TESTING FOR THE WEAK FORM OF MARKET EFFICIENCY IN BOMBAY STOCK EXCHANGE

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Abstract

Stock market behaviour has been an important topic of interest and study over the last many years. The efficient market hypothesis (EMH) and theories around randomness of stock prices as well as alternatives to randomness have been researched and documented. If a market is efficient then information is quickly absorbed into the current price and there is no more gain to be made from the security concerned. In an informationally inefficient market, the same is not true and abnormal returns can be made by investors who do indeed have an advantage of information. Initial studies on stock market efficiency suggested markets were efficient and the Random walk theory held true. Further research has shown exceptions to Random Walk Hypothesis (RWH) do exist as shown by empirical reseach. Another prominent work on efficient markets is the book "Random walk down Wall Street". On the contrary there is evidence from the action of investment leaders such as Warren Buffet who have had consistent gains on the stock market much beyond the normal stock market returns.

There is a curiosity on part of the researcher to investigate whether the Indian stock market follows a random behaviour or not. For the purpose of analysis, three indices from the BSE have been selected. The time period for analysis is Sept 2010 - Sept 2013. Two parametric tests and one non-parametric test have been used for determining the nature of the market, observations are tabulated and conclusions are arrived at. The parameteric tests include the L-Jung Box Test and the Lo-Mackinlay Variance Ratio Test. The Ljung Box test is a type of statistical test of whether autocorrleations of a group of lags are tested rather than a test at each distinct lag of a time series of data. The second parameteric test used is the Lo-McKinlay Variance ratio test which computes the variance ratios for the selected three indices and compares with the critical values for obtained Z scores to either accept or reject the randomness hypothesesis. Finally the single non parameteric test called the Run Test uses the number of actual versus estimated or expected runs to arrive at a Z score.

The results clearly show that for the time period selected, the three indices do not exhibit random walk behaviour. In the absence of random walk behaviour, therefore there are undervalued securities which the investors can buy and overalued securities which the investors can sell, if they are able to predict the movement of stock market prices. This paper confines the scope of the research into formulating hypotheses regarding randomness in the values of the indices selected, for the said time period. Further, the paper does not try to guess what might be the cause or reason for any non-randomness.

Keywords: Efficient Market Hypothesis, Random Walk, Parametric Test, Non-Parametric Test

Nomenclature

VR	Variance Ratio
P/E	Price of share to Earnings per share
P/R	Price of share to Book Value of share
ρ_k	Correlation coefficient in the Ljung's Box Test
$\hat{M}_r(q)$:	Variance Ratio in the Lo Mackinlay Variance RatioTest
Q	Sub-period in Lo Mackinlay Variance Ratio Test
q	Q-Statistic in the Ljung's Box Test
r	Observed number of Runs in Run Test
$\bar{R}$	Estimated number of Runs in Run Test
n_1	Number of returns above mean in Run Test
n_2	Number of returns below mean in Run Test
S_R	Standard deviation in Run Test
Z(q)	Z-Statistic in the Lo Mackinlay Variance Ratio Test (Homoscedastic calculation)
Z*(q)	Z-Statistic in the Lo Mackinlay Variance Ratio (Heteroscedastic calculation)

Abbreviations

EMH	Efficient Market Hypothesis
RWH	Random Walk Hypothesis

1. INTRODUCTION

If the pattern in a series of numbers is random then one cannot predict what the next number in that series is going to be. If however they are not random then logically one could arive at a "pattern" and deduce what the next number in the series is going to be (with some reasonable margin of error in judgement). The premise of efficient market hypothesis, which states that markets are efficient and that future stock prices are a random walk has been a subject of much debate and analysis with data and research on both sides of whether or not the hypothesis of efficient markets is true or not .

If future prices could be predicted investors would rush in to buy underpriced stocks and their price would rise thereby eliminating opportunity to make a better return. However, the efficient market hypothesis in the weak form states that all public information is incorporated in stock prices and prediction of prices is impossible. There is substantial research on the contrary, of portfolios made of low P/E ratio stocks and low P/B ratios that return better than average market return, when held over long periods of time (3-5 years).

Other instances of where stock market over-reacts to events e.g. the internet boom leading to the

technology asset bubble in 2001 is largely attributed to behavioural aspect of investor behaviour and does not follow either the rationale of security analysis or the efficient market hypothesis.When investor behaviour is irrational, the market thinks assets are either undervalued, causing the price of equities to rise as in the year 2000 and early 2001. Robert Schiller has written in depth on this topic in his book "Irrational Exuberance" [1]. When the asset bubble burst, the equity prices particularly those in the technology sector came sharply down because investors realised their folly. Were markets then becoming "efficient" through this correction? Or was the correction too steep and thus irrational? Another instance of stock market over-reaction happened in 2008 related to the financial crisis. If markets were indeed efficient, then there would be no rise in the first place to warrant a "correction" as was witnessed in late 2008. Moreover this correction was steep in many analysts opinion, and the famous quote of Warren Buffet "Be greedy when others are fearful and fearful when others are greedy" possibly sums up that the market is indeed whimsical and not always efficient and at times even irrational.

