Testing the EMH on Indian Stock Market: with Special Reference to Weak Form Efficiency

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Abstract

This study examines the random walk hypothesis to determine the validity of weak-form efficiency for two major stock markets (BSE & NSE) in India. The study uses daily observation over the span from 01/01/2003 to 31/12/2012 comprising of 2497 observations each. The random walk hypothesis is examined using Normality, Run Test, Kolmogorov-Smirnov (KS) Test, autocorrelation using Q-statistic & Multiple Variance Ratio Test using homoscedastic and heteroscedastic test estimates. On the basis of empirical results given by various tests, we can reject our null hypothesis. This suggests that the Indian stock markets does not show characteristics of random walk and as such are not efficient in the weak form implying that stock prices remain predictable. This implies that the Indian stock markets are not weak form efficient signifying that there is systematic way to exploit trading opportunities and acquire excess profits.

Key words: *Indian Stock Market, Weak-form Efficiency, Random Walk Hypothesis, Efficient Market Hypothesis.*

Introduction

The history of the random walk dates back to the beginning of 20th century, when Bachelier (1900) found Brownian motion in stock prices, implying that stock price movements are random and does not follow any systematic patterns. Following Bachelier's study, Cowels (1933) attempted to study the behavior of stock market prices and supported the findings of Bachelier and observed that their returns were higher than the return of a nominal investor but was poorer than the returns from an outright investment in representative stocks for the periods. In the mid-1960s, Eugene Fama introduced the idea of an "efficient" capital market to the literature of financial economics. Put simply, the idea is that intense competition in the capital market leads to fair pricing of debts and equity securities. Alexander (1961) was consistent to that of Kendall with few variants and stated that a series obtained by cumulating

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random numbers, will for brevity and clarity be called usually a random-difference series, since it is the first difference of the series and not the series itself, which are random number. An **Efficient Capital Market** is one in which security prices adjust rapidly to the arrival of new information and, therefore, the current prices of securities reflect all information about the security. The **Efficient Market Hypothesis** deals with informational efficiency, which is a measure of how quickly and accurately the market digests information.

In his original article, Fama divided the overall efficient market hypothesis (EMH) and the empirical tests of the hypothesis into three sub hypotheses depending on the information set involved: (1) weak-form EMH, (2) semi strong-form EMH, and (3) strong-form EMH. The phrase "efficient market" used to describe the market price that fully reflects all available information was coined by Fama (1970). The efficient market hypothesis (EMH) has a cousin, the semi-efficient market hypothesis (SEMH). The essence of the SEMH is the notion that some stocks are priced more efficiently than others.

In a classic paper published in 1980, Grossman and Stieglitz pointed towards the “impossibility of Informationally efficient markets” Their argument is fairly straightforward and goes as follows: If market prices reflect all information about stocks, no one would indulge into equity research (as it involves cost) and everyone will simply accept market prices as the best estimates of intrinsic values, and if no one does equity research to obtain and analyse information about companies, how can market prices reflect all information about stocks?

Review of Literature

Fama (1965) propounded his famous efficient market hypothesis for US securities, a number of empirical research have been carried out to test its validity, mainly in the developed countries with booming financial markets (Summers, 1986; Fama and French, 1988; Lo and Mackinlay, 1988). Fama classified stock market efficiency into three forms. They are namely ‘weak form’, ‘semi-strong form’ and ‘strong form’. Porterba and Summers (1988) confirmed the presence of mean reverting tendency and absence of random walk in the U.S. Stocks. The study of rejection of random walk in the share prices due to mean reverting tendency which is a consequence of persistence of one sided volley in share prices was first presented by De Bondt & Thaler (1985).

