Test of Random Walk Hypothesis: A Study in Context of Indian Stock Market

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ABSTRACT

Presence or absence of random walk has always caught attention of academicians, stockbrokers, individuals, institutional investors, financial institutions, and regulators in the area behavioral finance. If the markets are 'weak form efficient', technical analysis fails to make any comments on future price behavior. With this view, the current paper contributes to the existing literature by investigating the weak-form market efficiency in Indian Stock market, one of the fastest emerging markets of the world. Daily data of Bombay Stock Exchange (BSE) 200 index-based companies over the period of 1 January 1991 to 31 December 2016 is tested employing Runs Test, Augmented Dickey–Fuller Test (ADF) Test, Phillips Perron Test (PP) Test, Normality Test and Variance Ratio Test. All five tests show that Indian stock market is not 'weak form efficient'; thus, the prices do not follow a random walk and there exists a pattern in them. If these patterns can be exploited at the right time and right manner, investors can earn abnormal returns from the market. This result also supports the relevance of technical analysis as a trading strategy. At the same time, the market regulators should re-think as to why the markets are not efficient despite numerous measures taken since 1991.

Keywords : Augmented Dickey Fuller Test, Phillip Parron Test, Random Walk, Runs Test, Variance Ratio Test, Weak Form Efficiency

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INTRODUCTION

Stock markets are efficient! Are they? Can there be abnormal gains by capitalizing on information asymmetry!

Stock markets are efficient or not, is a matter of concern to researchers. Markets are efficient if they reflect the true worth of a security and incorporate all the new information in its security prices in a rapid and unbiased manner. If the market incorporates new information quickly and quality of such adjustment is unquestionable, then no matter what conventional methods like technical charts are deployed, they will not guide investors to outperform the market. If the markets are efficient, there will be no way out to identify 'mispriced' securities and make profits. In this scenario, technical analysis becomes a questionable tool for forecasting.

Stock markets can be 'weak', 'semi-strong' and 'strong' form efficient. Weak form efficiency happens when today's share price fully reflects the information provided by all the previous price movements. This makes price movements totally independent of the earlier movements. Thus, technical charts do not help the investors in making any predictions. In addition to this, trading rules cannot function in the presence of weak form efficiency and no one can make more than average returns. Literature designates weak form of efficiency as 'random walk hypotheses'. When the information comprizes publicly available information in addition to private information, the markets are 'semi-strong' form efficient. When the markets are 'semi-strong' form efficient, investors cannot gain from bargain opportunities by analyzing published data. If the markets absorb and reflect not only published information, but also all relevant private information, it is said to be 'strong form efficient'. Insider trading due to privileged position cannot result into gains in the presence of 'strong form efficiency'. All forms of market efficiency are inter-related to each other in the sense that if a market has to be strong form efficient, it is imperative that it should be efficient at other two levels, Keane (1983).

While revealing rational expectations equilibrium, Grossman and Stiglitz (1980) pointed out that the technical analyst capitalizes into current market prices the hidden information of past price movements. On the contrary, once the technical analyst identifies these patterns, they start to trade, and destroy these patterns and in case there are markets with no pattern, they are made 'weak form efficient'. The moment a market becomes weak form efficient, technical analysis looses its significance, Grossman and Stiglitz (1980). This would only leave 'white noise' after filtering all possible patterns. On the other hand, in the absence of technical analysis, no one will be able to capitalize information inherent in historical patterns and it will leave no scope for those who identify these opportunities first. This makes efficient market hypothesis, the most disputed proposition in finance and economics. From here emerges the significance of the concept of market efficiency (specially weak form) as resource allocation and portfolio investment are the two subject areas, which call for checking the market efficiency, Fama (1965, 1970). Not only is the concept of market efficiency relevant, but also the time taken to move towards efficiency is of equal importance. It has been observed that as the market matures over time due to strengthening of regulatory environment and improvement in trading conditions, the stock market tends to move towards efficiency, Emerson et al. (1997) and Zalewska-Mitura and Hall (1999). In short, no investor can make greater returns than randomly selecte portfolio of individual stocks as the markets are efficient, Malkiel (2003).

The concept of weak form efficiency also holds its significance for the authorities that are anxious to know whether the reforms so far undertaken are effective or not. Investors and fund managers focus on trading strategies, asset pricing models, capital markets, market efficiency, etc. to make a judgment over just investments. Let us take a scenario. When random walk is present in the price series of a stock, characterized by positive autocorrelation or persistence in short period as well as negative autocorrelation or mean reversion in long period. An investor tends to invest more (less) in stocks if the relative risk aversion is greater (less) than unity. This does not happen when the returns are serially independent.

Psychology of foreign institutional investors can be rightly understood with the help of market efficiency. For them, the major concern is whether to invest or divest in stock markets of a foreign soil at a given point of time. If the prices follow a random walk, then equity is priced at equilibrium level, on the other hand when it does not follow random walk, it means distortions in the pricing of capital and risk. Thus, the study of market efficiency would give direction to allocate funds within an economy and play an important role in attracting foreign investment, boosting domestic saving and improving the pricing and availability of capital. In short, be it government, or market regulators, or retail or institutional investors (both domestic and foreign), the importance of EMH cannot be disputed.