2. LITERATURE REVIEW

Theory of Speculation [2] stated that distribution of prices at a fixed time is a Gaussian. This is thought of as the origins of the theory of random walk when applied to the stock and derivative market.

Research on equity prices [3] has found that the stock prices follow a random walk and drift towards a calculated or intrinsic value. The empirical results led to the conclusion that any type of chart or prediction of stock prices is not of any value.

The book "The Random character of Stock market prices" [4] further developed the idea that stock prices followed a random walk.

The book "A Random Walk Down Wall Street" [5] says that the price of a stock had an equal chance of closing higher or lower than the previous day (50 percent either way). The book examines some popular investing techniques, which include technical analysis and fundamental analysis, in light of academic research studies of these methods. Through detailed analysis, significant flaws are noted in both techniques, with the conclusion that for most investors, following these methods will produce inferior results over passive strategies.

Research in behavioral finance [6] performed several tests and studies on analysing trends in the stock market. One of the important observations included a study on the stock market for ten years. Throughout that period, the research looked at the market prices for noticeable trends and found that stocks with high price increases in the first five years tended to become under-performers in the following five years. Therefore it was possible to predict stock price movements over the relatively longer term. The researchers believed in the non-random walk hypothesis and cite this as a key contributor and contradictor to the random walk hypothesis.

Some contradictions to the random walk hypothesis have been observed in finding that stocks that have had an upward revision for earnings outperform other stocks in the following six months. Thus, with this knowledge, investors better predict what stocks to exit and what stocks to stay invested in. Clearly, this shows that it is possible to earn above market return, contrary to the random walk hypothesis, because according to this theory, there are trends and other tips to predicting the stock market.

An article titled "The SuperInvestors of Graham and Doddsville" [7] offered a different perspective that if the markets are efficient, then no one can beat the market in the long run; and apparent long-term success can happen by pure chance only. Several examples of how several long term funds beat the market, many times by over 10 percent points have been presented.

Research that long holding periods exhibit negative serial correlation [8] has suggested that data from past returns could help predict variability of returns in the long term

Evidence has also been presented that shows the random walk hypothesis to be wrong. The book titled "A Non-Random Walk Down Wall Street" [9] presents a number of tests and studies that reportedly support the view that there are trends in the stock market and that the stock market is somewhat predictable.

The variance ratio test [10], which has gained popularity in emprical determination of the efficiency of stock markets, has been applied to several Asian markets with inconsistent results eg. in Kuwait, the markets were found to be efficient while not so for Saudi Arabia [11].

Studies on the Indian stock market [12] have revealed inconsistent results also, where parametric and non-parametric tests were used to suggest random walk behaviour on monthly returns on BSE. Similar other results have also been obtained. [13].

The book titled "Irrational Exuberance" argued that stock markets were overvalued and this prediction did indeed come true. Much of the emphasis in the book is on the behavioural aspect of Finance.

A study concluded that the Indian stock market does not follow a random walk, when data was analysed from three leading indices in India [14].

3. METHODOLOGY

a) Ljung Box Test (Parameteric Test) for auto correlation [15]

The Ljung and Box Test for portmanteau Q-Statistic is used and the joint hypothesis that all autocorrelation coefficients ρ_k are zero is tested. The test statistic is

$$Q = n(n+2) \sum_{k=1}^{m} (\rho_k^2 / n-k) \text{ [n=number of observations, m=lag length]}$$

[n=number of observations, m=lag length]

For a significance level α, the critical region for rejection of the hypothesis of randomness is

$Q > \chi^2_{1-\alpha,h}$ where $\chi^2_{1-\alpha,m}$ is the α-quartile of the chi-squared distribution with m degrees of freedom.

H$_0$: The data are independently distributed (i.e. the correlations in the population from which the sample is taken are 0, so that any observed correlations in the data result from randomness of the sampling process).

