Testing the Weak-Form Market Efficiency in the Indian Stock Market : Evidence from the Bombay Stock Exchange Index (BSE) Sensex

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Abstract

Performance of the stock markets is considered as a very important tool to measure the performance of the economy. In recent years, the Indian stock market has witnessed a tremendous growth in all the facets of trading , that is, number of companies listed, market capitalization, membership, value of trading ,volume of trading per day, and so forth. The Indian benchmark stock index SENSEX by June 2015 had grown massively to over 27,780.83 from 3,658 in January 1998. This unprecedented growth in the Indian stock market raises the interest over the efficiency of the stock market. The present paper tested the weak-form of market efficiency in the Indian stock market by testing the random walk hypothesis in the return series. According to the random walk hypothesis, the stock movements are random and unpredictable. Weighted index of the Bombay Stock Exchange (SENSEX) was examined for the study from 1998 to July 2015 by using daily data and weekly data. A battery of tests were applied on the data , that is, autocorrelation test, unit root test, and variance ratio test. The empirical evidence found from the autocorrelation test conclusively rejected the serial dependency in the series observed, and hence proclaimed the existence of the random walk hypothesis in the Indian stock market. ADF, DF-GLS, PP, and KPSS tests were performed to find the significance of unit root, and the results from the unit root test were consistent with the autocorrelation test. Similar and very strong evidence was found from the results of the variance ratio test also. Reasonable empirical evidence was found to prove the weak-form of market efficiency in the Indian stock market through this paper.

Key words : random walk hypothesis, weak-form market efficiency, Indian stock market, Bombay Stock Exchange, autocorrelation test, unit root test, variance ratio test

JEL Classification : G1, G10, G14, G15

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Research on stock market efficiency is one of the dominant and interesting topics in academic world from the last one decade. Both the academicians and practitioners are very much interested in market efficiency. Academicians would like to know the returns patterns of the securities and determine the models for assets pricing. Practitioners want to delineate strategies to gain the advantage over the market with the knowledge of assets valuations, that is, knowledge of overvalue and undervalue assets. Although there are many studies in the field of market efficiency and random walk hypothesis, but still, there is a lot of interest in the field.

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Performance of the market is highly dependent upon the level of efficiency in the market. One of the important underlying features of an efficient market is all the securities are traded at rational prices, there is no chance to find any overvalue or undervalue securities ; hence, investors' strategies are futile to gain the advantage of holding undervalued securities to get abnormal returns in the future. The term efficient market was introduced by the American economist Eugine Fama in the early 1960s. According to Fama (1970), a market in which prices always "fully reflect" available information is called "efficient." In generic terms, the efficient market hypothesis predicts that the security prices in the stock market will fully reflect all the information available in the market. Malkiel (1992) said that a capital market is said to be efficient when it fully and appropriately reflects all the relevant information in determining security prices.

Fama (1970) identified three level of market efficiencies, (a) weak-form of market efficiency, (b) semi-strong form of market efficiency, and (c) strong - form of market efficiency. These three are various intensities of availability of information. Weak-form of market efficiency states that prices of the securities fully and instantly reflect all information of the past prices. This implies future prices are not predictable by using the past prices of the securities. Security prices are random as they don't follow the pattern of old price movements. No investor has an advantage to reap abnormal returns from their securities. The semi strong form of market efficiency states that asset prices will fully reflect all publicly available information. Therefore, only investors with additional inside information can have advantage in the market. Strong-form of market efficiency asserts that prices fully reflect both publically and insider available information. Less developed and emerging markets are normally suitable for weak-form of market efficiency. Developed countries depend on the information technology existing in their countries and they could be in semi strong kind of market efficiency.

An assumption over the EMH as given by Fama (1991) is that he considered the market efficiency hypothesis to be the simple statement that security prices fully reflect all available information. A precondition for this strong version of the hypothesis is that information and trading costs, the costs of getting prices to reflect information, are always zero (Grossman, 1980). A weaker and economically more sensible version of the efficiency hypothesis says that prices reflect information to the point where the marginal benefits of acting on information (the profits to be made) do not exceed marginal costs (Jensen, 1978). The random walk hypothesis (RWH) is a financial theory stating that stock market prices evolve according to a random walk and thus can't be predictable.

This paper explores the weak-form of market efficiency in the Indian stock market through random walk hypothesis models. This study focuses on analyzing the Indian benchmark index for stock market, that is, the SENSEX.

Review of Literature

The concept of efficient markets has been in literature since the 1960s as revealed from the study of Osborne (1959). Many economists conducted research on market efficiency and its nature. Fama (1965) tested the market efficiency of the Dow Jones Industrial average for the period from 1958 to 1962 (a period of 5 years). He employed serial correlation test and run test. He did not find linear dependency in price changes, and he identified the random walk (RW) in the stock market prices.

Poshakwala (1996) used the daily data of Bombay Stock Exchange from January 1987 to October 1994 to test the weak form efficiency in the Indian stock market. The results of the run test and the autocorrelation rejected the weak form efficiency of the Indian stock market.

Islam (2005) took the daily, weekly and monthly index data from the Dhaka Stock Exchange from 1990 to 2001. He employed unit root test, autocorrelation test, and variance ratio test to test the weak-form of market efficiency. They found evidence of weak form efficiency before the 1996 stock market crash.

Granger and Morgenstern (1970) found that there was weak form efficiency in the New York stock exchange only in the short run. Sharma and Kennedy(1977) compared the behavior of stock indices of Bombay, London, and New York Stock Exchanges during 1963-73 using run test and spectral analysis. Both run tests and spectral analysis confirmed the random movement of stock indices for all the three stock exchanges. They concluded that the stocks on BSE followed a random walk and were equivalent in the markets of advanced industrialized countries.