LITERATURE REVIEW

Predictability of stock prices has interested the researchers and academicians but till date there is lack of consensus on the subject. As a beginning in this field the very first research came out by Fama (1970) which has dealt with various forms of market efficiency with a single question in the fore front i.e., 'are financial markets efficient?' As of now, a comprehensive review of past studies in the domain of market efficiency on emerging markets has been done by Kuehner and Renwick (1980) and Lim and Brooks (2011). Most of the studies bring out the weak-form efficiency of the markets, Civelek (1991), Butler and Malaikah (1992), Al-Loughani (1995), El-Erian and Kumar (1995), Abraham et al. (2002), Onour (2004), Moustafa (2004), Smith (2004), Squalli (2006), Asiri (2008), Lagoarde-Segot and Lucey (2008), Marashdeh and Shrestha (2008) and Awad and Daraghma (2009).

Sharma and Kennedy (1977) examined monthly indices of Bombay, New York and London Stock Exchanges for the period 1963-73. They employed runs tests and spectral analysis and concluded that BSE follows random walk. Barua (1981) confirmed the presence of weak form efficiency of Indian stock market for 1977-1979 by using daily closing prices of 20 shares and the Economic Times index. Gupta (1985) did a more detailed study for testing random walk hypothesis employing daily and weekly share prices of 39 shares together with the Economic Times and Financial Express indices of share prices for the period 1971-1976. They conducted serial correlation tests and runs tests and concluded that Indian stock markets are competitive and weak form efficient. Adding to the literature Rao (1988) examined weekend price data over the period 1982-1987 by studying ten blue chip companies on the basis of means of serial correlation analysis, runs tests and filter rules. He provided evidence in support of random walk hypothesis. Sullivan et al. (1999) challenged the results of Brock et al. (1992) by stating that these results were spurious and they were in fact an artifact of data mining. Adding further he challenged the very selection of technical trading rules and criticized the biased selection of a few good performers representing a small section of the market.

On the contrary, Park and Irwin (2007) after surveying 95 modern studies found that technical trading strategies were profitable in 56 cases, which is a sign of weak form inefficiency. The results were ambiguous in 39 cases, which makes the weak form efficiency a weak proposition. These views are further supplemented by the findings of previous scholars using data from a different stock market (Toronto Stock Exchange) and blending techniques from Brock et al. (1992) and Lo et al. (2000). Market efficiency kept changing and gradually moved towards efficiency in Bulgaria, Hungary, Czech, Poland, Russia and Romania stock markets. This kind of a gradual shift from in-efficiency towards efficiency was observed in the case of Shanghai and Shenzhen stock markets, Li (2003). Batool Asiri, (2008) studied the behaviour of stock prices in the Bahrain Stock Exchange (BSE) employing random walk models such as dickey-fuller tests popularly used as basic stochastic test for a non-stationarity of the daily prices for all the listed companies in the BSE. They further employed autoregressive integrated moving average (ARIMA) and exponential smoothing methods to forecast the prices. The results of the study confirm the presence of 'Random walk with no drift'. Kam C. et.al (1992) employed unit root test and cointegration tests to examine the relationships among the stock markets in Hong Kong, South Korea, Singapore, Taiwan, Japan, and the United States to test for international market efficiency. The study found the presence of unit root in stock prices whereas there was absence of cointegration among the stock prices, which conferred the weak form efficiency individually and collectively in the long run. Hassan Shirvani & Natalya V. Delcoure (2016) examined the presence of unit roots in the stock prices of 16 OECD countries under the assumption of cross-sectional independence across the panel. The authors find no evidence of unit roots, thus failing to reject mean reversion in the stock prices for all the countries in the sample.

Though there is a plethora of literature supporting weak form efficiency, similarly, there are many studies having another view. Early studies on technical analysis depicted a limited evidence of the profitability of technical trading rules with stock market data. Roberts (1967) is credited with the job of distinguishing among week, semi strong, and strong form of efficiency. Ray (1976) extended the work of Rao and Mukherjee (1971) to account for index series for six industries. He hypothesized that the series were independent and compared the results with the results of all industries. The outcome of his research was that the rejection of the null hypothesis of independence. Rao did the very first study on random walk hypothesis and Mukherjee (1971) where they did spectral analysis on weekly averages of daily closing quotations of Indian Aluminum from 1955-70 with the conclusion that random walk hypothesis was rejected. Some very important and interesting results have been brought forward by Brock et al. (1992) using long period time series data from 1897 to 1986 by applying model-based bootstrap methodology. He created his model on simulated data, which had the similar properties as that of actual data. He employed widely recognized chart patterns to compare with the returns from buy and sell signals of actual price data to simulated price time series. The outcome was that the technical trading rules generated positive (negative) returns across all 26 rules and four sub-periods tested. This allowed the authors to draw statistical inferences on the profitability of various trading rules. Using widely recognized chart patterns they compared the returns obtained from the buy and sell signals in the actual price time series to the returns from the simulated price time series. Their results show that buy/sell signals from the technical trading rules generate positive (negative) returns across all 26 rules and four sub-periods tested. The entire buy–sell differences in returns were positive and were better than the returns generated by the simple buy-and-hold strategy.