H$_1$: The data are not independently distributed.

b) The Lo-Mac Kinlay Variance Ratio Test (Parametric Test)

This test uses variance ratios for different time periods to arrive at the z-statistic which can then be tested for statistical significance. Homoscedastic calculation focuses on the Variance ratio for the particular sub-period in question relative to the base period and associated Z(q)

i. Homoscedastic Calculations

$$\hat{M}_r(q) = (\sigma_c^2/\sigma_a^2) - 1$$

$$Z(q) = \sqrt{nq}\,\hat{M}_r(q)/\sqrt{\hat{\varphi}(q)} \text{ where } \hat{\varphi}(q) = [2(2q-1)(q-1)/3q]$$

Using q=4, n=43 (Monthly) and q=12, n= 14 (Quarterly) and q = 26, n = 7 (Half-Yearly).

ii. Heteroscedastic Calculations

In order to account for the possibility that variances in different time-periods are different, the heteroscadistic calculations are done. The weekly time series is used as the base and monthly, quarterly and half yearly variances are also computed and the respective Z*(q) values calculated.

$$\hat{\delta}(j) = \sum_{k=j+1}^{nq}(X_k - X_{k-1} - \hat{\mu})^2 \cdot (X_{k-j} - \hat{\mu})^2 / (\sum_{k=1}^{nq}(X_k - X_{k-1} - \hat{\mu})^2)^2$$

$$\hat{\theta}(q) = \sum_{j=1}^{q-1} \hat{\delta}(j) \cdot (2(q-j)/q)^2$$

$$Z^*(q) = \hat{M}_r(q)/\sqrt{\hat{\theta}(q)}$$

c) Run Test for Detecting Non-Randomness (Non-Parametric Test)

The run test uses the number of positive returns and the number of negative returns to determine the Z statistic which is then used to accept or reject the null hypothesis. A Run is defined as a series of increases or decreases in weekly return.

H$_0$: The data series is a set of random returns

H$_1$: The data series is not a set of random returns

$$Z = (R - \bar{R})/S_R$$

$$\bar{R} = \frac{2n_1 n_2}{n_1+n_2} + 1 \,, \; S_R^2 = \frac{2n_1 n_2(2n_1 n_2 - n_1 - n_2)}{(n_1+n_2)^2\,(n_1+n_2-1)}$$

Where, R = Observed number of runs, n_1 is the number of returns above the mean, n_2 is the number of returns below the mean.

$\bar{R}$ = Expected number of runs, S_R = Standard deviation.

If $|Z| > Z_{1-0.5\alpha}$ then the null hypothesis is rejected at the α level.

4. OBSERVATION AND TABLES

A) Ljung Box Test Results

Table 1. Ljung Box Test (lag length = 15)

Index name	L-B Q-Statistic	Singled Tailed probability of Chi-Squared Distribution	Result
BSE small cap	20.1	0.167	Reject H$_0$
BSE mid cap	15.1	0.446	Reject H$_0$
BSE 500	14.2	0.514	Reject H$_0$

B) Lo-MacKinlay Variance Ratio Test Results

Three indices are selected, with weekly returns as the base period for observation of returns between 20th September 2010 and 23rd September 2013 for a total number of observations = 170 for the base period. Variance ratios are reported in the main row while the test statistic Z(q) for the homoscedastic increments and the heteroscedastic robust Test statistic Z*(q) are reported in the second and third row respectively.

Z(q) dnotes the homoscedastic Z-score and Z*(q) denotes the heterosedastic Z-score

Under the random walk hypothesis, the Variance Ratio should have a value of 1.0 and the test statistic should be normally distributed

C) Run Test Results

Same three indices are selected, with weekly returns as the base period for observation of returns between 16th September 2010 and 23rd September 2013 for a total number of observations = 157 for the base period. The values of n_1, n_2, R, $\bar{R}$, S_R and |Z| are tabulated for each index.

5. DISCUSSION OF RESULTS

The L-Jungs Box Test results for each of the three indices give a value of the single tailed probability which is less than the critical value of 0.95, leading to a rejection of the hypothesis that the time series are randomly distributed. The critical value for the LB Q-Statistic is 6.58 which would have yielded a single tailed probability of 0.95 which would confirm randomness. However the obtained LB Q-Statistic for each index is much more than the cut off value of 6.58, thus leading to a rejection of the null hypothesis. The results are tabulated in Table 1.

The Lo-Mackinlay Variance ratio test for homoscedacity suggests that the variance ratio is statistically significantly different from 1 and for all three indices, for all three time periods (monthly,

weekly and half-Year). The heteroscedacity test reveals the same with some exceptions which are tabulated in Table 2.

Finally the run test indicates that for all three indices, the time series data are not random (rejection of the null hypotheses) and the resulting Z-scores and run results are tabulated in Table 3.