Venkatesan (2010) investigated the behavior of the Indian stock market (NSE) returns. The study results revealed that the return series was insignificantly different from zero, which is consistent with the random walk hypothesis. Li and Liu (2012) tested the random walk hypothesis using the variance ratio test in 34 MSCI countries of World Economic Outlook Database -2010. They considered the weekly data from January 5,1988 to December 28, 2010 ; they found that 25 out of the 34 markets followed the random walk. Ansari and Chen (2013) investigated the behavior of stock returns in 10 major Asia-Pacific countries (Australia, China, Hong Kong, Indonesia, Japan, Malaysia, Singapore, South Korea, and Taiwan) ; they took the stock market closing prices covering from January 2000 to December 2006. They employed unit root test, serial correlation test, variance ratio test, random walk models BDS test. They found reasonable evidence to prove the weak form of market efficiency.

Jain and Jain (2013) employed both parametric and non parametric tests on BSE and NSE of India. They considered the closing prices from April 1993 to March 2013. They concluded that the Indian stock markets hold weak form of market efficiency. Ryaly, Kumar, and Urlankula (2014) investigated the behavior of the daily stock returns in five Asian countries, namely India, South Korea, Singapore, Hong Kong, and Japan. They found reasonable evidences to prove the existence of weak form of market efficiency in the selected Asian stock markets.

Data and Methodology

This empirical study is based on the closing values of the index of the Bombay Stock exchange SENSEX. The closing values of the index were extracted from the website : http://finance.yahoo.com for the period starting from January 2, 1998 to July 30, 2015. Daily as well as weekly data were considered. Daily data is specified in terms of the daily returns, considered with the first difference of the natural logarithm :

$$r_t = log\,(p_t / p_{t\text{-}1}) \qquad (1)$$

where,

r_t represents the first difference logarithm at time t, p_t is the closing price at day t, $p_{t\text{-}1}$ is the closing price of the index at day t-1. Similarly, weekly returns are calculated as natural logarithm of index from Wednesday closing price with the pervious Wednesday closing price in order to avoid the weekend effect of trading and profit booking. If Wednesday price is not available, Thursday price is used for natural logarithm. The choice of Wednesday aims to avoid the effects of weekend trading and to minimize the number of holidays (Huber,1997). For the convenience of research, all the tests were applied only after the entire date is divided into two sub-periods. The first sub-period is covered from January 2, 1998 to December 31, 2008. The sub-period two consists of data from January 1, 2009 to June 30, 2015.

(1) Autocorrelation Test : Autocorrelation or serial correlation is the test of serial dependency. It is the most common test for RWM in a form of estimates of serial correlation for stock price indices. Fama (1965), Moore (1964), Cootner (1962), and Kendal (1943) calculated the serial correlation. The auto correlation test examines whether the coefficient of correlation is significantly different from zero or is nearly zero. The former one indicates that there is an evidence of serial correlation which indicates non randomness in series and the latter one implies the randomness of the series. Since the tested data is daily closing prices, so the lag selected for the test is 36.

$$R(\tau) = \frac{E[(X_t - \mu)(X_{t+\tau} - \mu)}{\sigma^2} \quad (2)$$

where, E is the expected period value, X_t is the value at day t, $X_{t+\tau}$ is the value at $t+\tau$, μ is the mean of the series. τ is the lag.

Hence, the hypotheses are :

H01: SENSEX series has serial dependency.

Ha1: SENSEX series does not have serial dependency.

(2) Unit Root Test : Testing the stationarity and non stationarity of the time series is the one of the ways to test the market efficiency. Unit root test is a useful test to find whether the stochastic process is stationary or not. If PDF (probability density function) does not change during the time series, the series is known as stationary in process, consequently, parameters such as mean and variance don't change over time and don't follow any trend. To test stationarity, ADF (Augmented Dickey Fuller Test), Elliott-Rothenberg-Stock DF-GLS test, Phillips - Perron test, and the KPSS test (Kwiatkowski-Phillips-Schmidt-Shin test) were applied.

The Augmented Dickey Fuller test is the augmented version of the Dickey Fuller test for more complicated and large set of time series models. The ADF test normally has a negative test value ; the more negative the test value, the more is the rejection of null hypothesis of the test. Here, the null hypothesis is that the time series has unit root or is non stationary. The ADF unit root test of null hypothesis of non-stationarity is expressed with the following regression equation :

$$\Delta y_t = \alpha + \beta t + \gamma y_{t-1} + \delta\Delta\gamma y_{t-1} + \cdots + \delta_{p-1}\Delta y_{t-p+1} + \varepsilon_t \quad (3)$$

Here, α is a constant, β is coefficient of time trend, ε_t is the white noise, $\Delta y_t = \Delta y_t - \Delta y_{t-1}$, γ is the coefficient to be estimated, and p is the lag order of the auto regressive process. The random walk model normally imposes constants, coefficient values set 0, $\alpha = 0$, and $\beta = 0$. The random walk model with drift will assume that constant value $\alpha = 0$. MacKinnon's critical values (1996, one sided p - values) are used to determine the significance of the test statistics.

H02 : SENSEX has unit root (or) not stationary ($\gamma = 0$).

Ha2 : SENSEX does not have unit root (or) SENSEX is stationary ($\gamma < 0$).

➭ **Elliott-Rothenberg-Stock DF-GLS Test :** Elliott-Rothenberg-Stock in the year 1996 proposed an efficient test to modify the Dickey Fuller test statistics using a generalized least squares (GLS) rational.

H03: SENSEX has unit root (or) not stationary.

Ha3: SENSEX does not have unit root (or) SENSEX is stationary.