The efficiency of stock markets is one of the most controversial and well studied propositions in the literature of capital market. Even if there have been a number of researches and journal articles, economists have not yet reached a consensus about whether capital markets are efficient or not. The studies such as Abrosimova et al. (2002), Muslumov et al. (2003), Bizhan (2009), Zhang et al. (2010), Ajao and Osayuwu (2012) supports the weak form efficiency in Foreign Market and Sharma and Kennedy (1977), Gupta (1985), Sharma and Mahendru (2007), Venkatesan (2010), Sapate and Ansari (2011) support the weak form efficiency in Indian market. There have been some studies like Afonso and Teixeira (1998), Li and Xu (2001), Hamid et al. (2010), Shawn et al. (2012) do not support the existence of weak form efficiency in Foreign Market and Rao and Mukherjee (1971), Chaudhuri (1991), Poshakwale (1996), Madhusoodanan (1998), Pant and Bishnoi (2002), Mishra (2009), Sharma and Seth (2011) do not support the existence of weak form efficiency in Indian Market. This disagreement regarding the Efficient Market Hypothesis has generated research interest in this topic.

Methodology

It is a longitudinal survey. For the purpose of this study SENSEX and S&P CNX NIFTY indexes consider to study the stock market in India because of their undoubted popularity across the global so as to represent the Indian stock market. The data for the study consist of daily closing prices from 01/01/2003 to 31/12/2012 comprising of 2497 observations each and collected from the website www.nseindia.com and www.bseindia.com.

- **Objectives of the Study**

  The basic objective of the study is to test weak from efficiency in Indian stock market and specific objective is to determine whether the movement in the stock return series in India is independent, random and follow normal distribution.

- **Research Hypothesis**

  (a) Prime Hypothesis

  Ho: Indian stock market is efficient in weak form

  (b) Sub Hypothesis

  Ho_1: The stock returns in India follow a normal distribution.

  Ho_2: The stock returns in India are random over the time period of the study.

  Ho_3: successive return series are independent.

- **Variables of Study**

Name of Variables	Descriptions
Daily Returns of SENSEX	Natural Log of SENSEX
Daily Returns of NIFTY	Natural Log of NIFTY

- **Log of return**

  The daily closing prices of the Sensex and Nifty are used to arrive at the daily stock return data ignoring the days when there was no trading. Daily stock returns (*Rt*) are calculated by the log difference change in the price index:

$$R_t = \log\left(\frac{P_t}{P_{t-1}}\right)$$

Where Rt = Daily return for period t

P_t = Daily stock price for period t.

Pt-1 = Daily stock price for period t-1.

Ln = Natural log.

- **Tools Used in Analysis**

(a) ***Descriptive Statistics***

Descriptive Statistics for the stock returns includes the Mean, Standard Deviation Jarque-Bera, Variance, Kurtosis, Skewness and studentized Range. The Jarque-Bera statistics is used to test the normality of the data series.

(b) Non-Parametric Test

Kolmogorov-Smirnov (KS) Test: The One-Sample Kolmogorov-Smirnov Test procedure compares the observed cumulative distribution function for a variable with a specified theoretical distribution, which may be normal, uniform, Poisson, or exponential.

Run Test: Run Test can be used to deter mine whether the change of prices is serial or random. A run is defined as a series of consecutive returns of the same sign. Put simply, ++, —, 0, indicates five runs where "+" stands for a price increase "-" represents a price decrease, and "0" posits no change in price. A 'run' is defined by (Siegel, 1956), as "a succession of identical symbols which are followed or preceded by different symbols or no symbol at all." Suppose the price changes are independent, the total expected number of runs E(r) can be estimated for large samples as:

$$\mu R \text{ or } E(r) = \frac{2N_1 N_2}{N} + 1$$

Where, N= is the total number of observations (price changes or returns) =N1+N2
N1= the number of price changes (sign +)
N2= the number of price changes (sign -)
If the number of observations is large (N > 30), E(r) has nor mal distribution. The Variance of E(r) (σ_r^2) is given by:

$$\sigma_r^2 = \frac{2N_1 N_2 (2N_1 N_2 - N)}{(N)^2 (N-1)}$$

The Standard normal Z-test statistics used to conduct a Run Test is given by:

$Z = (R \pm 0.5) - E(r)/ \sigma_r$
R = actual number of runs
E(r) = the expected number of runs
σ_r = standard error of the expected number of runs.

