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Testing Weak Form Market Efficiency Of Indian Stock Markets

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Abstract

This paper examines the weak-form market efficiency of Indian stock markets namely Bombay Stock Exchange and National Stock Exchange for the period August 1998 to July 2010. The data is also divided into intervals of three years, to find out the weak form efficiency over periods. Daily returns are examined for random walks using Unit Root Test, Auto correlation and runs tests. From the Unit Root, It has been found that data is stationary. From the analysis of whole period, it is found that Autocorrelation prevails in the market. But in the Interval of three year data, significant Autocorrelation is found only in the period August 2001 to July 2004. But thereafter, market became random walk because no significant autocorrelation found after 2004. Runs Test conclude that the whole period null hypothesis of random walk was not accepted. In all months, null hypothesis is accepted of random walk except January month. But in all days random walk is prevailing. The period of 2004 to 2010 support weak form Market Efficiency.

Keywords: *Weak form Market Efficiency, Bombay Stock Exchange (BSE), National Stock Exchange (NSE), Autocorrelation test, Runs test*

1. Introduction

The Efficient Market Hypothesis has been a widely accepted phenomenon in the behavioral finance. Numerous studies have been carried out almost in every corner of the world for the validity of Efficient Market Hypothesis. It is usually believed that developed markets are more efficient than developing and underdeveloped market due to flow, adjustment and magnitude of information. There are two

aspects to the price adjustment to new information that is speed and quality of information (Chaudhuri, 1991). Efficient market is the one in which the available information is fully reflected in stock prices. This definition is referred to informational efficiency. This means no trading strategies can be used to predict the market prices and no one can earn abnormal returns. Investors used past price information to frame their investment strategies, but the question is ; To what extent can the past history of a common stock's price be used to make meaningful predictions concerning the future price of the stock? According to the theory, the successive price changes are independent and identically random variable. This implies the series of prices have no memory (Fama, 1965). Efficiency of equity markets has great implications to the policy makers and investors. Market efficiency is divided into three forms depending the set of information namely weak, semi-strong and strong form (1991). We have tried to find out the empirical evidences on weak form of market efficiency of two major indices of Indian stock market. Weak form of efficient market says that the current market price reflect all information contained in the historical prices of assets. The idea of random walk was first put forward by Jules Regnault in 1863 followed by Louis Bachelier in 1900.

Considering the extensive literature in India and abroad, we intend to test the weak form of market efficiency for Indian stock markets because of transformational change and economic reforms in the last couple of decades. The observations of the literature also motivate us to have a fresh look at weak form of Market efficiency of Indian Stock Market.

3. Objectives and Methodology

Although the literature on the Efficient Market Hypothesis is very rampant, most studies focus on daily data and some of the studies focus on weekly and monthly data to maintain data synchronization. Some researchers do pursue their analysis using high frequency data. A careful survey of the existing literature reveals conflicting evidence on weak-form market efficiency for many markets, depending on which test a particular study used, or which type of data the researchers employed. The results are also conflicting with different statistical tests. Thus, the question of whether or not Indian Stock Markets namely National Stock Exchange and Bombay Stock Exchange are efficient is best answered by a comprehensive and concurrent analysis of the standard tests

and various types of data available while using the largest possible sample sizes.

The main objective of this study is to examine whether the Indian stock markets are weak-form efficient over the defined period. Purpose of this study is also to find out whether Indian stock returns violate the random walk hypothesis, to determine whether the selected stock market exhibits a trend towards increased efficiency over time, to test random walk hypothesis for the days of the week returns, to test random walk hypothesis between the Month of the year returns. Daily data for two indexes using the longest possible sample sizes and various types of the statistical tests are employed to examine market efficiency into consideration. To examine whether the time series predictability in Indian stock returns, we have castoff several statistical tests including autocorrelation, runs test and unit root tests for null hypothesis of a random walk. For doing so, we have divided the whole period in four sub periods.

4. Data

To examine Indian market efficiency, the data used in this study are daily price index data for Indian stock exchanges in BSE Sensex and CNX Nifty. The data of daily price indices are collected from the Ace Equity database software and the observation period is from August 1, 1998 to July 30, 2010.

5. Descriptive Statistics

A summary of descriptive statistics of both stock Market indices for the entire sample period August 1998 to July 2010 are presented in Table 1. From the Table 1, it can be seen that both indices have positive mean returns. The returns in both the market are almost same. The lowest minimum returns are in CNX Nifty and the highest maximum returns are in CNX Nifty with lower amount of standard deviation. The standard deviation of returns in BSE Sensex is marginally higher as compared to that of CNX Nifty.

The kurtosis or degree of excess, in all index returns is also considerably smaller, 8.43047 and 9.54567 for BSE Sensex and CNX Nifty respectively. The positive value indicates that the data is clustered around the center, and that the curve is highly peaked, thereby indicating leptokurtic distributions. The calculated Jarque-Bera statistics and corresponding p-values in Table 1 are used to test the null hypotheses that the daily distribution of BSE Sensex and CNX Nifty markets returns is normally distributed. All p-values are smaller than the 1 percent level of significance suggesting the null hypothesis cannot be accepted. Therefore,

none of these return series is then well approximated by the normal distribution.