The statistics for unit root test proposed by Phillips and Perron (1988) arise from their consideration of the limiting factors of the various of Dickey Fuller tests. The PP unit root test of null hypothesis of non-stationarity is expressed with the following regression equation :

$$\Delta y_t = \alpha + \beta t + \gamma y_{t-1} + \mu_t \quad (4)$$

where, $\Delta y_t = \Delta y_t - \Delta y_{t-1}$, α is a constant, β is coefficient of time trend, and μ_t is the error term.

H04: SENSEX has unit root (or) not stationary ($\gamma = 0$).
Ha4: SENSEX does not have unit root (or) SENSEX is stationary ($\gamma < 0$).

The most commonly used unit root test is KPSS test for stationarity. The Kwiatkowski - Phillips - Schmidt - Shin test developed this regression in 1992. This test provides the test of the null hypothesis of stationarity against the alternative of unit root.

$$y_t = \alpha + \beta t + \mu_t \qquad (5)$$
$$\mu_t = \mu_{t-1} + \varepsilon_t, \qquad \varepsilon_t \cong iid(0, \sigma^2_\varepsilon) \qquad (6)$$

where, $y_t = y_{t-1} + \mu_t$ is the random walk, the initial value $\alpha = 0$ is constant , t is the time index.

H05: SENSEX does not have unit root (or) SENSEX is stationary ($\sigma^2_\varepsilon = 0$).
Ha5: SENSEX has unit root (or) not stationary ($\sigma^2_\varepsilon > 0$).

KPSS test statistics is the LM (Lagrange Multiplier) testing null hypothesis H0 : ($\sigma^2_\varepsilon = 0$) against the alternative hypothesis ($\sigma^2_\varepsilon > 0$).

(3) Variance Ratio Test : Variance ratio test is considered a strong test of asset price predictability, and many researchers have used this test (Lo & MacKinlay, 1988) to test whether stock prices follow a random walk. It uses the property of the random walk hypothesis that when variances are compared over different periods, the variance of the incremental should be linear in the observation interval. The variance of $y_t - y_{t-2}$ is twice the variance of $y_t - y_{t-1}$. With this property, a test can be constructed that tests whether this requirement of the RWH is actually fulfilled. Hence, RWH can be given by the following equation :

$$y_t = \mu + y_{t-1} + \varepsilon_t \qquad (7)$$

where, y_t is the log price of the price at time t ; furthermore, μ is an arbitrary drift parameter and ε_t is the random distribution term. H : .$\varepsilon_t \cong iid(0, \sigma^2_0)$

H06: SENSEX has martingale ($VR(q) = 1$).
Ha6: SENSEX does not have martingale ($VR(q) \neq 1$).

In order to avoid the day effect, week effect of Friday and Monday, the date considered to test the variance ratio is weekly ; the first day of the week starts with Wednesday, if Wednesday is a holiday, the next day is taken as the first day. q considered are 2, 4, 8,16, and 32 week lags.

Analysis, Results, and Discussion

(1) Descriptive Statistics : Empirical analysis on data of SENSEX is based on daily observation as well as weekly observations. The results consisting of descriptive statistics are furnished as follows. The Tables 1 and 2 provide the details of mean, standard deviation, maximum, minimum, skewness, and kurtosis.

The sample average returns for SENSEX are positive and indicate that the stock index was growing during the period from 1998-2015. Daily average returns are 0.05951 for the whole period, 0.07172 and 0.07243 for sub-periods one and two, respectively. Variance of the daily average returns are expressed with the *S.D* witnessing

1.06,1.06, and 1.29 for the whole period, sub-period one, and sub-period two, respectively. Weekly average returns are furnished in the Table 2. The Table 2 shows that the SENSEX varies around 0.25 to 0.35 with variation of 3. The skewness and kurtosis are used to find out the shape of distribution of the data. Critical value of skewness is zero. A positive value of the skewness indicates that the series is elongated in the right tail , and negative indicates that it is elongated in the left tail. The critical value of the kurtosis is 3, a value greater than 3 indicates that the series in question is peaked relative to normal known as leptokurtic distribution ; the critical value less than 3 implies that the series is flat relative to normal. Values of both skewness and kurtosis of the data series indicate that the series is not normally distributed, kurtosis values are the evidence that there is a leptokurtic distribution in the given series. So, the returns are not normally distributed. The Figure 1 represents the trend of SENSEX during the period of the study.

(2) Autocorrelation Test : Autocorrelation (serial correlation) is the test of serial dependency. Serial dependency is the most common test for RWH (random walk hypothesis). Autocorrelation tests the evidence whether the coefficient of correlation is significantly different from zero (Granger & Morgenstern, 1970). If there is any correlation in the residual series, it is likely the first order serial correlation is between E_t and E_{t-1}. As per this, we need to correlate the same series between E_t and E_{t-n}. n is the number of lags. For instance, if there are 16 lag

Table 1. Summary of Descriptive Statistics of Daily Average Returns of SENSEX

Descriptive statistics of daily closing value of SENSEX			
Descriptive statistics	**Full period 1/2/1998 to 06 /30/2015**	**Sub-period one 1/2/1998 to 12 /30/2008**	**Sub-period Two 1/1/2009 to 12/30/2015**
Observations	4325	2725	1600
Mean	0.05951	0.07172	0.07243126
Standard Deviation	1.604532	1.603328	1.29538
Maximum	17.33933	8.971318	17.3393348
Minimum	-11.1385	-11.1385	-7.2470482
Skewness	0.100134	-0.23386	1.4496406
Kurtosis	6.586183	3.457715	21.123284