(c) Parametric Test

Auto-Correlation Function Tests (ACF): Fama (1965) recommends that serial correlation tests be commonly used to determine whether there is a dependency in the successive values of log-price changes. A serial correlation coefficient, ρ_k, is estimated from the change in two prices, and then compared with zero at a specified significance level. If ρ_k is not significantly different from zero, then the price changes are independent; otherwise, the price changes are dependent.

$$\rho_k = \frac{\sum_{t=1}^{n-k} (a_t - \bar{a})(a_{t+k} - \bar{a})}{\sum_{t=1}^{N} (a_t - \bar{a})^2}$$

ρ_k = ACF of change price of lag k
N = number of observations
a_t = price change over period t
$\bar{a}$ = the sample mean of price change
a_{t+k} = price change over period t+k
K = lag of the period

The null and alternate hypothesis for the serial correlation tests are as follows:

Ho: $\rho_k = 0$ (price changes are independent)

Ha: $\rho_k \neq 0$ (price changes are not independent)

The Ljung-Box Q- statistics are given by:

$$Q_{LB} = N(N+2) \sum_{j=1}^{k} \frac{\rho_j^2}{N-j}$$

ρ_j = j autocorrelation
N = Number of observations

Multiple Variance Ratio Test: Our parametric procedure for measuring serial dependence is called "a variance-ratio test" which was developed by Lo and MacKinlay (1988, 1989). Chow and Denning (1993) point out that Lo and MacKinlay (1988) fails to control the test size for variance ratio estimates, resulting in large Type I errors.

The null hypothesis is that VR (q) equals one. The hypotheses for Variance Ratio are:

$$H_0: VR=1$$
$$H_a: VR\neq 1$$

The variance ratio is computed by dividing the variance of returns estimated form the longer interval by the variance of returns estimated from the shorter interval and then by normalizing this value to one by dividing it by the ratio of the longer interval to the shorter interval as follows:

$$\text{Var}(P_t - P_{t-q}) = {}_q\text{Var}(P_t - P_{t-1}).$$

Where q is any positive integer, the variance ratio, VR (q), is then determined as follows:

$$VR(q) = \frac{\frac{1}{p} Var(p_t - p_{t-q})}{Var(p_t - p_{t-1})} = \frac{\sigma^2(q)}{\sigma^2(1)}$$

For a sample size of nq + 1 observation ($P_0, P_1, \ldots, P_{nq}$), the formulas for computing $\sigma^2(q)$ and σ^2 (1) are given in the following equations:

$$\sigma^2(q) = \frac{\sum_{t=q}^{nq}(p_t - p_{t-q} - q\mu)^2}{h}$$

Where,

$$h = q(nq+1-q)\left(1-\frac{q}{nq}\right)$$

And

$$\mu = \frac{1}{nq}\sum_{t=1}^{nq}(p_t - p_{t-1}) = \frac{1}{nq}(p_{nq} - p_o)$$

And

$$\sigma^2(1) = \frac{\sum_{t=1}^{nq}(p_t - p_{t-1} - \mu)^2}{(nq-1)}$$

Under the assumption of homoscedasticity and heteroscedasticity increments, two standard normal test statistics, Z (q) and Z*(q) respectively, developed by Lo and MacKinlay (1988). Z (q) assumes an independent and identical distributed normal error term. Then, the standard normal Z test statistics is computed as follows:

$$Z(q) = \frac{VR(q)-1}{[\phi(q)]^{1/2}} \approx N(0,1)$$

Z*(q) test statistics, allows for a general heteroscedasticity of error term. The heteroscedasticity consistent standard normal test statistics relaxed the assumption of normality. The formula is given as follows:

$$Z^*(q) = \frac{VR(q)-1}{[\phi(q)]^{1/2}} \approx N\ (0.1)$$

Where $\phi(q)$ is the asymptotic variance of the variance ratio under the assumption of homoscedasticity, and $\phi^*(q)$ is the asymptotic variance of the variance ratio under the assumption of heteroscedasticity:

$$\phi(q) = \frac{2(2q-1)(q-1)}{3q(nq)}$$

$$\phi^*(q) = \sum_{j=1}^{q-1}\left[\frac{2(q-j)}{q}\right]^2 \partial(j)$$

Where $\partial(j)$ is the heteroscedasticity-consistent estimator and computed as follows:

$$\partial(j) = \frac{\sum_{t=j+1}^{nq}(p_t - p_{t-1} - \mu)^2 (p_{t-j} - p_{t-j-1} - \mu)^2}{\left[\sum_{t=1}^{nq}(p_t - p_{t-1}\hat{\mu})^2\right]}$$

Note that both standard normal Z-statistics and Z* statistics are approaching N (0, 1).