As can be seen in Table 1, the skewness and kurtosis values indicate that returns of both indices are not normally distributed as consistent with Jarque-Bera statistics. Returns of both indices are negatively skewed or skewed to the left, this indicates, there is greater probability of large deceases in returns than rises. CNX Nifty has the highest negative value of skewness, while BSE Sensex has relatively lower. The evidence of negative skewness for all return series in both stock markets indices returns are similar to earlier findings of Huang (1995) in nine Asian stock markets, Gilmore and Worthington and Higgs (2004) in sixteen developed markets and four European emerging stock markets.

Table 2 portrays a descriptive statistics of month wise index returns of BSE and NSE. From table-2, it can be seen that in the month of November and December, the returns in both the markets are highest followed by September and October. The standard deviation is also moderately high in the same months. In the month of July, the returns in both the markets are lower with moderately lower standard deviation. The skewness is positive in all months except in the months of December. Returns of both indices are positively skewed or skewed to the right, indicating greater probability of large increases in returns than decreases except in the month of December. These results are contradicting as compared to the total observations. The calculated Jarque-Bera statistics and corresponding p-values in Table 1 are used to test the null hypotheses that the daily distribution of both stock market indices normal distribution. All p-values are smaller than 1 per cent level of significance suggesting the null hypothesis cannot be accepted. Therefore, none of these months in both stock market return series is then well approximated by the normal distribution. The investments in the month of September in CNX Nifty is better because return per unit of Standard deviation is highest, whereas the same is lower in January Sensex Returns.

6. Unit Root

Since a unit root is a necessary condition for a random walk, to test the null hypothesis of unit root, the Augmented Dickey-Fuller test and Phillips-Perron test were used. The results of ADF and PP test for a unit root of both market indices are presented in Table 3. ADF and PP unit root test were performed for the whole sample period August 1998 to July 2010 and all sub periods. ADF and PP Test were performed for the maximum lag period of 28.

The t statistics at 1%, 5% and 10% are -3.433046, -2.862617 and -2.567389 respectively and it clearly showed the stationary data series. The null hypothesis of a unit root is not accepted at the 1%, 5% and 10% level of significance. The result therefore indicates that there exists some evidence of random walk in both indices.

The t statistics at 1%, 5% and 10% are -3.433046, -2.862617 and -2.567389 respectively and it clearly showed stationary in all sub period. The null hypothesis of a unit root is not accepted at the 1%, 5% and 10% level of significance. The result therefore indicates that there exists some evidence of random walk in both indices in each of the periods.

Based only on unit root tests, it cannot be concluded that both stock markets indices are weak-form efficient, since the ADF and PP unit root test only examine the existence of stochastic trend components, but does not detect the predictable power in returns. Whether both stock market indices violate the random walk hypothesis is needed to examine further.

7. Auto Correlation Test

As noticed in the literature, Auto correlation test is the most commonly used tool to test weak form efficiency. Autocorrelation test measures the correlation between series of returns and lagged series and tested whether the correlation coefficients are significantly different from zero. This means the returns of both stock markets are tested whether returns can be characterized by serial dependence.

The results of the first ten sample autocorrelation coefficients and Ljung-Box statistics of both indices for the full sample period 1998-2010 are presented in Table 5.

Ho = No Significant auto Correlation at lag (n).

H1 = Significant auto Correlation at lag (n).

Table-5 provides the results of the sample autocorrelation coefficients and the Ljung-Box statistics for the daily returns on the indices for BSE Sensex and CNX Nifty markets for the full sample period 1998-2010. All returns are compounded continuously. ρk is the sample autocorrelation coefficient at lag k. Q(1) to Q(10) are the Ljung-Box statistic identifying the presence of first to tenth-order autocorrelation. Under the null hypothesis of no autocorrelation (Hin Yu Chung, 2006), values in parentheses are p-values.

The autocorrelation coefficient at lag one seems similar in BSE Sensex and CNX Nifty, 0.063 and 0.062 respectively. Both market indices under study shows significant positive autocorrelation at a lag

of one period for return series in both stock markets indices. For higher-order autocorrelation lag 10, all return series also show a consistent pattern of positive autocorrelation. Positive autocorrelation indicates predictability of returns in short horizon, which is the general evidence against market efficiency.

On the other hand, the presence of negative autocorrelation indicates mean reversion in returns series, with mean reversion being higher in both markets. BSE Sensex appears the significant negative autocorrelation at lag 2, 3, 5 and 6. CNX Nifty index also shows significant negative autocorrelation at lag 2, 5 and 6.

Ljung-Box statistics provide evidence of possible serial dependence in the first and higher moments of the return distributions. Looking at the Ljung-Box Q-statistics, the null hypothesis of no autocorrelation is not accepted for all returns on BSE Sensex and CNX Nifty index at lag 1 through 10 at the 1% level of significance.

The results of autocorrelation test are also consistent with the previous findings in emerging markets, Harvey (1995), Poshakwale (1996), Mobarek and Keasey (2002), Hassan et al. (2006). They have found significant presence of strong autocorrelation in the emerging stock market returns, which indicate the presence of various imperfections in the functioning of these markets and predictive power. Using autocorrelation, we found the significant coefficients particularly high at lags end for both market index returns. This may suggest that the historical information entrenched in longer period of lags would be as persuasive in determining the future price as that of information entrenched in longer lag lengths. These results clearly show the evidence of linear dependence in both markets indices for the full sample period 1998-2010.