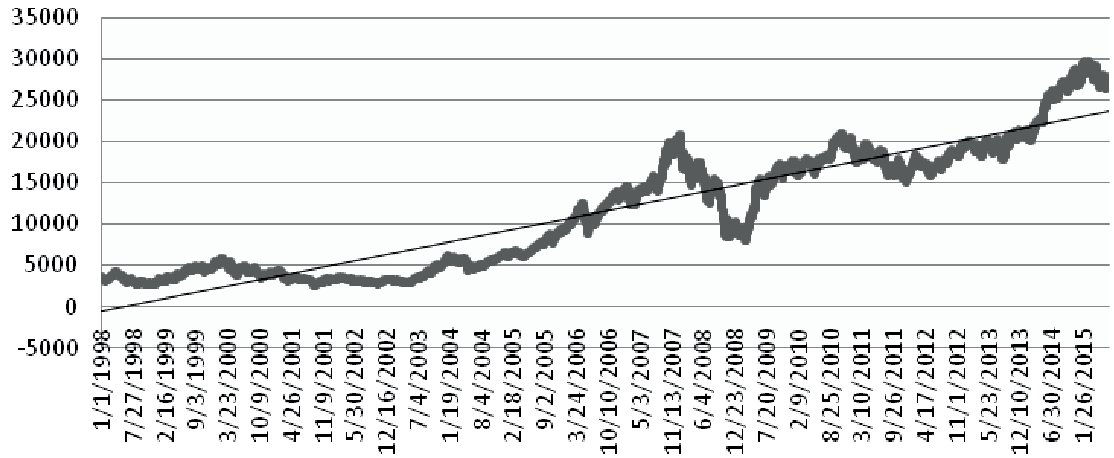
Note : The above numerical values have been considered after analyzing daily & weekly returns of Bombay Stock Market index SENSEX Countries. Extracted from https://in.finance.yahoo.com/

Table 2. Summary of Descriptive Statistics of Weekly Average Returns of SENSEX

Descriptive statistics of weekly closing value of SENSEX			
Descriptive statistics	**Full period 1/2/1998 to 06 /30/2015**	**Sub-period one 1/2/1998 to 12 /30/2008**	**Sub-period Two 1/1/2009 to 12 /30/2015**
Observations	912	574	338
Mean	0.278847	0.24188	0.358843
Standard Deviation	3.412964	3.735579	2.772535
Maximum	14.07764	12.83914	14.07764
Minimum	-15.9542	-15.9542	-9.44696
Skewness	-0.15377	-0.283	0.465366
Kurtosis	2.209954	1.75056	2.687029

Note : The above numerical values have been considered after analyzing daily & weekly returns of Bombay Stock Market index SENSEX. Data extracted from https://in.finance.yahoo.com/

Figure 1. Trend of SENSEX from 1998 to 2015



Note : Data was extracted from https://in.finance.yahoo.com/

correlations, the variable needs to check the serial dependency between E_t and E_{t-16}. Fama (1965) tested the autocorrelation in Dow Jones Industrial average. He found the coefficient value of 0.003, which is significantly near to zero. With this, he concluded that the market has a serial independence. Kendal (1943), Moore (1964), and Cootner (1962) tested the serial correlation for the daily and weekly returns. For examining the serial correlation for the large sample size (large time series) and high order serial correlation, the Ljung and Box (1978) statistics is used. The Ljung-Box test is a statistical test to examine whether any group of autocorrelation of time series is different from zero. This test is the modified version of the Box-Pierce chi-square statistic. Instead of testing randomness at each distinct lag, it tests the overall randomness based on a number of lags. If the autocorrelation and partial correlation values at all lags are zero or nearly zero, there is no serial correlation, and the values of Ljung- Box statistics should be insignificantly large. The test statistic is :

$$Q = n(n+2)\Sigma^{h}_{k=1} \frac{\rho^2_k}{n-k} \sim \chi^2_m \quad (8)$$

where, n is the sample size, ρ_k is the sample autocorrelation at lag k, h is the number of lags being used. The following autocorrelation test with 36 lags was performed on full sample and two sub-samples of daily and weekly data returns series.

The Table 3 represents the Ljung-Box statistics for high order autocorrelation for SENSEX. There are three columns of correlation coefficient for all the periods (autocorrelation, Q - statistics, and p - value). For the full sample period of 1998-2015, the Q-statistics are significant at all lags, and thus, these don't reject the serial dependency ; hence, there is not enough evidence from the full sample period. Looking at the results obtained for the sub-period one (1998-2008), the values are also consistent with the results of the full sample period. The Q-statistics shows significance at all lags. Thus, the null hypothesis (H01) of serial dependency is not rejected. However, the sub-period two (2009 - 2015) registers interesting results relating to serial dependency. The Q-statistics are insignificant for all lags of autocorrelation and thus provide enough evidence to prove the weak-form of market efficiency in SENSEX for the sub-period two.

The Table 4 furnishes the results of the Ljung-Box statistics for high order autocorrelation for weekly returns of SENSEX. For the full sample period, the Q-Statistics are insignificant for all lags and hence prove the weak-form of market efficiency, and the same results are found for the sample period two. However, the results reject the random walk hypothesis for the sample- period one.

