Test of Random Walk Hypothesis of the Daily SENSEX Return

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Abstract

The present study investigates whether the Indian Stock Market represented by BSE SENSEX is efficient or not. An attempt has also been made to test the assumption of independent and identically distributed (i.i.d) in respect to market returns in terms of daily SENSEX return data, which is the most restrictive version of the random walk hypothesis. The result of unit root test shows that the daily SENSEX returns are random. Moreover, to capture the possible non-linearity in the time series data TARCH(1,1) model has been fitted. Furthermore, BDS test has been applied to Standardized residuals of the above estimated model to check whether they are i.i.d. or not. The estimated result of the said test clearly indicates that null hypothesis of i.i.d. could not be rejected. Hence, it could be concluded that daily SENSEX returns follow Random Walk Model-I as described by Campbell et al (1997) and in general Indian Stock Market is efficient in its weak form during the study period.

Keywords: SENSEX, Random Walk Model-I, TARCH(1,1), BDS test..

1. Introduction

According to Fama (1970) in an efficient stock market price fully reflects all available and relevant information. It implies that share price changes are independent and fluctuate only in response to the random flow of news. Trading strategies based on past and current information, therefore, are useless in generating excess profit opportunities.

This implies a market where a random walk model best describes stock prices.

Three versions of random walk model had been described by Campbell et al (1997). Random Walk Model-I or strict white noise process requires sequences of price changes to be independent and identically distributed (i.i.d.) If the identically distributed assumption is dropped and the assumption that only price changes are independent is retained then it is Random Walk Model-II. Finally, in the Random Walk Model-III white noise process is obtained by relaxing both the independent and the identically distributed assumption.

Al Loughani and Chappell (1997) applied the BDS test to the daily changes of FTSE 30 share index of the London Stock Exchange and found evidence of non-linear dependence which they could successfully capture with a GARCH M (1,1) model.

Saadi and Gandhi (2006) argued that studies of the random walk hypothesis must be designed to detect both linear and non-linear dependencies, as share price movements

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that were unpredictable under linear models might be predictable if non-linear ones were considered. Not including non-linear models according to them, thus leads to erroneous acceptance of Efficient Market Hypothesis (EMH), a case of a Type II error.

Given the growing theoretical and empirical studies showing that share price returns are non-linear, evidence of uncorrelated share price changes is not a sufficient condition for a market to be efficient. Although there exists an extensive literature on capital market efficiency and stock returns, most of these works concentrate on the developed countries. However, with the increasing number of emerging markets among the less-developed nations and their growing importance in international portfolio diversification, the study of these markets is becoming more important. Therefore, the present study seeks to examine whether the Indian Stock Market represented by BSE SENSEX is efficient or not and to test the assumption of assumption of i.i.d in respect to market returns in terms of daily SENSEX return data, which is the most restrictive version of the random walk hypothesis.

2. Review of Literature

A considerable number of studies could be found testing weak form of efficiency in Indian Stock Market. Rao and Mukherjee (1971), Sharma (1983), Gupta (1985) etc documented strong evidences in favour of weak form of efficiency in Indian Stock Market.

Poshakwale (1996) examined daily prices of BSE 100 companies for the period from 1987 to1994. He found that the frequency distribution of the prices in BSE did not follow a normal distribution. Furthermore, his results of runs and serial correlation tests also provided evidence on non-random behavior of stock prices in BSE. Poshakwale (1996) also found evidence that the average returns were different on each day of the week, result showed that the returns achieved on Friday are significantly higher compared to rest of the days of the week. His study indicated that Indian market did not follow random walk during the study period.

Madhusoodanan (1998) in his study found that both the BSE Sensitive Index and BSE National Index did not follow random walk during the selected study period.

Ramasastri (1999) tested Random Walk Hypothesis on Indian Stock Market during the post liberalization period. The researcher came to the conclusion that the said market was not efficient during the study period.

Mitra (2000) using Artificial Neural Network (ANN) technique forecast Bombay Stock Exchange return and showed that random walk did not hold there.

Deb (2003) tested weak form of efficiency on five major indices. His study showed that except BSE 100 indices none other indices were efficient.