Table – 6 provides the results of the sample autocorrelation coefficients and the Ljung-Box statistics for the daily returns for the four periods of BSE Sensex and CNX Nifty markets. All returns are compounded continuously. ρk is the sample autocorrelation coefficient at lag k. Q(1) to Q(10) are the Ljung-Box statistic identifying the presence of first to tenth-order autocorrelation. Under the null hypothesis of no autocorrelation, values in parentheses are p-values.

Table-6 provides the results of the ACF statistic and Ljung-Box Q-statistics test for the four sub-periods i.e. August 1998 to July 2001, August 2001 to July 2004, August 2004 to July 2007 and August 2007 to July 2010. Before 2001, returns on both markets indices no significant

autocorrelation coefficients at all lags for both the markets. In the second period shows significant autocorrelation at almost all lags for both markets, mostly at the 1% level significance, except lag 1 and lag 3 in BSE Sensex at 10% and 5% level of significance respectively. In the Third period, null hypothesis is accepted for BSE Sensex at all level except lag 1, 2 and 6 at 5% and 10% level of significance which indicates there is no autocorrelation in general. But in NSE, the null hypothesis is accepted at 10% level of significance. Both the market indices show no sign of autocorrelation in general. The finding here indicates that in the period 2004 - 2007, both markets have become more efficient. In the final period, the null hypothesis of no autocorrelation in both market indices is accepted at 1% level of significance. At 5% level of significance, both market indices indicate no autocorrelation, except BSE Sensex at lag 1, 8, 9 and 10. The null hypothesis of Autocorrelation of NSE at all lags except lag 8, 9 and 10 is not accepted at 5% level of significance. This indicates market do not follow random walk in the period August 2001 to July 2004. From the above table, it can be seen that prior to 2001, market did not have autocorrelation. NSE seems to be more efficient than BSE Sensex at all periods. In the period August 2004 to July 2007, NSE was more efficient than BSE Sensex.

8. Runs Test

A runs test is another common approach used in literature to test for statistical independencies, but dissimilarity of autocorrelation coefficient is that it does not require normally distributed returns. A run can be defined as a subsequent change of consecutive price with the same sign. This means the direction of change in the price will be repetitively. The runs test is a non-parametric test. If the expected number of runs is close to the observed number of runs, then the series will be random. Consequently, it tests whether returns in both stock markets under study are predictable. The null hypothesis of randomness is tested by observing the number of runs for successive price changes.

The results of the runs tests for returns on both indices are presented in Table-7. For the full period, the runs test clearly shows that both stock market indices are weak form inefficient. All of the estimated Z-values are significant at the 1%, 5% and 10% level. The significant negative Z-values and p-value for full period returns on both indexes indicate that the actual number of runs falls short of the expected number of runs under the null hypothesis of return independence. Alternatively, the

negative Z values for returns on all indexes are indication of positive autocorrelation, which is also consistent with the results from autocorrelation tests.

January and November are the months in which both market indices indicate the weak form of market inefficient. The null hypothesis is not accepted at 5% level of significance of independence. In the month of May and October, only CNX Nifty shows the inefficiency of weak form at 5% level of significance. But in the month of November, BSE Sensex shows the weak form of inefficiency at 5% level of significance. In all other months i.e. February, March, April, June, July, August, September and December support weak form of efficiency at 1%, 5% and 10% level of significance which indicates both market indices under study support weak form market efficiency.

The results of the runs tests for day of the week on both indices are reported in Table - 8. For the each of the day, the runs test clearly shows that both stock market indices are weak form efficient. All of the estimated Z-values are insignificant at the 1% and 5% level of significance and the null hypothesis of return independence is accepted in all days from Monday to Friday. BSE Sensex on Friday is significant at 10% level of Significance which indicates inefficiencies on Friday in BSE Sensex.

The results of Sub Period indicate in table – 9 both the market after August 2004 became efficient in weak form. In the first period of 1998-2001, BSE Sensex do not support weak form and null hypothesis cannot be accepted at 10% level of Significance whereas CNX Nifty do not support weak form at 5% and 10% level of Significance. It is quite notable that from the period 1998 to 2004, stock market indices under study were inefficient and did not support weak form efficiency. The results are also consistent with auto correlation, which showed autocorrelation in the second period of 2001-2004.

Conclusion

The returns in both the markets are highest in November and December followed by September and October. The overall results from the empirical analysis suggest that the Indian Stock Markets are not weak form efficient for the whole period. However, the results of interval periods of three years indicate the weak form market efficiency after August 2004 which is consistent with Autocorrelation and Runs Test. For the whole period of 1998 to 2010, it is found that there is significant autocorrelation, which indicate weak form of inefficiency. It can also be observed from the autocorrelation test that in the

period of August 2001 to July 2004 and August 2007 to July 2010, market was weak form of inefficient, but in the periods August 1998 to July 2001and August 2004 to July 2007, market was in weak form efficient. Runs Test is also consistent with Autocorrelation Test which indicates that both markets are in weak form of inefficient in whole period. But in sub-period, it can be observed that after August 2004, both markets became random walk. Runs test in month of the year indicates a random walk in all months except in January followed by November. Runs Test in day of the week also indicate a random walk in all days.