Table 3. Summary of Results of Autocorrelation Test of Daily Returns of SENSEX

Autocorrelation of daily returns of SENSEX									
	Full period			Sub-period One			Sub-period Two		
lag	Auto-correlation	*Q*-Stat	*P*-value	Auto-correlation	*Q*-Stat	*P*-value	Auto-correlation	*Q*-Stat	*P*-value
1	0.081	28.2	0.000	0.084	19.353	0.000	0.076	9.1975	0.002
2	-0.023	30.5	0.000	-0.005	19.416	0.000	-0.042	12.003	0.002
3	-0.021	32.549	0.000	-0.019	20.365	0.000	-0.024	12.898	0.005
4	-0.012	33.149	0.000	-0.037	24.111	0.000	0.010	13.062	0.011
5	-0.021	35.128	0.000	-0.056	32.805	0.000	0.013	13.350	0.020
6	-0.033	39.888	0.000	-0.053	40.602	0.000	-0.012	13.581	0.035
7	0.009	40.233	0.000	0.022	41.889	0.000	-0.004	13.611	0.059
8	0.029	43.778	0.000	0.072	56.162	0.000	-0.011	13.789	0.087
9	0.022	45.819	0.000	0.014	56.708	0.000	0.021	14.472	0.106
10	-0.004	45.896	0.000	0.009	56.940	0.000	-0.021	15.150	0.127
11	-0.040	52.831	0.000	-0.053	64.498	0.000	-0.029	16.469	0.125
12	0.020	54.529	0.000	0.039	68.615	0.000	0.003	16.485	0.170
13	0.005	54.642	0.000	0.022	69.929	0.000	-0.012	16.732	0.212
14	0.033	59.396	0.000	0.076	85.562	0.000	-0.002	16.742	0.270
15	0.007	59.592	0.000	0.026	87.355	0.000	-0.014	17.052	0.316
16	0.014	60.436	0.000	0.012	87.725	0.000	0.011	17.246	0.370
17	0.040	67.452	0.000	0.041	92.379	0.000	0.040	19.851	0.282
18	-0.012	68.044	0.000	-0.022	93.741	0.000	-0.006	19.912	0.338
19	-0.014	68.906	0.000	-0.035	97.081	0.000	0.007	19.996	0.395
20	-0.035	74.251	0.000	-0.026	98.943	0.000	-0.044	23.084	0.285
21	-0.018	75.694	0.000	0.003	98.963	0.000	-0.030	24.555	0.267
22	-0.004	75.754	0.000	0.027	100.98	0.000	-0.031	26.145	0.246
23	-0.021	77.662	0.000	0.015	101.61	0.000	-0.054	30.881	0.126
24	-0.001	77.667	0.000	-0.004	101.66	0.000	-0.004	30.907	0.156
25	0.023	80.062	0.000	0.046	107.55	0.000	-0.002	30.913	0.192
26	-0.006	80.217	0.000	-0.009	107.77	0.000	-0.001	30.914	0.231
27	-0.012	80.830	0.000	-0.009	107.99	0.000	-0.017	31.403	0.255
28	0.005	80.952	0.000	0.029	110.33	0.000	-0.013	31.681	0.288
29	-0.013	81.701	0.000	-0.027	112.33	0.000	0.006	31.732	0.332
30	-0.012	82.339	0.000	-0.048	118.71	0.000	0.022	32.530	0.343
31	-0.023	84.715	0.000	-0.049	125.36	0.000	-0.000	32.530	0.391
32	0.015	85.669	0.000	0.013	125.83	0.000	0.011	32.724	0.431
33	0.003	85.719	0.000	-0.019	126.84	0.000	0.020	33.356	0.450
34	0.050	96.742	0.000	0.022	128.16	0.000	0.076	42.927	0.140
35	-0.028	100.06	0.000	-0.032	131.03	0.000	-0.033	44.727	0.126
36	0.009	100.40	0.000	0.014	131.57	0.000	-0.007	44.801	0.149

Source: Constructed values from SPSS, the above numerical values have been considered after analyzing daily & weekly returns of Bombay Stock Market index SENSEX. Data extracted from https://in.finance.yahoo.com/

Note : Q-Stat : Box-Ljung Statistic, Full Period indicates period from 1/2/1998 to 6/30/2015, Sub-period one indicates period from 1/2/1998 to 12/31/2008, Sub-period Two indicates the period from 1/1/2009 to 06/30/2015.

(3) Unit Root Test : For stochastic processes, it is very important to test whether the data is stationary or not. Unit root is necessary but not a significant condition for the random walk hypothesis. A series is said to be stationary if the mean and covariance of the series do not depend upon time. Unit root test results for first difference of weekly as well as daily closing value of SENSEX are furnished in the Table 5. The Augmented Dickey Fuller test (ADF) is