The rejection of any one or more H0i rejects the random walk null hypothesis. Let $\{\psi(q),.., \psi(q_m)\}$ be the set of z-statistics for RWH1 and let $\{\psi^*(q),.., \psi^*(q_m)\}$ be the set of z-statistics for RWH3. Then, if is denoted by $M\psi = \max |\psi\ (q_i)|_{i=1...m}$ and by $M\psi^* = \max |\psi\ (q_i)|_{i=1...m}$ the random walk hypothesis will be rejected if $|M\psi| > SMM(\alpha,m,\infty)$ or $|M\psi^*| > SMM(\alpha,m,\infty)$, where $SMM(\alpha,m,\infty)$ is the asymptotical critical value of the Studentized Maximum Modulus distribution with parameter *m* and ∞ degrees of freedom. In fact, this critical value can be computed by using standard normal distribution:

$$SMM\ (\alpha, m, \infty) = z_{\alpha +/2}$$

Where $\alpha^+ = 1-(1-\alpha)^{1/m}$

Data Analysis and interpretation

Figure 1: Daily Return of BSE SENSEX

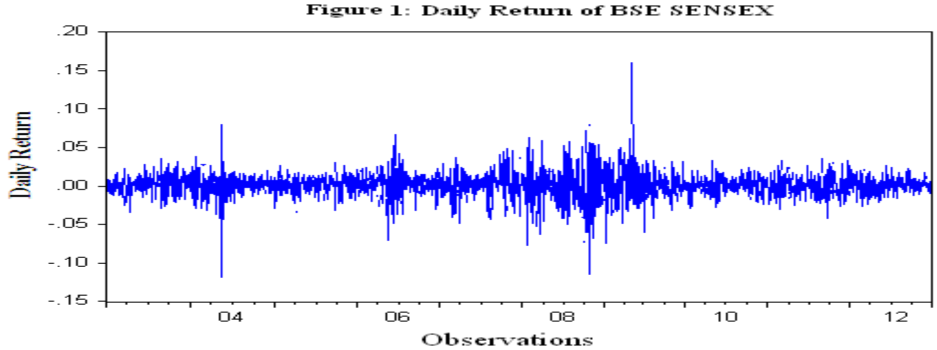
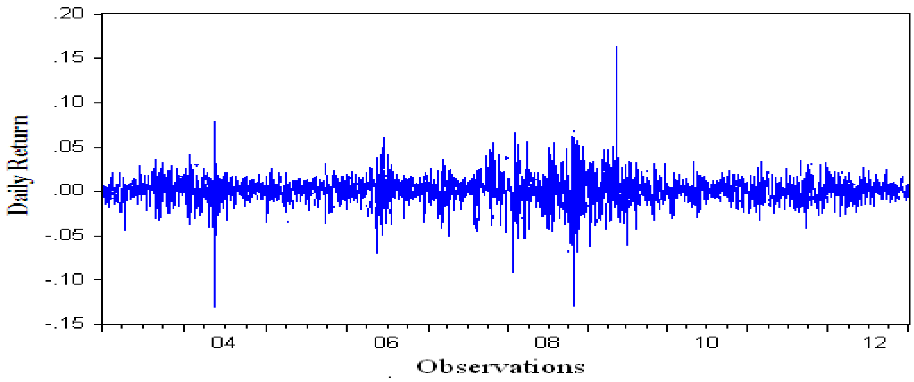


Figure 2: Daily Return of NSE NIFTY



Above figures plot the daily returns on BSE SENSEX and NSE NIFTY and it is very apparent from this that the amplitude of the daily stock returns is changing. The magnitude of the changes is sometimes large and sometimes small.