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2. Brief Literature Review

Sr. No.	Author/s	Markets Under Study	Period of Study	Methodology Used	Results Found
1	Fama (1965)	30 individual stocks quoted in the Dow Jones	1956 to 1962	serial correlation test, runs test and	Number of runs was smaller. Correlation was positive but was not statistically significant. Statistical tests show that there was not any dependence in the

		Industrial Average		Alexander's filter rule technique	successive price changes and the magnitude was very small and concluded the DJIA to be weak-form market efficient.
2	Sharma and Kennedy (1977)	India, U.S. and U.K.	BSE Index, the S&P 425 Index and the London FT Actuaries 500 Stock Index	Runs Test	Analysis of spectral densities of each index verified the randomness of the time series. The study concluded that stock prices on the BSE followed a random walk and reacted similarly to markets in the U.S. and U.K.
3	Sharma (1983)	Bombay Stock Exchange	23 stocks listed on the BSE in the period 1973 – 1978	Unit Root, Runs Test	The results indicated that price changes of stocks listed on the BSE possessed similar characteristics to those of other leading stock markets and concluded that stock price changes followed a general random-walk behavior.

Sr. No.	**Author/s**	**Markets Under Study**	**Period of Study**	**Methodology Used**	**Results Found**
4	Barnes (1986)	Kuala Lumpur Stock	30 companies and 6	Unit Root, Autocorrelation	The results of both tests showed that the KLSE has indicated a high degree of efficiency in the weak-form of

		Exchange	sector indexes for the 6 years period ended 1980		market efficiency.
5	Laurence (1986)	Kuala Lumpur and Singapore Stock Markets	1973 – 1978	Runs and Autocorrelation Test	The results of both tests suggest that markets understudy were not weak form efficient.
6	Parkinson (1987)	Nairobi Stock Exchange	1974 to 1978	Runs Test	The runs test showed that out of 50 companies in Nairobi Stock Exchange, 49 showed lesser numbers of the runs and concluded that market understudy was not random walk.
7	Lee (1992)	US, Australia, Belgium, Canada, France, Italy, Japan, Netherlands, Switzerland, United Kingdom, and Germany	1967-1988	Runs Test, Serial Correlation Test	He has used weekly data of indices and found that the 11 markets under study follow random walk model.
8	Butler and Malaikah	Kuwait and Saudi Arabian	1985 – 1989	Autocorrelation Test	The Kuwait was found to be an efficient but Saudi Arabian market was not found efficient for the selected

	(1992)	stock markets			period.
Sr. No.	**Author/s**	**Markets Under Study**	**Period of Study**	**Methodology Used**	**Results Found**
9	Roger Ignatius (1992)	Bombay Stock Exchange	1979 – 1990	Parametric and Nonparametric tests	The BSE showed seasonality in stock returns pattern. December has provided the highest mean monthly return while week 4 has the highest mean weekly return.
10	Choudhry (1994)	The United States, The United Kingdom, Canada, France, Germany, Japan and Italy	1953 – 1989	ADF and KPSS unit root tests, and Johansen's cointegration tests	All seven countries stock markets were efficient during the period. Their result from both ADF and KPSS tests showed that all seven time series seemed to contain a stochastic trend. The result of Johansen's co-integration test also supported market efficiency.
11	Dickinson & Muragu (1994)	Nairobi Stock Exchange	1979 – 1989	Autocorrelation and runs tests	Using Autocorrelation and Runs tests, he found that the Nairobi Stock Exchange support the weak-form of market efficiency.
12	Urrutia (1995)	Argentina, Brazil, Chile, and Mexico	1975 – 1991	Variance Ratio Test, Runs Test	There were conflicting results of Variance Ratio and Runs test. Variance ratio test rejects the random walk hypothesis, whereas runs test does not.
13	Chang et al. (1996)	Taiwan stock exchange	1967 to 1993	Ljung-Box Q, the runs and the unit root tests	The found that the Taiwan stock market is weak-form of efficient for the sample period

Sr. No.	Author/s	Markets Under Study	Period of Study	Methodology Used	Results Found
14	Al-Loughani and Chappel (1997)	United Kingdom stock market (FTSE 30)	1983 – 1989	LM serial correlation, DF unit root and Brock, Dechert and Scheinkman (BDS) non-linear tests	The result of Dickey Fuller tests showed the problem of unit root, so data were non stationary and rejected problem of unit root at first difference showed stationary in first differences, which showed the consistency of random walk. The data series were significantly heteroscedastic. BDS and serial correlation tests showed conflicting results against the DF and rejects random walk hypothesis.
15	Antoniou, A., Ergul, N., and Holmes, P. (1997)	Istanbul Stock Exchange (ISE Composite Index)	1988 – 1993	Serial Correlation, Moving Average Model	By using statistical tests, Author found that Istanbul Stock Exchange (ISE Composite Index) became efficient with high trading volume, reliable information and an appropriate institutional framework.
16	Karemera et al. (1999)	Argentina, Brazil, Chile, Hong Kong, Indonesia, Israel, Jordan, Korea, Malaysia, Mexico, Philippines, Singapore,	1986 – 1997	Single variance ratio, Multiple variance ratio, Runs Test	Author found that the random walk model is consistent in the market understudy. Results of runs test showed that the hypothesis of independence cannot be rejected for nine of the 15.