International stock returns were examined by Poterba and Summers (1987) in which they found positive autocorrelation over short horizons and negative autocorrelation over long horizons. They employed variance ratio tests to show that there was a presence of transitory component in stock prices, which accounts for more than half of the variance of monthly stock returns. They also found that the possible reasons of the mean reverting property in stock prices. One time-varying expected returns and two, slowly decaying “price fads” possible because of noise trading, also that about 50% transitory component in stock prices is difficult to explain by risk factors. Time-varying expected returns due to stochastic evolution of investment opportunities lead to negative autocorrelations in annual stock returns, Fama and French (1988). Same year another important study was done by Pandey and Bhat (1988), where they examined the attitudes and perceptions of users of accounting information about the efficiency of the stock market. A structured questionnaire based survey was conducted on 160 chartered accountants, academicians, investors and chief financial executives of companies. The survey reported that the Indian stock market was not efficient in any of its three forms.

Kirt C Bultler (1992) examined stock returns in Saudi Arabia and Kuwait over the period 1985-1989 where it was found that all 35 Saudi stocks show a significant departure from the random walk due to the prevalence of institutional factors contributing to market inefficiency like illiquidity, market fragmentation, trading and reporting delays, and the absence of official market makers. Another pioneering study was done by Lo et al. (2000) and they proposed automatic chart pattern recognition model. They identified 10 reversal patterns based on a set of consecutive extreme points, which traced a particular geometrical form attached to these patterns. The study was done on a large set of individual stocks traded on the NYSE/AMEX and NASDAQ over the 1962–1996 period as well as the market indices on these U.S. exchanges. They compared the quantiles of returns as depicted by technical patterns with returns and performed goodness-of-fit test. Sarath P. Abeysekera (2001) studied the behaviour of stock prices on the Colombo Stock Exchange (CSE) for a short period of January 1991–November 1996. They applied Runs, Autocorrelation and Cointegration tests to daily, weekly and monthly CSE index data which rejected the serial independence hypothesis. They concluded that stock prices in Colombo Stock Exchange do not confer weak form efficiency. They further checked day-of-the-week-effect and month-of-the-year-effect which were also absent in Colombo Stock Exchange stock prices. Frequency of occurrence of these patterns was in congruence with that of Lo et al. (2000). Another view on random walk is that it is a characteristic of a price series in which each price change denotes departure from previous price, Malkiel (2003). Lo et al. (2000) was extended by Dawson and Steeley (2003) using the UK stock market data and the same set of technical patterns. Following the similar approach, i.e., investigating the returns distributions conditioned on these technical patterns, they found that the returns were significantly different from the unconditioned returns distributions. Finding patterns in the price series has led to conducting non-linear studies (feed-forward neural networks or estimate the profitability of technical trading rules) as well. Many chart pattern studies to recognize the algorithms to chart patterns were developed and established, Lo et al. (2000) and Dawson and Steeley (2003). In the case of Jordanian stock market, market efficiency did not improve despite improvement in electronic trading system, Maghyereh and Omet (2003). Morocco and Egyptian markets became weak form efficient gradually against Kenya and Zimbabwe stock markets, Jeferis and Smith (2005).

A prominent study on technical analysis was done by Park and Irwin (2007), where an extensive review of literature on technical analysis was done bifurcating the period of study into two sub periods i.e., early (1960– 1987) and modern (1988–2004). The criteria for this bifurcation were transaction costs, risk factors, data mining issues, parameter optimization, verification of findings with out-of- sample data, and the statistical tests used in the analysis. Thereafter, further classification was done by splitting the modern studies into seven sub-groups based on differences in testing procedures like Parameter optimization and out-of- sample tests, adjustment for transaction costs and risk, and statistical tests, Park and Irwin (2004, 2007). An important study by Kuo-Ping Chang& Kuo-Shiuan Ting (2010) done on Taiwan's 1971–1996 stock prices employing weekly value-weighted market index confirmed the absence of random walk. At the same time there was a decrease in autocorrelation after the 1990 speculation fad. Francesco Guidi Rakesh Gupta Suneel Maheshwari (2011) tested the weak form efficiency of Central and Eastern Europe (CEE) equity markets for the period 1999–2009 employing autocorrelation analysis runs test and variance ratio test. It was seen that CEE stock markets did not follow a random walk process. Further employing GARCH-M model, the results indicated that the day-of-the-week effect is not evident in most markets. Matteo Rossi & Ardi Gunardi, (2018) carried out a study on Calendar Anomalies (CAs) in France, Germany, Italy and Spain stock exchange indexes, with the help of GARCH model and the OLS regression, they concluded that existence of Calendar Anomalies (CAs). Yet another study by Nagpal, Aishwarya Jain, Megha. (2018) was done to examine day-of-the-week effect and conditional volatility on NIFTY 50 data from the financial year, April 2000 to March 2017 employing EGARCH (1, 1) model, the results conveyed the presence of 'Wednesday Effect' in Indian stock market and thus there is evidence of informational efficiency in weak form.

Thus, there are varied views on the concept of market efficiency and till date there is no consensus on the same. These views differ due to the data, sample selection, period of study, level of development of a particular market and in extreme cases the results differ due to difference in research methodology and the type of tests employed. As right put in by Miller et al., 1994 and Antoniou et al., 1997 that the study should encompass institutional features of the emerging markets, which if ignored can lead to accept or reject the hypothesis wrongly. Therefore, GARCH models and their family Engle (1982) and advanced models by Bollerslev (1986) and Nelson (1991) could fit the non-linearity and infrequent trading in the price series.

