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Random Walk Hypothesis: A Historical Perspective with Select Review of Empirical Work

N.V.R.RAJAGOPALAN[♣]

ABSTRACT

Random Walk Model is applied for testing the Price efficiency of well informed markets. Successive price changes happen after the arrival of new information, which is a result of random shocks and the given price of commodities or shares reflects all the past information related to the commodities or shares. While normal walk has a sequence, random walk has no sequence or patterns. There has been questions from long back whether share price changes are random walk. If, share prices are proved to be random walks, then the stock market is said to be efficient in its easiest form called weak form. In this Paper an attempt is made to trace the history behind the concept of random walk, its linkage to stock market studies by presenting empirical review of literature and to comment on the methods and tools and the current status of the model. Over a period of 120 years, the random walk approach has been instrumental in assessing market efficiency and its usefulness in proving the weak form efficiency still remains intact in spite of the replacement of pure random walk with random walk with drift. It still remains as the foundation test of market efficiency before proceeding to have other forms of market efficiency.

***Key words**: Random Walk, Run Test, stochastic process, serial correlation, Returns, Variance Bounce, Time Series Data*

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RANDOM WALK HYPOTHESIS: A HISTORICAL PERSPECTIVE WITH SELECT REVIEW OF EMPIRICAL WORK

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Introduction

Stock market efficiency is a widely researched area from the beginning of 20th Century till date. Efficiency of stock markets denotes that the share prices and returns are random variables behaving on the arrival of information, which is assumed as well as proved as 'random', thereby offering no investor or group of investors to earn abnormal returns on a continuous basis. In other words, any attempt to predict the behaviour of share prices is a futile exercise, because the price of a given security reflects all historical information attached and adjusted to it, and which represents the "Fair Value' of that security. In his paper an attempt is made to provide select reviews of empirical work concerned with 'Random Walk Hypothesis', which has been instrumental in developing 'Time Series Techniques' and in use for testing stock market efficiency over a period of more than hundred years.

Significance

Even though the stock market research attracted much attention in recent times in India, especially from the beginning of 21st Century, financial service providers and financial advisors have been trying to project, which they are supposed to provide estimated returns to investors after a specific period of time. It is a dream, if the background of 'Random Walk' in the context of stock market is made known to the investing public. Interestingly in all the offer documents, a specific mention about the expected returns is present in the form of a footnote on the clause 'subject to Market Risks' that too in a size neither visible nor readable. But, it is clearly visible that the service providers or the fund managers are predicting the returns based on some assumptions, not

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actually present in actual situations or assumptions that are no at all possible and to have their face saved in case of not getting the returns on expected lines, they take the shelter under the clause of 'subject to Market Risks'. It does not mean that all the cases were coming under the above said biased assumption, which means that in some cases they did get the expected returns, but not because of choice; but because of chance. Even the chance effect is supposed to fade away in a relatively long- term perspective

In the context of 'Random Walk Hypothesis' projections are not getable in the real technical sense of returns, as the share price changes are random and any attempt to do that is unproductive. Therefore, in an effort to focus on empirical results of the academic world to counter argue the possibility of getting expected returns and to give a word of caution if not advice to the investing public, the paper highlights the presence of randomness in movement of share prices, which ultimately makes share price prediction – a waste of time

Objectives

1. To trace the origin and history of 'Random Walk' and to link it to stock market efficiency
2. To make a review of 'Random Walk Hypothesis' in developed markets and in Indian context
3. To enquire into the methods and tools adopted in the empirical work
4. To give a note on change in Random Walk Approach

Period of Coverage and Method

A period more than a century (1900- 2019) has been taken to review the select empirical work concerned with random walk and market efficiency. International studies concerned with the developed markets (The U.S, U.K, Germany) and developing markets are presented according to chronological order and studies in the Indian context follows in the same way. The methods and tools adopted for testing the randomness have been mentioned in respective reviews. As far as the International studies are concerned, unless otherwise stated, the reviews are pertaining to the U.S market, because the concept of

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stock market efficiency originated in the U.S and which had more number of studies when compared to other countries.

Limitation

The review is not exhaustive to cover all but only inclusive to present selected ones.

Origin and History of Random Walk

Rich amount of literature is available for studies concerned with security prices and returns in connection with informational efficiency of capital markets. In fact, it is very interesting to observe that testing the randomness of a price series had its origin from pure sciences as Scottish botanist Robert Brown noticed that grain of pollen suspended in water had a rapid oscillatory motion when viewed under a microscope and the British Physicist Lord Rayleigh (1880) through his work on sound variation has been believed to be aware of the notion of random walk.

John Vann, the British logician and philosopher had a clear concept of both random walk and Brownian motion. The concept of efficient market was clearly spot out in a book by George Gibson (1889) entitled The Stock Markets of London, Paris and New York. He contended that when shares became publicly known in an open market, the value which they acquire may be regarded as the judgment of the best intelligence concerning them.