		Taiwan, Thailand, Turkey			

Sr. No.	Author/s	Markets Under Study	Period of Study	Methodology Used	Results Found
18	Chang and Ting (2000)	Taiwan stock market	1971-1996	Variance Ratio Test	Their results reject the random walk hypothesis with weekly value weighted market index returns, but not with monthly, quarterly and yearly value-weighted market index returns.
17	Cheung, C.K., and Coutts, A. J. (2001)	Hong Kong stock exchange	1985 – 1997	Variance Ratio Test	Author has used both homoscedastic and heteroscedastic error variances to examine Random walk hypothesis and confirmed that Hang Seng follows a random walk hypothesis.
19	Abeysekera (2001)	Colombo Stock Exchange (CSE) in Sri Lanka	January 1991 – November 1996	Runs, Autocorrelation and cointegration test	The results of Runs, Cointegration and correlation tests reject the serial independence hypothesis that concludes CSE was not consistent with the random walk hypothesis. No day of the week and month of the year effect found in the period.
20	Pant & Bishnoi(2001)	Indian stock market indices	1996 – 2001	Autocorrelation using Qstatistic & Dickey-Fuller test, Variance Ratio Test	The results support that Indian stock market indices do not follow random walk, Variance ratio and autocorrelation test rejected random walk.
21	Abraham et	three	1992 –	variance ratio	Rejected the random walk hypothesis

	al. (2002)	major Gulf stock markets including Kuwait, Saudi Arabia, and Bahrain	1998	and runs tests	in all markets due to correction for infrequent trading and significantly alter the results of market efficiency and random walk test. .

Sr. No.	Author/s	Markets Under Study	Period of Study	Methodology Used	Results Found
22	Mobarek and Keasey (2002)	Dhaka stock market in Bangladesh	1988 – 1997	Non-parametric (KS test and run test) and parametric test (Auto-correlation test, Autoregressive model, ARIMA model)	Author used Non parametric and Parametric test and found that the share return series don to follow the random walk model and also found significant auto-correlation coefficient at different lags that rejects the null hypothesis of weak-form efficiency. The results were also consistent with observations in different sub-samples.
23	Gilmore, C. G., and McManus, G. M. (2003)	Czech Republic, Hungary and Poland	1995 – 2000	Unit root, variance ratio, autocorrelation, Johansen and Granger causality	Authors have used Univariate and Multivariate tests that provided some evidences of weak form efficiency. Some mixed results were found using Variance ratio test of Lo and McKinlay (1988). The results from NAÏVE with ARIMA and

				Naïve, ARIMA and GARCH).	Garch were consistent in rejecting the random walk hypothesis.
24	Hassan, K. M., Al-Sultan, W., and Al-Saleem, J. A. (2003)	Kuwait stock market	1995 – 2000	Logistic Map Model, GARCH-M and EGARCH Models	Authors found that the Kuwait Stock Market were weak form inefficient. Market efficiency has improved towards the end of 1990s. According to them, possible reasons for inefficiency is because of thinly trading in the most of the stocks in Kuwait Stock Exchange and the fact that their study covers the repercussion of various important regulatory reforms carried out in the KSE.

Sr. No.	Author/s	Markets Under Study	Period of Study	Methodology Used	Results Found
25	Moustafa, M. A. (2004)	United Arab Emirates (UAE) stock market	2001 – 2003	Unit Root, Runs Test	Authors has used Runs test and found the returns of 40 out of 43 stocks were significant at 5 per cent. According to his results, the UAE is found to be weak-form efficient.
26	Nath & Dalvi (2004)	S&P CNX NIFTY	1999 – 2003	Robust regression with biweights and dummy variables	The study found that before introduction of rolling settlement in January 2002, Monday and Friday were significant days. Mondays were found to have higher standard deviations followed by Fridays showing the existence of market inefficiency clearly.
27	Worthington	Austria, Belgium,	1987 –	Serial	Found that of the emerging

	and Higgs (2004)	Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland & the UK, and 4 emerging stock markets: Czech Republic, Hungary, Poland & Russian.	2003	correlation, runs, and multiple variance ratio tests	markets only Hungary is random walk whereas in the developed markets only Germany, Ireland, Portugal, Sweden and UK comply with random walk.

Sr. No.	**Author/s**	**Markets Under Study**	**Period of Study**	**Methodology Used**	**Results Found**
28	Abrosimova, N., Dissanaike, G., and Linowski, D. (2005)	Russian Trading System (RTS) index	1995 – 2001	Unit root, autocorrelation and variance ratio tests, ARIMA, GARCH	Authors used daily, weekly and monthly data to test null hypothesis. They have also used ARIMA and Garch to test serial dependence. The results provided some limited evidence of short term predictability on the RTS. All models except ARIMA (0, 2) relatively accurate short term forecast. With the ADF and the PP unit root tests found to be stationary difference. Results of both autocorrelation and variance ratio tests reject the null hypothesis of the random walk for the daily and weekly, but not for the monthly data.