Table 4. Summary of Results of Autocorrelation Test of Weekly Returns of SENSEX

Autocorrelation of weekly returns of SENSEX									
	Full period			Sub-period One			Sub-period Two		
lag	Auto-correlation	*Q*-Stat	*P*-value	Auto-correlation	*Q*-Stat	*P*-value	Auto-correlation	*Q*-Stat	*P*-value
1	0.081	28.203	0.593	0.004	0.0084	0.927	0.027	0.2546	0.614
2	-0.023	30.555	0.090	0.166	16.029	0.000	-0.022	0.4271	0.808
3	-0.021	32.549	0.143	0.004	16.039	0.001	-0.042	1.0448	0.790
4	-0.012	33.149	0.175	0.056	17.885	0.001	-0.001	1.0455	0.903
5	-0.021	35.128	0.071	0.043	18.957	0.002	-0.143	8.0990	0.151
6	-0.033	39.888	0.110	0.002	18.959	0.004	0.013	8.1599	0.227
7	0.009	40.233	0.166	-0.070	21.813	0.003	0.034	8.5608	0.286
8	0.029	43.778	0.230	-0.038	22.642	0.004	-0.009	8.5882	0.378
9	0.022	45.819	0.309	0.087	27.074	0.001	-0.065	10.067	0.345
10	-0.004	45.896	0.310	-0.122	35.849	0.000	0.038	10.584	0.391
11	-0.040	52.831	0.346	0.010	35.902	0.000	0.042	11.213	0.426
12	0.020	54.529	0.260	-0.096	41.317	0.000	-0.018	11.324	0.501
13	0.005	54.642	0.014	0.098	47.022	0.000	0.087	14.026	0.372
14	0.033	59.396	0.021	-0.018	47.209	0.000	0.023	14.214	0.434
15	0.007	59.592	0.007	0.133	57.598	0.000	-0.014	14.284	0.504
16	0.014	60.436	0.005	0.045	58.776	0.000	0.074	16.227	0.437
17	0.040	67.452	0.007	0.005	58.790	0.000	0.013	16.283	0.504
18	-0.012	68.044	0.010	0.045	59.988	0.000	-0.051	17.214	0.508
19	-0.014	68.906	0.013	0.016	60.137	0.000	-0.074	19.209	0.443
20	-0.035	74.251	0.018	-0.008	60.178	0.000	0.026	19.457	0.492
21	-0.018	75.694	0.017	-0.022	60.478	0.000	-0.083	21.947	0.403
22	-0.004	75.754	0.015	0.090	65.281	0.000	0.022	22.131	0.452
23	-0.021	77.662	0.021	-0.056	67.178	0.000	0.033	22.527	0.489
24	-0.001	77.667	0.026	0.034	67.884	0.000	0.068	24.206	0.450
25	0.023	80.062	0.030	-0.054	69.616	0.000	-0.000	24.206	0.507
26	-0.006	80.217	0.038	-0.015	69.756	0.000	0.017	24.313	0.558
27	-0.012	80.830	0.032	-0.047	71.090	0.000	-0.006	24.327	0.612
28	0.005	80.952	0.041	-0.043	72.222	0.000	0.009	24.358	0.662
29	-0.013	81.701	0.040	0.079	75.982	0.000	0.005	24.367	0.711
30	-0.012	82.339	0.047	-0.051	77.572	0.000	0.040	24.971	0.726
31	-0.023	84.715	0.041	0.160	93.216	0.000	-0.032	25.354	0.752
32	0.015	85.669	0.035	-0.019	93.439	0.000	-0.000	25.354	0.791
33	0.003	85.719	0.041	0.077	97.033	0.000	0.010	25.388	0.826
34	0.050	96.742	0.051	-0.003	97.039	0.000	-0.011	25.432	0.855
35	-0.028	100.06	0.053	-0.052	98.698	0.000	-0.008	25.459	0.882
36	0.009	100.40	0.059	-0.025	99.082	0.000	-0.001	25.459	0.905

Source: Constructed values from SPSS, the above numerical values have been considered after analyzing daily & weekly returns of Bombay Stock Market index SENSEX. Data extracted from https://in.finance.yahoo.com/

Note : Q-Stat : Box-Ljung Statistic, Full Period indicates period from 1/2/1998 to 6/30/2015, Sub-period one indicates period from 1/2/1998 to 12/31/2008, Sub-period Two indicates the period from 1/1/2009 to 06/30/2015.

considered a very important test for unit root when the size of the sample is large. ADF, DF-GLS, PP, and KPSS tests were performed to find the significance of unit root. MacKinnon's critical values are used in order to determine the significance of the test statistic associated with $\rho 0$. The ADF Test performed at first difference with ZERO constant and drift rejected the unit root for all sample periods, that is, full sample period and sub-sample periods one and two. The DF-GLS also provides the same results which are associated with the ADF test. The PP test incorporates an automatic correction to the non-Augmented Dickey-Fuller procedure to allow for auto correlated residuals. The KPSS test has the reverse assumption that the null hypothesis H05 is not rejected for stationarity of the data. Hence, the null hypothesis H05 must be not rejected for existence of non unit root. The KPSS test for all the sample periods does not reject the null hypothesis H05 ; so, the series is stationary. The KPSS test is useful to compare the test results with ADF, and PP test to check if the outcome of unit root is superior.

Table 5. Summary of Results of Unit Root Test

Summary of results of Unit root test				
Unit root test with First difference of weekly returns of SENSEX				
Data Period	**ADF TEST**	**DF-GLS test**	**PP test**	**KPSS TEST**
SENSEX weekly closing	-29.64324	-29.21036	-29.54863	0.172324
from 1/2/1998 to 6/30/2015	(H02:rejected)	(H03:rejected)	(H04:rejected)	(H05:Not rejected)
1st sub period from	-14.18993	-14.01256	-24.03851	0.130229
1/2/1998 to 12/31/2008	(H02:rejected)	(H03:rejected)	(H04:rejected)	(H05:Not rejected)
2nd sub period	-17.61230	-16.83862	-17.87178	0.134251
from1/1/2009 to 30/06/2015	(H02:rejected)	(H03:rejected)	(H04:rejected)	(H05:Not rejected)
Unit root test with first difference of Daily returns of SENSEX				
Data Period	ADF TEST	DF-GLS test	PP test	KPSS TEST
SENSEX daily closing	-60.59223	-60.01640	-60.49060	0.150899
From 1/2/1998 to 6/30/2015	(H02:rejected)	(H03:rejected)	(H04:rejected)	(H05:Not rejected)
1st sub period from	-47.94760	-47.11047	-47.91461	0.162108
1/2/1998 to 12/31/2008	(H02:rejected)	(H03:rejected)	(H04:rejected)	(H05:Not rejected)
2nd sub period	-36.98632	-36.25862	-36.93002	0.094812
from1/1/2009 to 30/06/2015	(H02:rejected)	(H03:rejected)	(H04:rejected)	(H05:Not rejected)

Source: Constructed values from E Views 9. The above numerical values have been considered after analyzing daily & weekly returns of Bombay Stock Market index SENSEX. Data extracted from https://in.finance.yahoo.com/

Note : For Augmented Dickey Fuller test, Elliott-Rothenberg-Stock DF-GLS test, and Phillips - Perron test, the Critical Values of 1%,5%, and 10% level are -2.56 ,-1.94, and -1.61, respectively. MacKinnon's critical values (1996,one sided *p* - values) are used to determine the significance of the test statistics for Kwiatkowski-Phillips-Schmidt-Shin test. Asymptotic critical values at 1%, 5%, and 10% level are 0.739, 0.463, and 0.347, respectively.