The focus of market efficiency has shifted to emerging markets in the recent years, Chaudhuri and Wu (2003), Gough and Malik (2005), Cooray and Wickremasinghe (2008), Lean and Smyth (2007) and Phengpis (2006). These are the markets were the problem lies and need to be addressed. Concept of market efficiency was re-explored by employing GARCH-M (1,1) and Kalman filter state–space for finding out the time-varying dependency of the daily returns on their lagged values, Emerson et al. (1997), Zalewska-Mitura and Hall (1999), Rockinger and Urga (2000, 2001), Hall and Urga (2002), Harrison and Paton (2004) and Posta (2008). When the market progresses towards efficiency, this time-varying dependency is expected to become more stable and becomes infinitely small. This approach leads to identify a continuous and smooth change in the movement of prices over a period of time. This is in contrast to earlier approaches of splitting the period of study rather than into sub-periods on the basis of postulated factors as in Antoniou et al. (1997), Muslumov et al. (2003), Hassan et al. (2003), Abrosimova et al. (2005), Coronel-Brizio et al. (2007) and Lim and Brooks.

Market efficiency has caught attention all over the world, be it the markets of Egypt, Asal (1998), Mecagni and Sourial (1999) and Tooma (2003) or Kuwaiti stock market, Hassan et al. (2003), both negate the existence of efficient market hypothesis with a slight exception that efficiency improved in Egyptian market towards the end of 1997. None of the markets, viz., Egyptian, Moroccan, Tunisian stock, Kenya, Nigeria, South Africa and Zimbabwe followed a random walk, Alagidede and Panagiotidis (2009) rather there were volatility clustering, leptokurtosis and leverage effects.

We see evidently that past literature contains a large number of studies on random walks and market efficiency in developed and emerging markets as well. Many of them have focused on developed single markets, Groenewold and Kang (1993), Ayadi and Pyun (1994), Lian and Leng (1994), Huang (1995), Groenewold and Ariff (1998), Los (2000), Lee et al. (2001) and Ryoo and Smith (2002)]. The current study also falls in line and checks market efficiency in Indian stock market.

Also, most of the previous studies have relied upon a single testing procedure, [see, for instance, Poshakwale (1996), Karemara et al. (1999), Ryoo and Smith (2002) and Abraham et al. (2002)]. Whereas, in the current study, multiple Test, Normality Test and Variance Ratio tests have been employed.

Studies on market efficiency have always given mixed results when it comes to developed markets and emerging markets. For instance, in a study conducted by Chaudhuri and Wu (2003), random-walk hypothesis was rejected for ten out of the 14 emerging markets taken for the study. Phengpis (2006) extended the study of Chaudhuri and Wu (2003) employing the same data set and concluded that the results differ when methodology adopted was changed. Chaudhuri and Wu (2003) in the first instance had followed the structural break methodology adopted by Zivot and Andrews (1992) whereas Phengpis (2006) used the Lee and Strazicich (2003a) approach. Narayan and Smyth (2005) fell in line with sequential trend break test of Zivot and Andrews (1992) for checking market efficiency of 22 OECD countries. The results of their study were the presence of random walk in the price series of OECD countries inspite of the presence of significant structural breaks. Narayan and Smyth (2007) later examined G7 stock price data using the Lumsdaine and Papell (1997) and Lee and Strazicich (2003a; 2003b) tests and conferred that the random-walk hypothesis is supported for all the G7 countries but for Japan. In a nutshell, literature shows contrasting results for developed and emerging markets. Random walk is prevalent in developed markets whereas there is no consensus in case of emerging markets whether they exhibit random walk or otherwize, (Nurunnabi, 2012).

Many of the earlier work has considered weekly or longer time periods [see, for example, Karemara et al. (1999), Los (2000)], the results of which can be ambiguous sometimes. Current paper incorporates daily prices data to draw precise inferences, which are likely to be obscured at longer sampling frequencies.

The current paper makes an attempt to fill the gap in previous literature by accounting for checking weak form efficiency (by employing multiple tests dealing with normality, independence, randomness, stationarity, equal variances, etc.) using daily prices data for one of the fastest emerging markets of the world, viz., India.

For the critics of efficient market hypothesis, forecasting of future price changes is not possible as there are large number of trained participants who transfer the information very fast which makes the market more and more efficient, Lo and MacKinlay (1999). This conflict in the view and literature over the usefulness of efficient market hypothesis is an important motivation for the current study.

OBJECTIVES OF THE STUDY

Main objective of the study is:

"To examine the efficient market hypothesis in its weak form in the Indian stock market".

Weak form efficiency cannot be examined straight way and it has to pass several tests of normality, independence, randomness, stationarity, equal variances, etc. For this purpose, various sub objectives are framed as follows:

(I) To examine if the BSE_200 price series follow normal distribution

(ii) To investigate if the BSE_200 price movements are random

(iii) To ascertain if the BSE_200 price series is stationary

(iv) To check if the BSE_200 price series has equal variances for multiple time frames

HYPOTHESIS OF THE STUDY

To fulfill the above-mentioned objectives, the main hypothesis of the study is:

H0: Indian Stock Market is Weak Form Efficient.

The following are the sub-hypotheses framed:

H01: Daily price series of BSE_200 are normally distributed

H02: Successive price changes of BSE_200 are random

H03: BSE_200 price series has a unit root

H04: BSE_200 price series has equal variances

If not one, but the entire set of above null hypotheses as framed above are rejected, then it would convey that Indian stock market is not weak form efficient for the period under study.