29	Akinkugbe, O. (2005)	Botswana Stock Exchange	1989 – 2003	Autocorrelation, and Unit Root Tests	In his study, Author found that the Botswana Stock Exchange exhibited efficiency both in the weak and semi strong forms. The autocorrelation test showed an evidence of no significant autocorrelation and the series did not have a problem of Unit root, therefore implying weak-form efficiency.
30	Tas and Dursonoglu (2005)	Istanbul Stock Exchange (ISE 30 Indices)	1995 – 2004	Dickey-Fuller unit root and runs tests	Authors found that the results of unit root and runs test are similar and rejected random walk hypothesis in ISE.
31	Khaled, M., and Islam, A. (2005)	Dhaka stock market	1990 – 2001	Unit Root and Variance Ratio Tests	Market efficiency could not be rejected in for monthly data. However for weekly data and daily data, market efficiency was rejected for the pre-boom period, but not for the post-crash. Using Heteroscedasticity-robust tests, they found short term predictability of the stock returns.

Table – 1 Descriptive Statistics (Whole sample period)

Descriptive Statistics	BSE SENSEX	CNX NIFTY
Mean	0.00058	0.00060
Median	0.00135	0.00141
Maximum	0.15990	0.16334
Minimum	-0.11809	-0.13054
Std. Dev.	0.01761	0.01747
Skewness	-0.16304	-0.24826
Kurtosis	8.43047	9.54567
Jarque-Bera	3687.2090	5368.5910

Probability	0.0000	0.0000
Sum	1.74746	1.77910
Sum Sq. Dev.	0.92658	0.91255
Observations	2990	2990

Table 2 – Descriptive Statistics (for respective months)

	January		February		March		April		May		June	
	BSE SENSEX	NIFTY 50	BSE SENSEX	NIFTY 50	BSE SENSEX	NIFTY 50	BSE SENSEX	NIFTY 50	BSE SENSEX	NIFTY 50	BSE SENSEX	NIFTY 50
Mean	0.0068	0.0069	0.0068	0.0070	0.0065	0.0067	0.0067	0.0069	0.0063	0.0065	0.0058	0.0060
Median	0.0003	-0.0007	0.0011	0.0007	0.0009	0.0012	0.0015	0.0016	0.0021	0.0022	0.0014	0.0024
Maximum	0.6223	0.6073	0.6095	0.5726	0.6471	0.6387	0.6625	0.6669	0.5986	0.5623	0.3389	0.3268
Minimum	-0.5778	-0.5269	-0.6621	-0.6355	-0.5975	-0.5711	-0.5572	-0.5236	-0.3022	-0.2873	-0.2888	-0.2482
Std. Dev.	0.0886	0.0857	0.0883	0.0845	0.0832	0.0804	0.0860	0.0843	0.0682	0.0663	0.0482	0.0462
Skewness	2.5078	3.0999	1.4601	1.5264	2.7897	2.9369	3.2617	3.6613	4.9001	4.7402	3.5857	3.7699
Kurtosis	32.5755	33.3823	34.6205	34.8030	40.5123	40.7829	40.4525	40.4641	45.1784	42.0061	35.0848	31.8779
Jarque-Bera	9298.61	9935.72	9957.80	10079.90	14682.63	14925.05	13970.72	14086.03	19844.42	17053.47	11664.29	9613.00
Probability	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sum	1.6762	1.7012	1.6155	1.6555	1.6042	1.6424	1.5609	1.6020	1.6125	1.6562	1.5096	1.5533
Sum Sq. Dev.	1.9382	1.8144	1.8382	1.6836	1.6896	1.5766	1.7068	1.6414	1.1763	1.1125	0.5987	0.5518
Observations	248	248	237	237	245	245	232	232	254	254	259	259

	July		August		September		October		November		December
	BSE SENSEX	NIFTY 50	BSE SENSEX	NIFTY 50	BSE SENSEX	NIFTY 50	BSE SENSEX	NIFTY 50	BSE SENSEX	NIFTY 50	BSE SENSEX
Mean	0.0056	0.0058	0.0064	0.0065	0.0072	0.0073	0.0070	0.0070	0.0074	0.0075	0.0073
Median	0.0011	0.0016	0.0024	0.0018	0.0020	0.0019	-0.0006	-0.0003	0.0029	0.0030	0.0028
Maximum	0.3370	0.3166	0.4265	0.4136	0.4416	0.4440	0.5599	0.5662	0.5272	0.5047	0.5781
Minimum	-0.2225	-0.1913	-0.3099	-0.2710	-0.2370	-0.1934	-0.4184	-0.4012	-0.6276	-0.6383	-0.8307
Std. Dev.	0.0471	0.0450	0.0539	0.0494	0.0570	0.0538	0.0808	0.0786	0.0809	0.0788	0.0863
Skewness	3.7359	4.0178	3.8498	4.2197	4.1928	4.6912	3.4706	3.6720	0.9833	0.7706	-1.0065
Kurtosis	31.9055	30.9248	37.0892	38.5910	31.5641	34.7747	29.2193	30.5246	34.2185	37.0517	50.9435
Jarque-Bera	9767.76	9252.84	12926.01	14159.90	9194.57	11388.24	7509.57	8284.47	9866.15	11715.79	24081.71
Probability	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sum	1.4612	1.5122	1.6160	1.6382	1.7889	1.8070	1.7090	1.7235	1.7952	1.8105	1.8291

Sum Sq. Dev.	0.5824	0.5312	0.7348	0.6176	0.8065	0.7165	1.5945	1.5056	1.5786	1.4948	1.8615
Observations	263	263	254	254	249	249	245	245	242	242	251