Table 2. Lo-MacKinlay Variance Ratio Test

Index name	Variance Ratio (VR) (Monthly/ Weekly) q=4	Variance Ratio (VR) (Quarterly/ Weekly) q=12	Variance Ratio (VR) (Half Yearly/W eekly) q=26
BSE small cap	1.139	1.049	1.012
Z(q)	7.99[*]	3.63[*]	2.39[*]
Z*(q)	5.87[*]	2.59[*]	0.67
BSE mid cap	1.120	0.953	1.118
Z(q)	7.85[*]	3.29[*]	2.64[*]
Z*(q)	0.27	3.40[*]	0.67
BSE 500	1.645	1.515	1.462
Z(q)	11.54[*]	5.24[*]	3.45[*]
Z*(q)	5.89[*]	2.59[*]	0.65

[*] Rejection of null hypothesis at the 0.05 level.

Table 3 Run Test

Index name	n_1	n_2	R	$\overline{R}$	S_R	|Z|
BSE small cap	78	79	107	79	24	4.47[*]
BSE mid cap	82	75	100	79	6.23	3.31[*]
BSE 500	77	80	105	79	6.23	3.93[*]

[*] Rejection of null hypothesis at the 0.05 level.

6. CONCLUSION

The results and analysis show that the three indices selected for analysis do not exhibit a random walk. Therefore the weak form of market efficiency is rejected for the three indices for the time period in consideration.

This could imply that there are opportunities for the investor to analyse equity markets further, assay trends and possibly take positions in stocks and/or derivatives, however only after discovering the formula or model which predicts somewhat accurately future stock prices. This exercise however may be tantamount to hunting for a needle in a large haystack(s).

7. FURTHER WORK

The results and analysis here have only shown that random walk hypothesis does not hold true in the BSE in the time period selected. It does not tell what then are predictor variables which could be used in forecasting equity prices.

The time period for the study can be increased to include more data points. However, periods of downturn (early 2001, late 2008) or bull markets (1999) may yield non-random behaviour and the inclusion of such periods may distort the studies.

Further work could include running tests on causal factors including external macro economic information such as FII and FDI flows, currency exchange rate, and consumer sentiment in India and abroad in order to estimate why these departure from random behaviour occur. Psychological factors such as herd behaviour could also be considered during times of sell-offs or times when assets seem over valued.

8. REFERENCES

[1] Schiller Robert, *Irrational Exuberance*, Crown Publishers, 2000.

[2] Bachalier Louis, *The Theory of Speculation*, Annales Scientifiques de l'École Normale Supérieure Vol. 3, Issue 17, pp. 21–86, 1900.

[3] Fama Eugene F., *Random Walks In Stock Market Prices*, Financial Analysts Journal, Vol. 21, Issue 5, pp. 55–59, 1965.

[4] Cootner Paul H., *The random character of stock market prices*, MIT Press, 1964.

[5] Malkiel Burton G., *A Random Walk Down Wall Street,* 6th Edition, W.W. Norton & Company, Inc., 1973.

[6] Fromlet Hubert, *Behavioral Finance-Theory and Practical Application*. Business Economics, 63, 2001.

[7] Buffett Warren, *The Superinvestors of Graham-and-Doddsville*, Hermes: The Columbia Business School Magazine, 4–15, 2004.

[8] Fama Eugene F., *Market Efficiency, Long-Term Returns, and Behavioral Finance,* (Feb 1997), http://ssrn.com/abstract=15108 or http://dx.doi.org/10.2139/ssrn.15108 Retrieved on

[9] Lo Andrew W., Mackinlay Archie Craig, *A Non-Random Walk Down Wall Street*, 5th Edition, Princeton University Press, 2002.

[10] Lo Andrew W., Mackinlay, Archie Craig, *Stock Markets do not follow Random Walks: Evidence from a Simple Specification Test*, Rodney L. White Center of Financial Research, 29-87, 1987.

[11] Butler K.C., Malaikah S.J., *Efficiency and inefficiency in thinly traded stock markets: Kuwait and Saudi Arabia,* Journal of Banking and Finance, Vol. 16, Issue 1, pp. 197–210, 1992.

[12] Sharma J.L., Kennedy R.E., *A comparative analysis of stock price behavior on the Bombay London, and New York stock exchanges*, Journal of Financial and Quantitative Analysis, Vol. 12, Issue 3, pp. 391–413, 1977.

[13] Gupta O.P. *Behaviour of share prices in India: a test of market efficiency*, National Publishing House, New Delhi, 1985.

[14] Pandey Anand, *Efficiency of Indian Stock Market,* http://ssrn.com/abstract=474921 or http://dx.doi.org/10.2139/ssrn.474921 Retrieved on 2nd Jan. 2014.

[15] Ljung G.M., Box G.E.P., *On a Measure of a Lack of Fit in Time Series Models*, Biometrika, Vol. 65, Issue 2, pp. 297–303, 1978.