(4) Variance Ratio Test : Variance ratio test is considered more powerful and more reliable than the traditional tests ADF, PP, and serial correlation. There are two tests that are applicable to calculate the variance ratio. Lo and MacKinlay (1988) developed a test for single variance ratio test, which shows that the variance ratio statistics is derived from the assumption of linear relations in observation interval regarding the variance of increments. Two test statistics were produced by Lo and MacKinlay (1988) under the null of homoscedastic and heteroscedastic increments random walk, respectively. If the null hypothesis (H06) is not rejected, the performed test statistic has an asymptotic standard normal distribution. Chow and Denning (1993) developed multiple variance ratio test. Chow and Denning's (1993) multiple variance ratios generate procedure for multiple comparison of the set of ratios with unity. They used maximum value of Z-statistic for a particular period in time. At the 5 % significance level, the Z statics value must be within $\pm$ 1.96 to reject the null hypothesis H06 and accept the alternative hypothesis Ha6 .

The Table 6 provides the variance ratio test for the SENSEX, with probabilities calculated by using asymptotic normal results defined by Lo and MacKinlay (1988). The variance ratio estimates are provided for the daily and weekly data for full sample period as well as the two sample sub- periods. Since the test is for more than one period, there are two sets of results ."Join test" is the test of the joint null hypothesis H06 for all periods (2,4,8,16, and 32),where the individual variance ratio test is applied to the individual periods.

Table 6. Summary of Results of Variance Ratio Test

Variance ratio from daily returns of SENSEX
Null Hypothesis H06: SENSEX is a martingale
Sample: 1/01/1998 6/30/2015
Heteroskedasticity robust standard error estimates

Joint Tests		Value	*df*	Probability
Max |*z*|(at period 2)*		3.331446	4326	0.0043
Individual Tests				
Period	**Var. Ratio**	**Std. Error**	***z*-Statistic**	**Probability**
2	1.081156	0.024361	3.331446	0.0009
4	1.088482	0.046217	1.914469	0.0556
8	1.040363	0.074390	0.542593	0.5874
16	1.040297	0.109719	0.367273	0.7134
32	1.056000	0.155665	0.359744	0.7190

Sample: 1/01/1998 12/31/2008
Heteroskedasticity robust standard error estimates

Joint Tests		Value	*df*	Probability
Max |*z*| (at period 2)*		1.968323	2725	0.2223
Individual Tests				
Period	**Var. Ratio**	**Std. Error**	***z*-Statistic**	**Probability**
2	1.084983	0.043176	1.968323	0.0490
4	1.114255	0.081116	1.408541	0.1590
8	1.020478	0.129868	0.157682	0.8747
16	1.062037	0.188480	0.329144	0.7420
32	1.203457	0.263593	0.771861	0.4402

Sample: 1/02/2009 6/30/2015
Heteroskedasticity robust standard error estimates

Joint Tests		Value	*df*	Probability
Max |*z*| (at period 2)*		3.086179	1600	0.0101
Individual Tests				
Period	**Var. Ratio**	**Std. Error**	***z*-Statistic**	**Probability**
2	1.076381	0.024750	3.086179	0.0020
4	1.062593	0.048250	1.297274	0.1945
8	1.057543	0.078699	0.731175	0.4647
16	1.014777	0.120062	0.123076	0.9020
32	0.916296	0.174881	-0.478634	0.6322

Variance Ratio from Weekly returns of SENSEX
Null Hypothesis H06: SENSEX is a martingale
Sample: 12/29/1997 6/29/2015
Heteroskedasticity robust standard error estimates

Joint Tests		Value	*df*	Probability
Max |*z*| (at period 32)*		1.070554	913	0.8123
Individual Tests				
Period	**Var. Ratio**	**Std. Error**	***z*-Statistic**	**Probability**
2	1.019696	0.047690	0.413009	0.6796
4	1.087139	0.091308	0.954337	0.3399
8	1.105864	0.144240	0.733946	0.4630
16	1.127368	0.211999	0.600797	0.5480
32	1.321638	0.300441	1.070554	0.2844

Sample: 12/29/1997 12/29/2008
Heteroskedasticity robust standard error estimates

Joint Tests		Value	*df*	Probability
Max |*z*| (at period 8)*		1.465699	574	0.5370
Individual Tests				
Period	**Var. Ratio**	**Std. Error**	***z*-Statistic**	**Probability**
2	1.003911	0.077063	0.050749	0.9595
4	1.183447	0.152206	1.205256	0.2281
8	1.357935	0.244208	1.465699	0.1427
16	1.353220	0.354923	0.995202	0.3196
32	1.442223	0.494455	0.894365	0.3711

Sample: 1/05/2009 6/29/2015
Heteroskedasticity robust standard error estimates

Joint Tests		Value	*df*	Probability
Max |*z*| (at period 8)*		0.612328	338	0.9554
Individual Tests				
Period	**Var. Ratio**	**Std. Error**	***z*-Statistic**	**Probability**
2	1.033269	0.059695	0.557320	0.5773
4	1.007629	0.109710	0.069535	0.9446
8	0.896175	0.169558	-0.612328	0.5403
16	0.876068	0.251552	-0.492669	0.6222
32	0.786925	0.263426	-0.523456	0.7325

