study are divided into three segments, the first segment deals with the Statistical Description of the Returns for all the three indices (Table 1), second deals with the comparative analysis of the movement of the indices (Fig 1) while the third segment discusses the results of testing of the Random Walk Hypothesis on South Asian Markets (Table 3 to 7).

Statistical Description of monthly ln returns of the three stock indices (India, Pakistan & Sri Lanka) for the period April 1, 2005 –March 31, 2015 is given in table 1 below :-

TABLE 1: Statistical Description of data for the period April 1, 2005 – March 31 2015

Stock Index	BSE Sensex	Karachi Stock Exchange KSE 100	Sri Lanka's Colombo Exchange
No. Of Observations	119	119	119
Mean	0.012718583	0.01216986	0.011057151
Median	0.01443858	0.020782511	0.010243615
Skewness	-0.607676516	-2.364806917	0.230132832
Kurtosis	2.570564106	11.62040678	0.771226187
STD Dev	0.070849847	0.075299675	0.068254629
Variance	0.005019701	0.005670041	0.004658694
JB *	**8.238261809**	**479.3749393**	**25.68058273**



$$JB = \frac{n}{6}\left(S^2 + \frac{1}{4}(K-3)^2\right)_*$$

7. TEST FOR NORMALITY OF RETURNS

Since calculated value of JB > 5.99 for all the stock returns , all the variables under consideration Return on Sensex, KSE 100 & CSE ASPI do not appear to be normally distributed (Null Hypothesis of normality of returns is rejected)

b. Movement of the Returns on the three indices of South Asia; India's (BSE Sensex), Pakistan (KSE 100) & Sri Lanka's (CSE ASPI) for the ten year period (April 1, 2005-March 31, 2015) is given in Fig (1) below. The figure shows that the Pakistan's KSE 100 is the most volatile of the three indices. KSE 100 had a period of high volatility during Oct 2008- May 2009. The CSE

ASPI on the other hand has shown the lowest volatility out of the three indices during the ten year period.

c) Results for testing of the Random Walk Hypothesis on South Asian Markets

Table No. 3 to 7 given below show the results of testing of the randomness of South Asian Markets. The different test Statistics used for this purpose are as under:-

i) ADF – Unit Root test

ii) Box & Pierce 'Q' Statistics

iii) Ljung – Box (LB) Test

iv) Turning Point Test

v) Runs Test of Successive Differences.

TABLE 3: Results for testing of the random walk (Unit Root : ADF Test)

Variable (Return on Indices)	N	Coeff	SE	$\|t_{cal}\|$	$\|t_{table}\|$	Randomness of Time Series (Yes / No)
		β_2-1	(β_2-1)		Dickey-Fuller	
BSE SENSEX	118	-0.90523	0.092245	9.81	2.89	No
KSE 100	118	-0.8725	0.092938	9.387966	2.89	No
CSE ASPI	118	0.82807	0.091832	9.017215	2.89	No

The absolute value of 't' statistics for the coefficient i.e. **β_2-1**(Table 3) is compared with Dickey Fuller table value which for '100' sample size is 2.89& '250' sample size is 2.88 (with constant term included) . Since our computed value (see Table 3) is higher than 2.89in all the three variables under study, we conclude that our variables are not random i.e. are Stationary. *This simply implies that our Null Hypothesis of β_2-1 =0 or that the variable follows a random walk is rejected in all the three cases.*

TABLE 4: Results for testing random walk (Box and Pierce Q Test)

Variable (Return on Indices)	n	Computed 'Q' Statistics	Chi Square with 'm' df	Randomness of Time Series (Yes / No)
SENSEX	119	54.64994843	11.07	No
KSE 100	119	20.17308469	11.07	No
CSE ASPI	119	79.57654105	11.07	No

Null Hypothesis (H_0): Time series is random.
Alt Hypothesis (H_a): Non Random Time Series

TABLE 5: Results for testing random walk (*Ljung – Box (LB)* Test)

Variable (Return on Indices)	N	Computed 'LB' Statistics	Chi Square with 'm' df	Randomness of Time Series (Yes / No)
SENSEX	119	58.67777226	11.07	No
KSE 100	119	22.03450659	11.07	No
CSE ASPI	119	85.09022598	11.07	No

Null Hypothesis (H_0): Time series is random.
Alt Hypothesis (H_a): Non Random Time Series

The table value of Chi Square distribution at 5 degrees of freedom (lag level selected) at 5 % level is 11.07, Since the computed value of 'Q' (Table 4) is higher than this value , we conclude that all our variables are non-randomwhen Box and Pierce 'Q' Test is applied.

On applyingLjung – Box (LB) Test of Randomness the result again showed acceptance of null hypothesis i.e. that all our variables are non-random(Table 5). The test also follows Chi Square distribution.

TABLE 6 : Results of Turning Point (Trough & Peak)Test for Randomness

Variable (Return on Indices)	N	P	Mean	Standard Deviation	$\|z_{cal}\|$	z_{table}	Randomness of Time Series (Yes / No)
SENSEX	119	83	78	4.56	1.096	1.96	Yes
KSE 100	119	66	78	4.56	2.631	1.96	No
CSE ASPI	119	75	78	4.56	0.657	1.96	Yes

The results of the turning point test (Table 6) show that two of our variables havetheir 'Z' computed values lower than 1.96 (Table value at 5 % level) , thereby proving that these two indices viz. Return on Sensex and Return on CSE ASPI are random .

TABLE 7: Results of the runs test of successive differences for testing the randomness of our sampled stock indices

Variable (Return on Indices)	N	No. of Runs	C1 = (μ – 1.96 σ)	C2 =(μ + 1.96 σ)	Randomness of Time Series (Yes / No)
BSE SENSEX	119	83	70.05386489	87.94613511	Yes
KSE 100	119	66	70.05386489	87.94613511	No
CSE ASPI	119	75	70.05386489	87.94613511	Yes

The results of the runs test of successive differences where the criteria is that no. of runs must lie between the two critical points , also gives similar results as given by earlier turning point test, i.e. only two indices viz. Return on Sensex and Return on CSE ASPI are found to be random.

8. CONCLUSION

The present study made an attempt to test the Random Walk Hypothesis on three prominent South Asian Markets viz. India, Pakistan and Sri Lanka by applying Parametric and Non Parametric teststo ten year ln returns on their indices for the period April 1, 2005- March 31, 2015. The findings of the study throw some interesting observations about the results.

It is interesting to find that whereas Unit Root Test & the Box Pierce 'Q' statistics & Ljung – Box (LB) test have shown that all the three indices do not follow random walk , the turning point test & the difference of the runs test show that two of the indices under study follow random walk.

It is not difficult to understand why the results are different. If we focus on our Unit Root test, the linear equation of these tests have been proved to be of low power against the alternative hypothesis of Stationarity or Mean reverting nature of the variables*(see Chaudhuri, K., & Wu, Y. (2003))*

The problem as identified is due to the structural change in the variables and if the test does not incorporate this aspect, there can be some doubts over the accuracy of the results. On the other hand the results of the non-parametric tests like turning point & difference of the runs do not suffer from these issues.Here one may again argue that results based upon parametric tests are always more reliable as they are more scientific and based upon the behavior of distributions; which although is true but again to get the best of parametric tests, one has to consider the resultswithin the framework of assumptions of the model. Therefore considering all the above aspects our study we have very little option but to put more weight on the results of the non-parametric tests and thereby conclude that two of our markets are random.

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