(a) Analysis of Descriptive statistics

Table 1: Descriptive statistics

Description	SENSEX	NIFTY
Number of Observation	2497	2497
Mean	0.000701	0.000675
Median	0.001246	0.001376
Std. Dev	0.016319	0.016525
Minimum	-0.118092	-0.130539
Maximum	0.1599	0.163343
Range	0.28	0.29
Skewness	-0.084376	-0.25955
Kurtosis	10.90983	11.88223
Jarque-Bera	6512.37	8236.309
Studentized Range	17.16	17.55

The mean returns for both markets are very close to zero indicating that the series are mean reverting. The result shows that (table 1) the SENSEX and NIFTY has a left tail because both the Index have negative Skewness. Kurtosis values of the market return series for both the indices are much higher than three, indicating that the return distribution is fat-tailed or leptokurtic relative to a normal distribution and sharply peaked about the mean as shown in figure 3 & 4. The reported probability is the probability that a Jarque-Bera statistic exceeds (in absolute value) the observed value under the null hypothesis a small probability value leads to rejection of the null hypothesis of normal distribution. The values of Studentized Range are larger than 6 for the sample period further suggesting that the stock returns on NSE and BSE are not normally distributed.

Figure 3: Descriptive statistics of BSE SENSEX

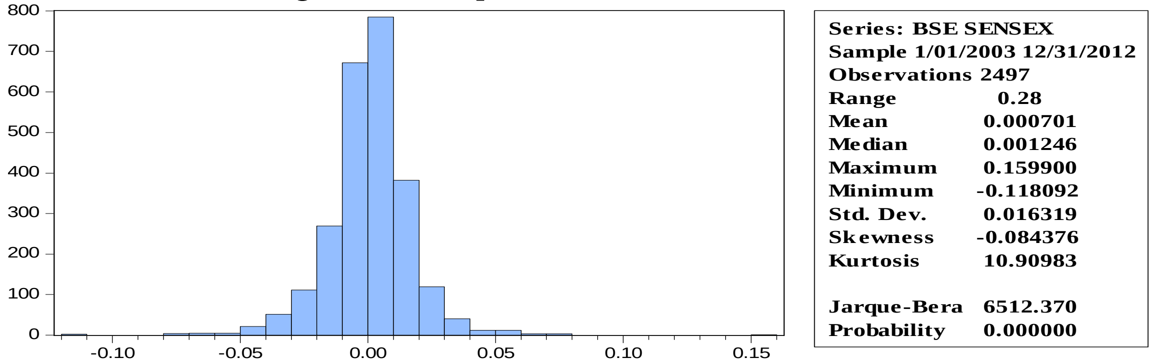
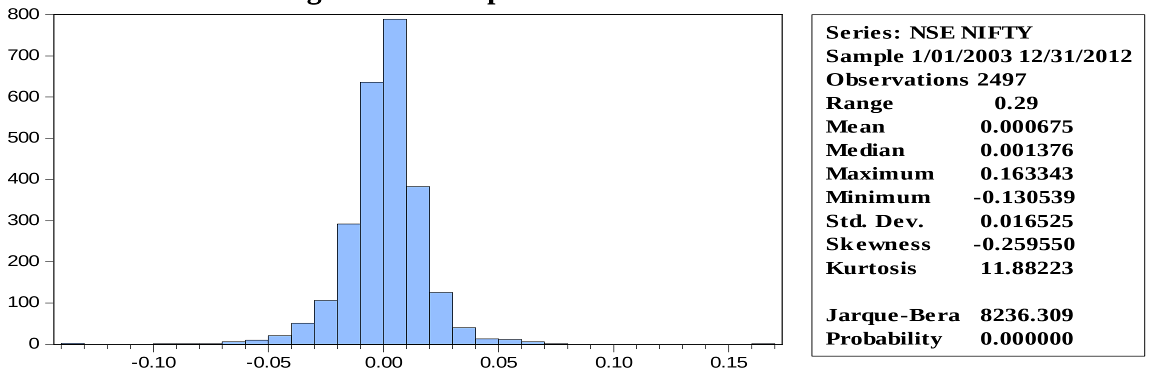


Figure 4: Descriptive statistics of NSE NIFTY



(b) Result of Non-parametric Test

Table 2: Result of One-Sample Kolmogorov-Smirnov Test

Particular		SENSEX	NIFTY
N		2497	2497
Normal Parameters[a,,b]	Mean	0.0007	0.0007
	Std. Deviatio	0.01632	0.01652
Most Extreme Differences	Absolute	0.072	0.071
	Positive	0.068	0.063
	Negative	-0.072	-0.071
Kolmogorov-Smirnov Z		3.585	3.556
Asymp. Sig. (2-tailed)		0	0

As given in the table, returns of the Indexes, SENSEX and NIFTY do not follow normal distribution as the value of probability is less than 0.05 at 5% level of significance.