Studies conducted by Chaudhuri and Wu (2004) and Ahmed et al (2006) also failed to establish the weak form of efficiency in Indian Stock Market.

Verma and Rao (2007) examined the weak form of efficiency of the companies included in the BSE 100 index as on 31st March, 2001. The results showed that in 1998-99 and 1999-2000 there were no evidence of market efficiency. However, in the year 2000-01 market was found efficient.

Weak form of efficiency of the two major stock indices in the country has been tested by Gupta and Basu (2007) for a period from 2001 to 2006.The study reported significant autocorrelation in the returns and thereby rejected the Random Walk Hypothesis in respect to the said indices.

Study conducted by Sah and Omkarnath (2007) reported mixed results in case of daily NIFTY returns when weak form of efficiency is concerned.

Sharma and Chander (2011) found that there was possibility to develop predictable pattern of stock return from its past values during the study period from July 1997 to December 2007.

Most of the previous research studies in this context primarily focused on detecting linear structure in the financial data. Applying autocorrelation test or runs test studies looked into the linear predictability of future share price changes. If the share returns turned out to be uncorrelated, then the EMH was accepted and the stock market in question were taken to be informationally efficient, and vice versa. The traditional tests of serial correlation, which checks for linear predictability, cannot explicitly test for the i.i.d. assumption implied by Random Walk Hypothesis.

Dhankar and Chakraborty (2007) investigated whether the non-linear dependence in major daily indices of the three South Asian countries provided by the respective stock exchanges is caused by predictable conditional volatility. The BDS test was applied for investigating the same has strongly rejected the null hypothesis of independent and identical distribution of the return series.

3. Data

The present study is based on the daily closing time series data of SENSEX, the well known stock index of India, covering the period from 2nd January, 2000 to 31st October, 2011, downloaded from the website www.finance-yahoo.com.

The sample consists of 2910 observations. Since one data point has been lost after calculating daily returns, ultimately 2909 observations remain there.

4. Methodology

4.1. Calculation of Daily Market Returns

Daily Market Returns (r_t) have been computed as follows:

$$r_t = \ln(I_t) - \ln(I_{t-1})$$

Where, ln denotes natural logarithm

I_t is the closing index value at day 't'

I_{t-1} is the closing index value at day before 't'

4.2. Distribution of Data

To observe the pattern of distribution of the time series data skewness and kurtosis have been calculated. Zero skewness implies symmetry in the distribution whereas, kurtosis indicates the extent to which probability is concentrated in the centre and especially at the tail of the distribution. Kurtosis measures the peakedness of a distribution relative to the normal distribution. A distribution with equal kurtosis as the normal distribution is called 'mesokurtic'; a distribution with small tails is called 'platykurtic' and a distribution with a large tail is called 'leptokurtic'.

Furthermore, to test normality of the time series data the study applies Jarque-Bera Test in the following form:

$$JB = n\left[\frac{S^2}{6} + \frac{(K-3)^2}{24}\right]$$

Where, n= number of observations,

S = Skewness

K= Kurtosis

For a normal distribution the values of S and K should be 0 and 3 respectively so that JB becomes equal to 0. A high value of JB is an indicator of non-normality.

4.3. Unit Root Test

The equation of the random walk with drift process is:

$$r_t = \mu + r_{t-1} + \varepsilon_t \qquad \varepsilon_t \sim i.i.d(0,\sigma^2)$$

Where, μ is the drift parameter, ε_t is the random error term. In the RW1 random walk hypothesis (Campbell et al., 1997) the ε_t s are independently and identically distributed (i.i.d.) with mean 0 and variance σ^2.

To test the random walk of the time series return data Phillips-Perron Unit Root Test has been used. Phillips and Perron (1988) propose a nonparametric method of controlling for serial correlation when testing for a unit root. The PP method estimates the non-augmented DF test equation

$$\Delta y_t = \alpha y_{t-1} + x_t\delta + \varepsilon_t \qquad (1)$$

and modifies the t-ratio of the coefficient so that serial correlation does not affect the asymptotic distribution of the test statistic. The PP test is based on the statistic:

$$\tilde{t}_\alpha = t_\alpha\left(\frac{\gamma_0}{f_0}\right)^2 - \frac{T\left(f_0-\gamma_0\right)\left(se\left(\hat{\alpha}\right)\right)}{2 f_0^{1/2} s} \qquad (2)$$

Where $\hat{\alpha}$ is the estimate, and t_α the t ratio of α, $se\left(\hat{\alpha}\right)$ is coefficient standard error, and s is the standard error of the test regression. In addition, γ_0 is a consistent estimate of the error variance in (1) (calculated as , $(T-k)s^2/T$ where k is the number of regressors), f_0 is an estimator of the residual spectrum at frequency zero.