DATA AND METHODOLOGY

BSE 200 index has been taken as a proxy for Indian stock market due to several reasons:

(I) There has been a phenomenal increase in the number of companies listed on BSE over the years. Earlier S&P BSE SENSEX was serving the purpose of quantifying the price movements, but due to rapid growth of market which needed a new broad-based index series reflecting the market trends and at the same time provide a better representation of the increased equity stocks, two new broad-based index series like S&P BSE 200 and S&P Dollex 200, which were launched in 1994.

(ii) The equity shares of 200 selected companies from the specified and non-specified lists of BSE are considered for inclusion in the sample for 'S&P BSE 200'. 200 companies is a sufficiently large number to represent the market as a whole.

(iii) The selection of companies is primarily done on the basis of current market capitalization of the listed scrips. This makes BSE 200 a true representation of the market and the results derived from the analysis of this market can be reckoned credible.

(iv) Finally, BSE 200 index covers market activity of the companies as reflected by the volumes of turnover and certain fundamental factors also. This way it represents technical as well as fundamental aspects of the companies forming part of this index.

Data is extracted from PROWESS database of the CMIE (Centre for Monitoring Indian Economy) for the period January 1991 onwards till 31March 2016. This period of study accounts for the entire period of stock market developments. Website of BSE has also been referred for the same. Various tests are applied one by one to check weak form efficiency like Normality Test, Runs test, Augmented Dickey–Fuller test (ADF) Test, Phillips Perron Test (PP) Test, and Variance Ratio Test. These tests address various issue of 'Weak form Efficiency' like normality, independence, randomness, stationarity and equal variances.

(I) TESTING FOR NORMALITY (JARQUE-BERA)

To check if the series is well modeled by a normal distribution and the likelihood of a random variable to be normally distributed is done prima facie to accept or reject the null of random walk. Graphical view of the plot gives a clue whether the series is normally distributed or not (see figure2). Skeweness and kurtosis are also observed. The value for skewness should be 0 and kurtosis should be 3 for a distribution to be normal. Finally, Jarque-Bera statistic and its associated p value are seen to check for normality.

(II) TESTING FOR RANDOMNESS/SERIAL CORRELATION (RUNS TEST)

Another aspect to check for the random walk is to know the presence or absence of serial correlation. Runs test checks for serial correlation, which is formulated as :

$\mu r = (2n1n2 \div n1+n2) +$

1..Equation(1)

Where, μr is mean number of runs, n1 is number of positive runs, n2 is number of negative runs and r is the total number of runs (actual sequence of counts). Prices should be independent for the market to be efficient, which calls for checking serial correlation in the series.

(III) TESTING FOR STATIONARITY (AUGMENTED DICKEY AND FULLER TEST AND PHILLIP PERRON TEST)

If the series has a unit root, it causes shocks to prices that permanently alter price path. Presence of unit implies that any pattern in the prices is due to only some white noize, which makes prediction possible. In the absence of unit root in the price series, it implies that the series is stationary and will tend to revert to its mean over a period of time, which makes forecasting impossible. The most popular and traditional test for checking the presence or absence of unit root in the series is Augmented Dickey and Fuller (1979) unit root test. Critics of ADF test postulate that it fails to take account of structural break in the price series leading to type 2 error i.e., identifying a stationary series as non-stationary due to the presence of structural break in slope or intercept, Perron (1989) and Zivot and Andrews (1992). Since then several tests for stationarity in the presence of structural breaks have been developed like breaks proposed by Zivot and Andrews (1992), Lumsdaine and Papell (1997), Lee and Strazicich (2003), Narayan and Popp (2010) and Narayan and Liu (2013). Conventional efficiency tests often applied to these emerging markets are considered inadequate since they do not account for non-linear and infrequent trading caused by thinness, lack of liquidity and regulatory changes. In addition, these tests measure the efficiency in a given point of time and do not account for its evolution over time, expected to move towards weak-form efficiency as markets evolve and traders become more sophisticated.

Many existing studies done to check the market efficiency in Indian stock market have employed Dickey-Fuller and/or Phillips-Perron unit root tests without structural breaks (see eg. Ahmed et al., 2006; Ali et al., 2013; Alimov, et al. 2004; Gupta & Basu, 2007; Jayakumar et al., 2012; Jayakumar & Sulthan, 2013; Kumar & Singh, 2013; Mahajan & Luthra, 2013; Mehla & Goyal, 2012; Srivastava, 2010). Also, many of them have conducted over a short period of time (see eg. Ali et al., 2013; Jayakumar & Sam, 2012) which fail to account for structural breaks.

To overcome the problem of single testing, two tests for stationairity were employed in the current study. First, the ADF test for stationarity and then PP test for stationarity to account for structural breaks. This study contributes as well as fills the gap in literature in two ways. First by contributing to the existing literature employing tests for stationarity (see eg. Ali et al., 2013; Alimov et al., 2004; Gupta & Basu, 2007; Jayakumar et al., 2012; Jayakumar & Sulthan, 2013; Kumar & Maheswaran, 2013; Kumar & Singh, 2013; Mahajan & Luthra, 2013; Mehla & Goyal, 2012; Srivastava, 2010). Second, by addressing the gap of single testing by employing two tests for unit root ie., ADF and PP test.

Since the data set was large and more complicated, augmented Dickey–Fuller test (ADF) was applied to examine the existence of unit root in the time series. The ADF test is stated as:

$\Delta R_t = b_0 + b_1 p_0 R_{t-1} + å^{j}{}_{t-1} j \Delta R_{it-1} +$

e_t..Equation (2)

Here, R_t is the price at time *t* and *ΔRt* is the change in price. An alternative to ADF if PP test which is a non-parametric method of controlling for serial correlation.