Table 3: Result of Run test

a. Mean	SENSEX	NIFTY
Test Value [a]	0.0007	0.0007
Cases < Test Value	1186	1186
Cases >= Test Value	1311	1311
Total Cases	2497	2497
Number of Runs	1176	1192
Z	-2.824	-2.182
Asymp. Sig. (2-tailed)	0.005	0.029

The result of the run test (table 3) for daily observations of both Index show that they do not follow random walk over the time of study and for this reason both NSE and BSE are considered to be weak form inefficient.

(c) Result of Parametric Test

Table 4: Result of Auto-Correlation Function BSE SENSEX

Lag	ACF	T	Ljung-Box	S.E	df	Sig.[b]
1	0.07*	3.5	12.194	0.02	1	0
2	-0.042*	-2.1	16.611	0.02	2	0
3	-0.008	-0.4	16.768	0.02	3	0.001
4	-0.004	-0.2	16.803	0.02	4	0.002
5	-0.027	-1.35	18.618	0.02	5	0.002
6	-0.047*	-2.35	24.073	0.02	6	0.001
7	0.013	0.65	24.506	0.02	7	0.001
8	0.054*	2.7	31.882	0.02	8	0
9	0.018	0.9	32.727	0.02	9	0
10	0.031	1.55	35.197	0.02	10	0
11	-0.008	-0.4	35.351	0.02	11	0
12	0	0	35.351	0.02	12	0
13	0.031	1.55	37.809	0.02	13	0
14	0.047*	2.35	43.297	0.02	14	0
15	-0.004	-0.2	43.338	0.02	15	0
16	0.003	0.15	43.361	0.02	16	0
17	0.049*	2.45	49.506	0.02	17	0
18	-0.012	-0.6	49.89	0.02	18	0
19	-0.006	-0.3	49.99	0.02	19	0
20	-0.042*	-2.1	54.517	0.02	20	0
21	0.001	0.05	54.518	0.02	21	0
22	0.005	0.25	54.582	0.02	22	0
23	-0.036	-1.8	57.847	0.02	23	0
24	0.031	1.55	60.277	0.02	24	0
25	0.033	1.65	62.967	0.02	25	0
26	0.031	1.55	65.339	0.02	26	0
27	0.013	0.65	65.788	0.02	27	0
28	0.014	0.7	66.272	0.02	28	0
29	-0.02	-1	67.297	0.02	29	0
30	-0.03	-1.5	69.511	0.02	30	0

*Signification Autocorrelation at Two Standard Error Limits $\geq 0.02 \times 2 = \pm 0.04$
T-Value Less or Greater ± 1.96 (At 5%Level of Significances)
LB statistics significant at 5% level of significance
Based on the asymptotic chi-square approximation.

Table 5: Result of Auto-Correlation Function NSE NIFTY

Lag	ACF	T	Ljung-Box	S.E	df	Sig.[b]
1	0.066*	3.3	10.841	0.02	1	0.001
2	-0.038	-1.9	14.539	0.02	2	0.001
3	-0.004	-0.2	14.584	0.02	3	0.002
4	0.006	0.3	14.675	0.02	4	0.005
5	-0.027	-1.35	16.49	0.02	5	0.006
6	-0.052*	-2.6	23.28	0.02	6	0.001
7	0.017	0.85	24.02	0.02	7	0.001
8	0.047*	2.35	29.604	0.02	8	0
9	0.015	0.75	30.18	0.02	9	0
10	0.03	1.5	32.464	0.02	10	0
11	-0.014	-0.7	32.977	0.02	11	0.001
12	-0.003	-0.15	33.002	0.02	12	0.001
13	0.035	1.75	36.167	0.02	13	0.001
14	0.052*	2.6	42.884	0.02	14	0
15	-0.002	-0.1	42.897	0.02	15	0
16	0.001	0.05	42.901	0.02	16	0
17	0.05*	2.5	49.15	0.02	17	0
18	-0.019	-0.95	50.026	0.02	18	0
19	-0.004	-0.2	50.074	0.02	19	0
20	-0.049*	-2.45	56.174	0.02	20	0
21	0.002	0.1	56.181	0.02	21	0
22	0.003	0.15	56.206	0.02	22	0
23	-0.033	-1.65	58.965	0.02	23	0
24	0.032	1.6	61.571	0.02	24	0
25	0.028	1.4	63.504	0.02	25	0
26	0.023	1.15	64.79	0.02	26	0
27	0.013	0.65	65.233	0.02	27	0
28	0.01	0.5	65.511	0.02	28	0
29	-0.026	-1.3	67.17	0.02	29	0
30	-0.027	-1.35	69.039	0.02	30	0