The MacKinnon(1996) critical value calculations have been used to compare the computed t value and if p value is significant then there is no unit root in the series.

One can test whether the returns are i.i.d. or not by directly testing the time series return data. Instead, the time series data could be filtered for any non linearity and then the above test could be applied. The present study fit GARCH type model on return data.

4.4. Testing the 'ARCH Effects'

Before estimating a GARCH-type model, it is sensible first to compute the Engle (1982) test for ARCH effects to make sure that this class of models is appropriate for the data. For this the following AR(1) equation has been run:

$$y_t = \alpha + \beta y_{t-1} + \varepsilon_t \quad (3)$$

Where, y_t is the market return at day t.

A test for the presence of ARCH in the residuals has been calculated by regressing the squared standardized residuals on a constant and *p* lags, here *p* has been taken as 5

$$\varepsilon_t^2 = \beta_0 + \left(\sum_{s=1}^{p} \beta_s \varepsilon_{t-s}^2 \right) + v_t \quad (4)$$

The *F*-statistic is an omitted variable test for the joint significance of all lagged

Squared residuals. The Observed*R-squared statistic is Engle's LM test statistic, computed as the number of times of observation from the test regression. The exact finite sample distribution of the *F*-statistic under H_0 is not known, but the LM test statistic is asymptotically distributed as a χ^2(p). If F-statistic and the LM statistic are found significant then there is ARCH effect.

4.5. Estimation of TARCH (1,1) Model

The estimation of the GARCH(1,1) model involves both the estimation of a mean and a conditional variance equation. The conditional mean equation is

$$Y_t = X_t\theta + \nu_t \quad (5)$$

Where, X_t is the vector of exogenous variables.

If there is no exogenous variable the above equation can be re-represented as

$$Y_t = C + \varepsilon_t \quad (6)$$

The conditional variance σ_t^2 can be stated in the following equation

$$\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \beta \sigma_{t-1}^2 \quad (7)$$

Where, α_0 = mean

ε_{t-1}^2 = volatility from the previous period, measured as the lag of the squared residuals from the mean equation. It is also called the ARCH term.

σ_{t-1}^2 = last period's forecast variance. It is also called the GARCH term.

For non negativity $\alpha_1 \geq$ and $\beta \geq 0$ and $\alpha_1 + \beta \geq 1$.

However, GARCH models enforce a symmetric response of volatility to positive and negative shocks. The conditional variance in equation (7) is a function of the magnitudes of the lagged residuals and not their signs (by squaring the lagged error in (7), the sign is lost). However, it has been observed that a negative shock to stock market return time series is likely to cause volatility to rise by more than a positive shock of the same magnitude, (Black (1976)).This is called the leverage effect.

Glosten, Jaganathan and Runkle(1993) introduced Threshold GARCH model (TARCH) which is also known as GJR model which is an extension of GARCH with an additional term to account for possible asymmetries. The conditional variance can be represented as:

$$\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \beta \sigma_{t-1}^2 + \gamma \varepsilon_{t-1}^2 I_{t-1} \quad (8)$$

Where, $I_{t-1} = 1$ if $\varepsilon_{t-1} < 0$
= 0 otherwise

In this model $\varepsilon_{t-i} > 0$ is good news and $\varepsilon_{t-i} < 0$ is bad news. They have differential effects on conditional variance. Good news has an impact on α_1 and bad news has on $\alpha_1 + \gamma$.

For a leverage effect, γ >0. For non negativity $\alpha_1 \geq$ and $\beta \geq 0$ and $\alpha_1 + \gamma \geq 0$.