Table-3: Results of the Augmented Dickey-Fuller, and Phillip Perron Unit Root Test for Both Indices (Whole period)

	ADF	**PP**
SENSEX	-51.2883	-51.241
p-value	0.0001*	0.0001*
NIFTY	-51.3465	-51.2834
p-value	0.0001*	0.0001*

* indicate 1% level of Significance

Table-4: Results of the Augmented Dickey-Fuller, and Phillip Perron Unit Root Test for Both Indices (intervals of 3 years)

	August 1998 to July 2001		**August 2001 to July 2004**		**August 2004 to July 2007**		**August 2007 to July 2010**	
Market Indices	**ADF**	**PP**	**ADF**	**PP**	**ADF**	**PP**	**ADF**	**PP**
SENSEX	-26.0643	-26.0376	-25.5347	-25.5358	-25.6687	-25.6286	-25.0918	-25.0562
p-value	(0.0000)*	(0.0000)*	(0.0000)*	(0.0000)*	(0.0000)*	(0.0000)*	(0.0000)*	(0.0000)*
NIFTY	-26.0643	-26.0376	-25.5347	-24.4954	-25.6687	-25.6286	-25.5694	-25.5708
p-value	(0.0000)*	(0.0000)*	(0.0000)*	(0.0000)*	(0.0000)*	(0.0000)*	(0.0000)*	(0.0000)*

* indicate 1% level of Significance

Table-5: Results of Auto Correlation Test (Whole period)

	BSE	**NSE**
ρ1	0.063	0.062
ρ2	-0.029	-0.046
ρ3	-0.006	0.001
ρ4	0.007	0.012
ρ5	-0.023	-0.01
ρ6	-0.052	-0.054
ρ7	0.014	0.008

ρ8	0.04	0.036
ρ9	0.037	0.029
ρ10	0.02	0.028
Q(1)	12.0420	11.614
p-value	(0.0010)*	(0.0010)*
Q(2)	14.6440	17.913
p-value	(0.0010)*	(0.0000)*
Q(3)	14.7700	17.919
p-value	(0.0020)*	(0.0000)*
Q(4)	14.9310	18.341
p-value	(0.0050)*	(0.0010)*
Q(5)	16.5540	18.623
p-value	(0.0050)*	(0.0020)*
Q(6)	24.7110	27.364
p-value	(0.0000)*	(0.0000)*
Q(7)	25.3140	27.536
p-value	(0.0010)*	(0.0000)*
Q(8)	30.2130	31.521
p-value	(0.0000)*	(0.0000)*
Q(9)	34.2770	34.034
p-value	(0.0000)*	(0.0000)*
Q(10)	35.4440	36.372
p-value	(0.0000)*	(0.0000)*

* indicate 1% level of Significance

Table-6: Results of Auto Correlation Test (intervals of 3 years)

	August 1998 to July 2001		**August 2001 to July 2004**		**August 2004 to July 2007**		**August 2007 to July 2010**	
	BSE	NSE	BSE	NSE	BSE	NSE	BSE	NSE
ρ1	0.044	0.048	0.069	0.106	0.062	0.050	0.077	0.058
ρ2	0.016	-0.039	-0.086	-0.127	-0.060	-0.049	-0.031	-0.015
ρ3	-0.024	-0.014	0.037	0.052	-0.016	-0.017	-0.017	-0.013

ρ4	-0.001	-0.002	0.138	0.127	0.020	0.027	-0.046	-0.036
ρ5	-0.023	0.020	-0.020	-0.014	0.057	0.054	-0.053	-0.053
ρ6	-0.068	-0.060	-0.023	-0.027	-0.060	-0.042	-0.056	-0.071
ρ7	-0.005	-0.033	0.025	-0.002	-0.028	-0.024	0.037	0.052
ρ8	0.002	0.007	0.004	-0.016	0.009	0.007	0.096	0.094
ρ9	0.092	0.076	-0.004	0.004	0.042	0.022	0.009	0.009
ρ10	0.012	0.041	0.036	0.063	0.042	0.041	0.003	-0.009
Q(1)	1.479	1.688	3.590	8.486	2.903	1.884	4.413	2.526
p-value	(0.224)	(0.194)	(0.058)***	(0.004)*	(0.088)***	(0.170)	(0.036)**	(0.112)
Q(2)	1.660	2.827	9.167	20.717	5.627	3.707	5.116	2.686
p-value	(0.436)	(0.243)	(0.010)*	(0.000)*	(0.060)***	(0.157)	(0.077)	(0.261)
Q(3)	2.101	2.976	10.196	22.787	5.817	3.916	5.321	2.807
p-value	(0.552)	(0.395)	(0.017)**	(0.000)*	(0.121)	(0.271)	(0.150)	(0.422)
Q(4)	2.102	2.980	24.637	35.057	6.129	4.488	6.908	3.778
p-value	(0.717)	(0.561)	(0.000)*	(0.000)*	(0.190)	(0.344)	(0.141)	(0.437)
Q(5)	2.514	3.292	24.954	35.197	8.586	6.694	8.976	5.868
p-value	(0.774)	(0.655)	(0.000)*	(0.000)*	(0.127)	(0.244)	(0.110)	(0.319)
Q(6)	5.966	5.989	25.346	35.752	11.323	8.061	11.277	9.604
p-value	(0.427)	(0.424)	(0.000)*	(0.000)*	(0.079)***	(0.234)	(0.080)***	(0.142)
Q(7)	5.982	6.796	25.815	35.754	11.925	8.482	12.325	11.648
p-value	(0.542)	(0.450)	(0.001)*	(0.000)*	(0.103)	(0.292)	(0.090)***	(0.113)
Q(8)	5.986	6.828	25.829	35.953	11.989	8.515	19.230	18.281
p-value	(0.649)	(0.555)	(0.001)*	(0.000)*	(0.152)	(0.385)	(0.014)**	(0.019)**
Q(9)	12.417	11.174	25.842	35.966	13.359	8.876	19.288	18.343
p-value	(0.191)	(0.264)	(0.002)*	(0.000)*	(0.147)	(0.449)	(0.023)**	(0.031)**
Q(10)	12.522	12.451	26.820	38.964	14.676	10.184	19.297	18.406
p-value	(0.252)	(0.256)	(0.003)*	(0.000)*	(0.144)	(0.425)	(0.037)**	(0.048)**