The following is PP test statistic:

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$t_a = t_a (Y_0/f_0)^{1/2} - \underline{T(f_0 - \gamma_0)(se(\hat{\alpha}))}$

2 f0² s

....Equation(3)

where $\hat{\alpha}$ is the estimate, and t_a the t-ratio of α, (se ($\hat{\alpha}$)) is coefficient standard error and s is the standard error of the test regression.. In addition, Y_0 is a consistent estimate of the error variance (calculated as, T – K) s^2/T where K is the number of regressors). The remaining term, f_0, is an estimator of the residual spectrum at frequency zero.

(IV) TESTING FOR EQUAL VARIANCES (VARIANCE TEST RATIO)

Model-based bootstrap approach was first discussed in Brock et al. (1992) and an effective tool was bootstrap reality check method which includes reality check, White (2000) and genetic programming, Koza's (1992).

[When the error terms are not an i.i.d. sequence, the random walk process is denominated martingale process, whereas the sequence {εt} T t=1 is the so-called martingale difference sequence (m.d.s.). Campbell et al. (1997) refers to the "random walk 3". 2 Daniel (2001) explores a wider range of possible test statistics.]

Testing for random walk hypothesis means testing for weak-form efficiency, (Fama, 1970; 1991) which helps to measure the long-run effects of shocks on the path of real output in macroeconomics (Campbell and Mankiw, 1987; Cochrane, 1988; Cogley, 1990).

Given a time series $\{y_t\}_{t=1}^{T}$, the RWH correspond to $\varphi = 1$ in the first-order autoregressive model

$$y_t = \mu + \varphi y_{t-1} + \varepsilon t$$

....Equation(4)

where, μ is an unknown drift parameter and the error terms εt are, in general, neither independent nor identically distributed.

Testing for random walk has numerous procedures available in the literature but variance-ratio methodology has gained a lot of attention of late see, e.g., Campbell and Mankiw, 1987; Cochrane, 1988; Lo and MacKinlay, 1988; Poterba and Summers, 1988).

In this methodology, random walk is tested with the assumption that variances are linear in all sampling intervals, i.e., the sample variance of k-period return (or k-period differences), $y_t - y_{t-k}$, of the time series y_t, is k times the sample variance of one-period return (or the first difference), $y_t - y_{t-1}$. The VR at lag k is then defined as the ratio between $(1/k)^{th}$ of the k-period return (or the k^{th} difference) to the variance of the one-period return (or the first difference). Hence, for a random walk process, the variance computed at each individual lag interval k (k = 2,3,...) should be equal to unity. The reason for the popularity of VR methodology when testing mean reversion is that VR statistic has optimal power against other alternatives, (e.g., Lo and MacKinlay, 1989; Faust, 1992; Richardson and Smith, 1991). But this method is a little complicated as this method employs overlapping data in computing the variance of long-horizon returns. The VR test is often used (see Cochrane, 1988; Lo and MacKinlay, 1988; Poterba and Summers, 1988; among others) to test the hypothesis that a given time series or its first difference (or return), $x_t = y_t - y_{t-1}$, is a collection of i.i.d. Observations or that it follows a martingale difference sequence.

EMPIRICAL RESULTS

(I) RESULTS OF CHECKING NORMALITY

Normality plot is depicted in the figure 1 along with descriptive statistic.

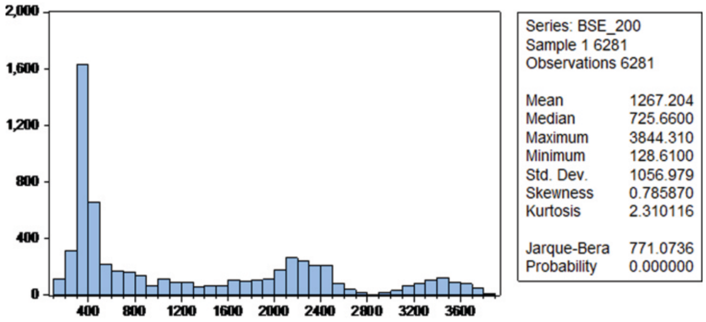

Figure 1: Normality Plot and Descriptive Statistics

An initial observation of the histogram (see figure 1) gives a clue that the prices are not normally distributed as the histogram is skewed to the left. In addition to the histogram, descriptive statistic of BSE_200 companies makes it clear that the prices are not normally distributed. Frequency distribution of the prices gives the skewness is .78 and kurtosis is 2.3. Additionally, Jarque-Bera statistic is 771.07 with p value of .00 and hence the null of normal distribution i.e., H_{01} is rejected.

(II) RESULTS OF CHECKING FOR RANDOMNESS

Runs test was applied on the series to know if the BSE 200 companies follow a trend. Mean of the price series for the period under study is 1267.2. With total runs of 20 against the expected runs of 3033, standard deviation is as high as 38.2. Total number of observations in the series was 6281, with 3724 positive runs against 2557 negative runs. Z value is -78.76 with a p value .00. We thus conclude that price series is not random as the p value is less than .05, and it means that the succeeding price changes are not independent and there is a presence of trend in the series.

There is a clear indication of inefficiency of stock market in its weak form. Thus, this result helps investors to predict the future movement of prices based on previous price information.