4.6. BDS Independence Test

The most important and useful test available in the literature for detecting nonlinear patterns i.e., the existence of potentially forecastable structures, is due to Brock et al. (1987, revised 1996), denoted as BDS test. The BDS test as described in Brock et al. (1996) has been applied to standardized residuals of estimated equation 8 to check whether the residuals are independent and identically distributed (i.i.d.).

The BDS test is based on the correlation integral as the test statistic. Given a sample of i.i.d. observations, $\{x_t : t = 1,2,3,......,n\}$ Brock et al (1996) showed:

$$BDS = \sqrt{n-m+1}\,\frac{b_{m,n}(\xi)}{\sigma_{m,n}(\xi)} \rightarrow N(0,1)$$

Where, $b_{m,n}(\xi) = c_{m,n}(\xi) - c_{1,n-m+1}(\xi)^m$, $c_{m,n}(\xi)$ and $c_{1,n-m+1}(\xi)^m$ are correlation integrals. $\sigma_{m,n}(\xi)$ is the standard error of $b_{m,n}(\xi)$. ξ is the distance and *m* is the dimension. Present study considers ξ = 0.7 and m = 2 to 6.

The null hypothesis (H_0): The series is i.i.d., meaning that for a given ξ and an m > 1, $c_{m,n}(\xi) - c_{1,n-m+1}(\xi)^m$ = 0. If the computed BDS statistic is significant at 1% level the null hypothesis would be rejected and the series is not i.i.d.

5. Empirical Results

5.1 Descriptive Statistics

Descriptive statistics of the daily SENSEX return have been reported in the Table 1. It could be seen that the returns during the study period varies between -0.118092 to 0.159900. So a wide fluctuation in daily returns could be witnessed. The mean return during the whole study period is 0.000420 which is very near to zero. Skewness is negative indicating a relatively long left tail compared to the right one. Christie (1982) discoverd a negative correlation between current returns and future volatilities which increased the skewness of the return distribution.

Kurtosis in excess of 3 indicating heavy tails and the distribution is leptokurtic. These findings are similar to the existing literature. Moreover, a highly significant large JB statistic confirms that the return series is not normally distributed.

Table 1 Descriptive Statistics

Mean	*0.000420*
Median	0.001164
Maximum	0.159900
Minimum	-0.118092
Std. Dev.	0.017059
Skewness	-0.186878
Kurtosis	9.066652
Jarque-Bera	4477.916
Probability	0.000000
Sum	1.222205
Sum Sq. Dev.	0.846266
Observations	2909

5.2. Unit Root Test

The PP test result is reported in the Table 2. The computed value of PP is -49.84278* which is far greater (in absolute term) than the critical value of -3.4363 at 1% significant level. Therefore, unit root test strongly accepts the null hypothesis of random walk of the return series under consideration.

Table 2 PP Test

	Adj. t-Stat	*Prob.*
Phillips-Perron test statistic	-49.84278	0.0001

5.3. Test Results of ARCH Effect

The regression results of equation (3) have been presented in Table 3.

Table 3 Regression Result of Equation(3)

Variable	*Coefficient*	*Std. Error*	*t-Statistic*	*Prob.*
C	0.000381	0.000316	1.208478	0.2270
RET(-1)	0.078506	0.018490	4.245778*	0.0000

*Significant at 1% level.

The squared residuals from the above regression has been taken for ARCH- LM test

The ARCH- LM test results (equation 4) have been reported in Table 4.

Table 4 ARCH-LM test Results

Heteroskedasticity Test: ARCH				
F-statistic	60.40348	Prob. F(5,2897)		0.0000
Obs*R-squared	274.0706	Prob. Chi-Square(5)		0.0000
Test Equation:				
Dependent Variable: RESID^2				
Method: Least Squares				
Date: 11/28/11 Time: 20:54				
Sample (adjusted): 7 2909				
Included observations: 2903 after adjustments				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.000143	1.68E-05	8.495669	0.0000
RESID^2(-1)	0.140899	0.018547	7.596690	0.0000
RESID^2(-2)	0.099839	0.018527	5.388675	0.0000
RESID^2(-3)	0.057902	0.018587	3.115169	0.0019
RESID^2(-4)	0.148976	0.018526	8.041540	0.0000
RESID^2(-5)	0.058205	0.018547	3.138237	0.0017

From the above Table it appears that both the *F*-statistic and the *LM*-statistic are highly significant, suggesting the presence of ARCH effect in the daily SENSEX returns.