*Signification Autocorrelation at Two Standard Error Limits ≥ 0.02 × 2 = ± 0.04
T-Value Less or Greater ± 1.96 (At 5%Level of Significances)
LB statistics significant at 5% level of significance
Based on the asymptotic chi-square approximation.

According to the values of ACF presented in table 4 & 5, the values for NIFTY are found to be significant at lags 1,6,8,14,17 and 20. The behaviour of SENSEX is found to be worse as compared to NIFTY because ACFs are significant at lags 1, 2,6,8,14,17 and 20 twice the standard error. The nonzero auto-correlation of the series is further tested by Ljung-Box Q statistics, which are jointly significant at 5% level at 30 degrees of freedom. . From the Ljung-Box Q Test, we see that there is sufficient evidence to reject the null hypothesis of no autocorrelation at the 95% confidence level for all the daily returns.

(d) Results of Variance Ratio Test

Index	Period (q)	q =2	q =4	q =8	q =16	Max |Z|
SENSEX	VR(q)	0.5605	0.2704	0.1277	0.0677	
	Z(q)	-21.95*	19.48*	-14.73*	-10.58*	21.95*
	Z*(q)	-11.27*	-10.67*	-8.66*	-6.59*	11.27*
NIFTY	VR(q)	0.5563	0.2666	0.1281	0.0676	
	Z(q)	-22.17*	-19.59*	-14.73*	-10.58*	22.17*
	Z*(q)	-11.29*	-10.54*	-8.57*	-6.61*	11.29*

*Probability approximation using studentized maximum modulus with parameter value 4 and infinite degrees of freedom 3.022 (sample sizes>120, m=4, α=0.01)

* Indicates statistically significant from 1 per cent level

VR (q) is variance ratio, z (q) is homoscedasticity test statistic, and Z*(q) is heteroscedasticity test statistic.

Since $\text{Max}|Z(q)|_{SENSEX} = 21.95 > 3.022$ and $\text{Max}|Z(q)|_{NIFTY} = 22.17 > 3.022$, we strongly reject the null hypothesis that the logarithm of the stock price index follows a homoscedastic random walk. Similarly, since, $\text{Max}|Z^*(q)|_{SENSEX} = 11.27 > 3.022$ and $\text{Max}|Z^*(q)|_{NIFTY} = 11.29 > 3.022$, we strongly reject the null hypothesis that the logarithm of the stock price index follows a heteroscedastic random walk and homocadasticity. We can conclude that autocorrelation of daily increments in the natural logarithm of the stock market price index results in the Random Walk Hypothesis being rejected for the Indian equity market.

Conclusion

On the basis of empirical results given by various tests in previous section, we can reject our null hypothesis and accept the following alternate hypothesis:

1. The stock returns in India do not follow a normal distribution.
2. The stock returns in India are not random over the time period of the study.
3. Successive return series are not independent.

By rejecting the null hypothesis and accepting the above alternative hypothesis, we reject our prime null hypothesis and accept the following alternative hypothesis:

Indian stock market is not efficient in weak form.

There are opportunities of predicting the future prices there by earning excess profits in Indian stock markets. Market inefficiency may imply excess price volatility in the short run because prices change by more than the value of the new information People such as corporate officers who have inside information can do better than the market averages, and individuals and organizations that are especially good at digging out information on small, new companies are likely to consistently do so well. Market inefficiency is also, an indicative of sub-optimal allocation of portfolios into capital market of India.

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