(III) RESULTS OF CHECKING FOR STATIONARITY

Original series is plotted in the following figure where close denotes closing price of BSE 200 sensex.

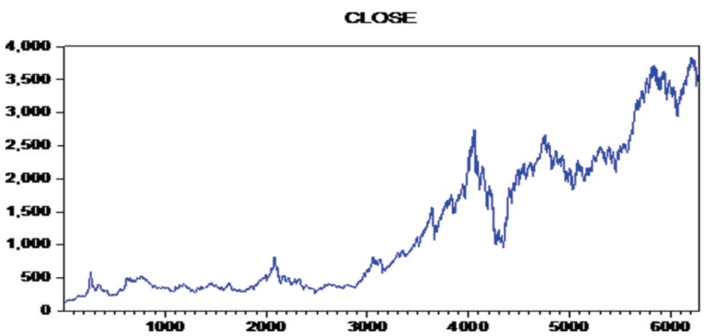

Figure 2: Original Plot of BSE_200 Index Series

Figure 2 makes it clear that the series is not stationary and there is a presence of trend. Further to support it statistically, two tests for unit root tests are done. Results of ADF and PP test are presented in table 1. Null hypothesis (H_{03}) for the both the tests is: BSE_200 has a unit root. For ADF, lag length is 1 with maximum lag of 33 based on automatic SIC. Least square method is adopted to give minimum chances of error in residuals. Total number of observations is 6279 after adjustments. Durbin Watson statistic is 1.99.

For PP test the bandwidth is 18 as per Newey West automatic selection using Bartlett Kernel. Durbin Watson is 1.79. Residual variance with no correction is 424.6621 and HAC corrected variance statistic is 508.97. Results are given in Table 1.

	ADF Test	PP Test
T-Statistic	0.123585	0.145072 (Adjusted)
Probability	0.9675	0.9690
Test Critical Values (1% level)	-3.431212	-3.431212
Test Critical Values (5% level)	-2.861806	-2.861806
Test Critical Values (10% level)	-2.566954	-2.566954

Table 1: Result of ADF and PP Test

Null hypothesis for ADF test as well as for PP test cannot be rejected, as the p values in both the cases are more than .05. These results convey there is a trend in the series and the series is not stationary.

(IV) RESULTS OF CHECKING FOR EQUAL VARIANCES

Canadian dollar, French franc, German mark, Japanese yen and the British pound for the 1139 weeks from August 1974 through May 1996.

Wright employed time series data on nominal exchange rates to illustrate his modified variance ratio tests. He checked whether exchange rate returns, as measured by the log differences of the rates are i.i.d or martingale difference, or alternately, whether the exchange rates themselves follow an exponential random walk. He extended his study to panel data as well. But the current study is restricted to time series analysis on single series, named BSE 200. The variance ratio test is performed using the 'differences, log differences, or original data in the series as random walk innovations. Variance ratio test has three major assumptions i.e.,

(i) Series follow a random walk, so the variances are computed for differences of the data.

(ii) Series follow an exponential random walk, so, the innovations are obtained by taking log differences.

(iii) Series contains the random walk innovations themselves.

Lo and MacKinlay 1988 variance ratio test statistics is computed assuming hetroskedastic increments to the random walk. Test probability is computed using the default asymptotic normal results (Lo and MacKinlay 1988), or using Wild bootstrap (Kim 2006). For Bootstrap error distribution (two point, rademacher, normal), number of replications, random number generator, and to specify an optional random number generator seed. Interval based variances are compared with the variance of one period innovations by providing a user specified list of values or name of a vector containing the values. First of all, 'Exponential random walk' is observed by working with log returns to check for heteroskedastic robust with no bias correction. User specified test periods are 2,5,10,30 to match the test periods to give more meaningful inferences. Standard error estimates assume no heteroskedasticity

Results of Variance Ratio Test are given in Table 2. The null hypothesis for variance ratio test is stated:

H_{04}: Log BSE 200 is a random walk having equal variances

Joint Tests	Value	Degrees of freedom	Probability
Max |z| (at period 2)*	10.03019	6280	0.0000
Wald (Chi-Square)	132.0938	4	0.0000

Individual Tests

Period	Var. Ratio	Standard Error	Z-Statistic	Probability
2	1.126570	0.012619	10.03019	0.0000
5	1.235143	0.027647	8.505320	0.0000
10	1.311368	0.042606	7.308044	0.0000
30	1.619999	0.077811	7.968044	0.0000

*Probability approximation using studentized maximum modulus with parameter value 4 and infinite degrees of freedom

Test Details (Mean = 0.000523532851404)

Period	Variance	Variance Ratio	Observations
2	0.00029	1.12657	6279
5	0.00032	1.23514	6276
10	0.00034	1.31137	6271
30	0.00042	1.62000	6251

Table 2: Results of Variance Ratio Test

Results are shown in two sets as there are two test periods specified. The 'joint test' are the tests of the joint null hypothesis for all periods, while the 'individual tests' are the variance ratio tests applied to individual periods. Chow denning $^{|z|}$statistic is 10.03, which is associated with period two individual tests. Null hypothesis for random walk is strongly rejected as the approximate p-value of 0.00 is obtained using studentized maximum modulus with infinite degrees of freedom. As for Wald test statistic for the joint hypothesis is concerned, the results are similar. The individual statistics also reject the null hypothesis, as all periods have ratio statistics p value of zero. Mean, individual variances, and number of observations used in each calculation is shown in the lower panel of the output. These results also convey that the series does not follow a random walk. The analysis is further extended to allow for heteroskedasticity employing 'wild bootstrapping' and checking for statistical significance. Two point distribution with 5000 replications (the knuth generator), and a seed for random number generator of 1000 is emphasized. The results of wild bootstrap are given in Table No 3. The null hypothesis for wild bootstrap is specified:

Null Hypothesis: Log BSE_200 is a martingale

Joint Tests	Value	Degrees of freedom	Probability	
Max |z| (at period 2)*	10.03019	6280	0.0000	
Individual Tests				
Period	Var. Ratio	Standard Error	Z-Statistic	Probability
2	1.127483	0.025320	5.034929	0.0000
5	1.239020	0.053225	4.490756	0.0000
10	1.320374	0.077567	4.130309	0.0000
30	1.648287	0.129381	5.010698	0.0000
Test Details (Mean = 0)				
Period	Variance	Variance Ratio	Observations	
2	0.00029	1.12748	6279	
5	0.00032	1.23902	6276	
10	0.00034	1.32037	6271	
30	0.00043	1.64829	6251	

Table 3: Results of Wild Bootstrap

As the test methodology is not consistent with the use of heteroskedastic robust standard errors in the individual tests, Wald test is no longer displayed (see Table 3). Observation at this stage is that the probability values generated using 'wild bootstrap' are similar to the previously obtained results, except for the 10th period. The individual period two test, which was borderline insignificant in the homoscedastic test, is no longer significant at conventional levels. The chow denning joint test statistic of 5.03 has a bootstrap p value of 0, which strongly rejects the null hypothesis that Log of BSE 200 is a martingale. In the end the Wright's rank variance is computed, with ties replaced by the average of the tied ranks. Permutation bootstrap is used to compute the test probabilities. The results are:

Joint Tests	Value	Degrees of freedom	Probability	
Max |z| (at period 2)*	11.61489	6280	0.0000	
Wald (Chi-Square)	157.2005	4	0.0000	
Individual Tests				
Period	Var. Ratio	Standard Error	Z-Statistic	Probability
2	1.146567	0.012619	11.61489	0.0000
5	1.281090	0.027647	10.16728	0.0000
10	1.361436	0.042606	8.483181	0.0000
30	1.609402	0.077811	7.831860	0.0000
Test Details (Mean = 0)				
Period	Variance	Variance Ratio	Observations	
2	1.14375	1.14657	6279	
5	1.27794	1.28109	6276	
10	1.35809	1.36144	6271	
30	1.60545	1.60940	6251	

Table 4: Results of Permutation

The standard errors employed in forming the individual z statistics are obtained from the asymptotic normal results. The probabilities of the individual z statistics and the joint max |z| and Wald Statistics, which strongly reject the null hypothesis are obtained from wild bootstrap.

CONCLUSION

This paper aimed at investigating evolving weak form market efficiency in Indian stock market. The evidence crystallized in this study does not support the market efficiency in its weak form after going through all checks of normality, randomness, stationarity and equality of variances. The results convey that the prices today are affected by the past prices and they have important information content in them. The one who is smart to exploit this information content wins over the market by making more than normal gains. The investors are, therefore, likely to benefit much by studying and utilizing the historical price data. The current study adds value to the existing literature as it employs unit root testing on high frequency data of emerging markets and also by considering heteroskedasticity when testing for a random walk with high frequency financial data. The results of the study reveal a clear departure from weak-form efficiency. Reason for this kind of behavior could be the unstable efficiency paths being affected by the contemporaneous crises. Also, Indian stock markets are highly sensitive to past shocks indicating that undesirable shocks exert their influence for a long period. It also reveals the ineffectiveness of the stock market reforms undertaken in India.

To overcome this, Indian stock market can speed up the base of privatization, diversify financial services and improve the investment climate in order to infuse more domestic and/or foreign savings to equity markets. Additionally, liquidity provision function can be improved by introducing market making besides counteracting the shortcomings of the large individual trading by enhancing investment culture and wide spreading institutional trading.

Current study is restricted to BSE 200 companies only; the study can be extended to cover intraday data as the single variance ratio test suffers from low robustness, which becomes less effective in high frequency, Ronen (1997) and Andersen et al. (2001). Another extension of the study can do the similar analysis on other emerging markets, as the fundamental characteristics of these markets are similar. Findings of the current study become even more relevant as it has studied the entire time period of stock market evolution in India

At macro level, study of efficient market hypothesis helps in efficient allocation of resources. In the presence of efficient markets, the market participants have complete information about all companies as depicted by corresponding stock prices. On the other hand, in the absence of market efficiency, the allocation of resources is not just and fair. Therefore it is suggested that regulators and policy makers should make stringent rules to protect the interests of the investors.

In the recent years, the focus of many researches has gradually shifted to emerging markets due to certain peculiarities attached specific to these markets. There is information asymmetry in emerging markets due to poor information disbursement mechanism. There is non-uniformity in disbursement of news to various investor groups at different points in time. This creates a lead-lag relationship between disbursement of news and its reception at the other end and dis-equilibrium is created which brings some group of investors in informational advantageous position than others. Another peculiarity of emerging markets is that of undeveloped institutional infrastructure for regulating markets, which is an essential feature for efficient market at least in the initial stages of development.

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