5.4. Estimated Results of TARCH (1,1) Model

The estimated results of equation 8 has been reported in Table 5

Table 5 Estimated Results of TARCH (1,1) Model

	Variance Equation		T statistic	Probability
C	7.44E-06	8.43E-07	8.822468	0.0000
RESID(-1)^2 [α_1]	0.061428	0.007586	8.097752	0.0000
RESID(-1-)^2*(RESID(-1-)<0)[γ]	0.130015	0.014951	8.695931	0.0000
GARCH(-1) [β]	0.845879	0.009719	87.03060	0.0000

From the above table it could be observed that $\alpha_1 + \beta$ is quite high (approximately, 0.90) the bad news has more effect on volatility than the good news. Moreover, since γ is positive, there is news asymmetry.

Table 6 Box-Pierce Q Statistics of Squared Residuals

	AC	PAC	Q-Stat	Prob
1	-0.018	-0.018	0.9845	0.321
2	-0.007	-0.007	1.1256	0.570
3	0.014	0.014	1.7118	0.634
4	0.019	0.019	2.7211	0.606
5	-0.009	-0.008	2.9473	0.708
6	-0.009	-0.009	3.1609	0.788
7	-0.006	-0.007	3.2579	0.860
8	-0.020	-0.021	4.4437	0.815
9	-0.018	-0.018	5.3539	0.802
10	0.037	0.037	9.3944	0.495
11	-0.017	-0.015	10.266	0.507
12	-0.002	-0.001	10.284	0.591
13	0.006	0.005	10.402	0.661
14	0.009	0.007	10.625	0.715
15	0.003	0.004	10.643	0.777
16	0.012	0.012	11.038	0.807
17	-0.001	-0.001	11.040	0.854
18	-0.012	-0.012	11.483	0.873
19	-0.004	-0.004	11.521	0.905
20	0.001	-0.001	11.526	0.931
21	0.017	0.020	12.419	0.928
22	0.020	0.021	13.538	0.917

To see whether any ARCH effect is still present or not Q statistic [$Q = n\sum_{k=1}^{m} \hat{\rho}_k^2 \sim \chi^2 m$

Where, n = sample size and m= lag length. Since the present study uses daily data, a lag length up to 22 has been considered. The reason behind this is that there could be at most 22 trading days in a 30 days month.

If the computed Q statistic is significant then it indicates the presence of autocorrelation.

On the squared residuals of estimated equation (8) has been calculated and the result has been reported in Table 6. It is clear that none of the Q statistic at any lag is significant. So no ARCH effect is left.

5.5. Result of BDS Test

BDS test has been applied to detect if there is any non-linear dependence in the TARCH(1,1) standardized residuals. The results have been reported in Table 7.

Table 7 BDS Test Results

Dimension	BDS Statistic	Std. Error	z-Statistic	Prob.
2	-0.001520	0.001301	-1.168148	0.2427
3	-0.002584	0.002057	-1.256271	0.2090
4	-0.002044	0.002436	-0.839373	0.4013
5	-0.001299	0.002524	-0.514775	0.6067
6	-0.000432	0.002420	-0.178628	0.8582

From the above table it could be seen that none of the BDS statistics at the chosen ξ, i.e., 0.7 is significant. Hence, null hypothesis of i.i.d. could not be rejected.

6. Conclusion

An attempt has been made in the present study to investigate whether the Indian Stock Market represented by BSE SENSEX is efficient or not and the assumption of i.i.d in respect to market returns in terms of daily SENSEX return data, which is the most restrictive version of the random hypothesis, holds good or not.

The result of unit root test shows that the daily SENSEX returns are random. Moreover, to capture the possible non-linearity in the time series data TARCH(1,1) model has been fitted. Furthermore, BDS test has been applied to test if standardised residuals are i.i.d. or not. The estimated result of the said test clearly indicates that null hypothesis of i.i.d. could not be rejected.

Hence, it could be concluded that daily SENSEX returns follow Random Walk Model-I as described by Campbell et al (1997) and in general Indian Stock Market is efficient in its weak form during the study period.

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