Source: Constructed values from E Views 9. The above numerical values have been considered after analyzing daily & weekly returns of Bombay Stock Market index SENSEX. Data extracted from https://in.finance.yahoo.com/

Empirical evidence obtained from the variance ratio of daily returns of SENSEX indicates that the random walk hypothesis is not rejected under heteroskedasticity. In the case of variance ratio for the full sample period, the Chow-Denning maximum $|z|$ is associated with the period 2 individual test statistics. The Z value (3.33) is high and rejects the null hypothesis H06 of Martingale at the 1% significance level ; whereas, except period 2, all the remaining individual test statistics for 8, 16, and 32 are not significantly high Z values to reject the null hypothesis H06, but for the individual test at period 4, the Z-value is rejected at the 10% significance level. The sub-period one and two also found similar results with the joint test and rejected the null hypothesis H06 at individual test at 2 at the 5% significance level in the first sample period and the 1% significance level for the second sample-period. However, all the other individual test statistics except for period 2 have very low Z values and probability also is very high. Hence, the H06 null hypothesis is not rejected. By consolidating the results for all the samples except the individual test statistics for period 2, all others have not rejected the null hypothesis H06 and provide a strong evidence to prove the weak-form of market efficiency in the Bombay Stock Exchange (SENSEX). The results of the variance ratio test for daily are consistent with the results obtained from the serial-correlation test and the unit root test for the daily average returns.

Looking at the variance ratio test for weekly returns (Table 6) for the full sample period as well as the two sample periods - for the full sample period, the Chow-Denning maximum $|z|$ is associated with the period 32 individual test statistics Z Value (1.07, which is less than the 5% significance level of ±1.96, which is very low to reject the null H06, the probability value (0.8123, which is quite higher than the 5% significant value) is also very high to reject the null hypothesis H06 of Martingale, and the individual test statistics are also consistent with the joint test. Similar results are found from the sub-period one and two also. Evidences from the variance ratios test statistics for joint and individual test statistics for weekly returns of SENSEX provide very strong proof for significance of the random walk hypothesis in the Indian stock exchange. Hence, the 30 script weighted stock index SENSEX provides the certificate that the Indian stock market is weak-form of market efficiency.

Research Implications

Measuring the performance of emerging markets has always been interesting as these markets have been exhibiting a variety of features. Testing the efficient market hypothesis is one of the crucial aspects to find the performance of the market. Fair value of the financial assets will be determined based upon the form of stock market efficiency. The Indian stock market is one of the emerging markets which is continuously evolving in regulatory, technical, and other aspects. By analyzing the Indian stock market, one can be aware of the features of the market. We analyzed the Indian stock market through BSE index SENSEX. This paper would be helpful to understand the informational efficiency of the market and make use of this study to decide their investments and portfolios. This study will guide the investors to understand the market and valuation of stocks so that they can make rational decisions of their investment holdings. This study will be helpful for the research scholars to explore the Indian stock market efficiency.

Conclusion

This paper examines the existence of weak - form of market efficiency in the Indian stock market with the evidence of test results on benchmark index of India (SENSEX). The samples were considered from 1998 to June 2015 by considering the daily closing values and weekly closing values of SENSEX. For conducting the study, the total sample period was divided into two sub-samples, and all the tests were applied on the full sample as well as the two sub samples. Three different procedures were employed to examine the random walk hypothesis: (a) the parametric auto correlation coefficient with Ljung-Box statics to test the serial dependency, (b) the test of unit root test with Augmented Dickey Fuller test (ADF), Elliott-Rothenberg-Stock DF-GLS test, Phillips - Perron test (PP), and Kwiatkowski-Phillips-Schmidt-Shin test to check stationarity of the samples, (c) the variance ratio test statistics were used to test the random walk hypothesis.

Even though this entire test explains the weak-form of market efficiency through numerical value, the stock markets talk about numbers rather than the qualitative aspects. One can understand the stock market features through the quantitative aspects of the market through this study. The results for the test of autocorrelation are different in daily samples and weekly samples ; the results for the full sample and the first sample period of daily average returns conclusively reject the weak-form of market efficiency ; whereas, the second sub-period rejects the null of serial dependency. Hence, during the period from 2009-2015, the significance of weak form of market efficiency (RWH) is found ; whereas, the results of the weekly returns for all three samples conclusively reject the significance of serial dependency, hence pronounce the significance of random walk hypothesis in the Indian stock market. From the parametric test of serial correlation coefficient, we conclude that the Indian stock market is weak-form of market efficiency. Being consistence with the auto-correlation test, the unit root test concludes that the stationarity of the data is one of the necessary conditions for the random walk hypothesis.

Finally, the results of the variance ratio test for both daily as well as weekly samples conclusively provide strong evidence of the random walk hypothesis in the Indian stock markets as the joint test statistics as well as the individual statistics for all the lags are within the acceptance region of the *Z*- distribution, so the null hypothesis of Martingale is accepted. Finally, this paper concludes from the test results that the Indian stock market is a weak-form of market efficiency.

Limitations of the Study and Scope for Further Research

This research paper examines the evidence of weak form of market efficiency in the Indian stock market by analyzing the stock index SENSEX. This study is based on the concept that price movement of the stocks are fully reflected with all available information. Major limitation of the study is that it did not examine how the prices of the stocks moved with relation to the available information. This study is limited to the stock index SENSEX only. This study has tested only whether the stock movements are random or not, the series are auto-correlated or not, and whether the series have unit root or not. It did not create a link between the information and valuation of the stocks. With the evidences of this study, future researchers can explore in depth about how the price movements are related and move related to the available information, and how the fair value of stocks are determined based on the market efficiency.

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