* indicate 1% level of Significance

** indicate 5% level of Significance

*** indicate 10% level of Significance

Table-7: Results of the runs test (month wise)

Times series	Total cases	Cases < mean	Cases ≥ mean	Number of runs	Z-statistic	p-value
Whole Period						
BSE Sensex	2990	1410	1580	1388	-3.786	0.000*
CNX Nifty	2990	1419	1571	1399	-3.416	0.001*
January						
BSE Sensex	248	168	80	84	-3.698	0.000*
CNX Nifty	248	169	79	94	-2.151	0.031**
February						
BSE Sensex	237	163	74	96	-1.030	0.303
CNX Nifty	237	162	75	98	-0.833	0.405
March						
BSE Sensex	245	166	79	102	-0.887	0.375
CNX Nifty	245	165	80	110	0.181	0.856
April						
BSE Sensex	232	156	76	95	-1.226	0.220
CNX Nifty	232	156	76	93	-1.525	0.127
May						
BSE Sensex	254	169	85	106	-1.146	0.252
CNX Nifty	254	157	97	100	-2.786	0.005*
June						
BSE Sensex	259	154	105	115	-1.403	0.161
CNX Nifty	259	159	100	116	-1.022	0.307
July						
BSE Sensex	263	164	99	118	-0.851	0.395
CNX Nifty	263	164	99	122	-0.325	0.745
August						
BSE Sensex	254	164	90	115	-0.305	0.760
CNX Nifty	254	166	88	119	0.413	0.679
September						
BSE Sensex	249	167	82	105	-0.862	0.389
CNX Nifty	249	170	79	101	-1.155	0.248

October						
BSE Sensex	245	166	79	98	-1.474	0.141
CNX Nifty	245	169	76	89	-2.522	0.012**
November						
BSE Sensex	242	157	85	96	-2.162	0.031**
CNX Nifty	242	157	85	98	-1.879	0.060***
December						
BSE Sensex	251	164	87	103	-1.633	0.102
CNX Nifty	251	170	81	105	-0.828	0.408

* indicate 1% level of Significance

** indicate 5% level of Significance

*** indicate 10% level of Significance

Table-8: Results of the runs test (day wise)

Times series	**Total cases**	**Cases < mean**	**Cases ≥ mean**	**Number of runs**	**Z-statistic**	**p-value**
Monday						
BSE Sensex	596	278	318	306	0.687	0.492
CNX Nifty	596	281	315	298	-0.002	0.998
Tuesday						
BSE Sensex	595	274	321	304	0.607	0.544
CNX Nifty	595	276	319	290	-0.573	0.567
Wednesday						
BSE Sensex	597	271	326	295	-0.162	0.871
CNX Nifty	597	270	327	295	-0.147	0.883
Thursday						
BSE Sensex	598	276	322	279	-1.584	0.113
CNX Nifty	598	277	321	281	-1.430	0.153
Friday						
BSE Sensex	585	275	310	269	-1.948	0.051***
CNX Nifty	585	269	316	279	-1.051	0.293

* indicate 1% level of Significance

** indicate 5% level of Significance

*** indicate 10% level of Significance

Table-9: Results of the runs test (whole period & intervals of 3 years)

Times series	Total cases	Cases < mean	Cases ≥ mean	Number of runs	Z-statistic	p-value
Whole Period						
BSE Sensex	2990	1410	1580	1388	-3.786	0.000*
CNX Nifty	2990	1419	1571	1399	-3.416	0.001*
Period – I August 1998 to July 2001						
BSE Sensex	746	353	393	349	-1.758	0.079***
CNX Nifty	744	361	383	340	-2.400	0.016**
Period - II August 2001 to July 2004						
BSE Sensex	752	359	393	341	-2.576	0.010*
CNX Nifty	752	359	393	335	-3.015	0.003*
Period - III August 2004 to July 2007						
BSE Sensex	751	357	394	358	-1.288	0.198
CNX Nifty	751	353	398	354	-1.550	0.121
Period - IV August 2007 to July 2010						
BSE Sensex	738	356	382	352	-1.294	0.196
CNX Nifty	738	350	388	368	-0.075	0.940

* indicate 1% level of Significance

** indicate 5% level of Significance

*** indicate 10% level of Significance