It was in 1900 when the French mathematician, Louis Bachelier published his Ph.D., thesis 'Theorie de la speculation' and deduced that the mathematical expectation of a speculator is zero and it was he who developed the mathematics and statistics of Brownian motion five years before Einstein (1905), who developed equations for Brownian motion , but completely unaware of Bachelier's work. Later Karl Pearson, then professor and Fellow of Royal Society, introduced the term 'random walk' in 1905 in the letters pages of 'Nature'. In an attempt to establish his identity, Bachelier (1914) published the book, Le Jev La Chance, et le Hasard (The game, the chance and the Hazard) which was sold over six thousand copies.

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Being a French mathematician, financial economics school did continue its overlooking attitude to acknowledge him. Bachelier's work was way ahead of it's time and was ignored until it was rediscovered by Leonard Jimmie Savage in 1955 when he came across Bachelier's 1914 publication in the Chicago/ Yale library and sent half a dozen blue ditto post cards to his colleagues asking whether any of them knew him. Paul Samuelson was one of the recipients of the card but he could not find the book in the MIT library but he was fortunate enough to locate a copy of Bachelier's Ph.D. thesis.

In 1956, Bachelier's name reappeared in financial economics as an acknowledged forerunner by the student of MIT, Paul.A.Samuelson, in his thesis on 'Options like pricing'. The random nature of share prices and returns has been subjected to research by different researchers at one time or another for a long time, but all those work did figure a first citation - the work by Bachelier who concluded that speculation is apparently a 'fair game' in which neither buyers nor sellers should expect to make a profit. In such a competitive market, prices tend to follow a random walk. This contention formed the basis for evolution of the concept of market efficiency by later researchers.

What made random walk and informationally efficient market a linked one? Even though the concept of random walk developed by pure science pool and the concept of efficient markets developed by social science pool seem to be different at first sight, since the two pools worked independently on their respective research, random walk has been the empirical evidence to prove that the markets are informationally efficient.

But random walk research preceded the agenda by intuition as well as empirical studies by pure science pool to form theories of motion, and when the random walk method is applied to financial and commodity markets, social science researchers were tempted to assess why share and commodity prices follow random walk. Their contention landed at a unanimous opinion that unless markets are informationally efficient it would not follow a random walk. Since then the financial literature started focusing on informationally efficient market and in the process of proving that, it utilized the random

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walk model as a tool, which is characterized by various tests namely run test, filter rules and correlation test to confirm to randomness.

In the following paragraphs, some pioneering contributions by researchers in random walks, empirical studies related to past information content in prices/ returns, the evidences for and against random walk in stock prices/returns in various international stock markets and Indian stock market are presented.

Past Information Content in Stock Returns - International

Working Halbrook (1934) in his analysis of time series data observed the random behaviour of prices and he concluded that stock returns behave like numbers from lottery. However Cowles and Jones (1937) found significant inefficiencies in stock market as they evidenced serial correlation in averaged time series indices of NYSE stock prices and subsequently in 1960 Cowles revisits the results, correcting an error introduced by averaging and still found temporal dependence results, but Working was of the opinion that the use of averages could introduce serial correlations which was not present in the original series.

Kendal (1953) had the credit of publishing the first systematic study confirming the random behaviour of share price movements. He studied the behaviour of weekly changes in the indices of shares on the London Stock Market and commodity markets with respect to cotton and wheat in U.S. and in the process of trying to find patterns in share and commodity prices he failed to obtain any such patterns but to his surprise they were essentially random both in equity and commodity markets. He was also the first to note the time dependence of the empirical variance (non-stationary).

Roberts (1959) demonstrated a series of cumulative random numbers and compared it with share price time series data. As an observer, he tried to see patterns with hindsight and in the process the simulated stock prices changes with a normal distribution property with a mean of 0.5 and a standard deviation of 5.0. He succeeded in his attempt partially as he concluded that although the chance model seemed to be satisfactory in simulating the market in the short run it would not be sufficient enough for long run purposes due to long run economic growth factors. He suggested that predictive analysis

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based on past price alone would be inadequate without the knowledge of economic theory. His study was also called as simulation test.

Osborne (1959) attempted to apply the concept of Brownian motion - the movement of every small particles suspended in a solution to confirm the randomness of share price movements. He compared the share prices with the random movement of microscopic particles suspended in a solution. To his surprise, he observed a high degree of conformity between movements in share prices and the law of physics governing Brownian motion. He identified that variance of price changes over successively larger intervals of time, increases in accordance with the square of the length of time, which implied that logarithms of price changes were independent of each other. It formed a sound argument for random walk in stock prices and it also provided empirical evidence of the square root of time rule.

Alexender (1961) attempted to show that past price movements could be used to make excess returns and introduced the technique of filter rules – suggesting purchase of a share if its price increased by a percentage over it's previous low and suggesting disposal if the price falls by a set percentage from previous high. He reported test of the filter technique for filters ranging from 1 per cent to 50 per cent to include different time periods from 1897 to 1959. He succeeded in his attempt as an inventor of new tool for trading as small fillers of 4-5 per cent produced larger rates of return but failed to impress the investing world because of the existence of transaction cost, when taken into consideration the abnormal returns disappeared for filler rules. His results contradicted the random walk in share prices that price changes are independent but it did not contradict the past information content in making abnormal return consistently. He concluded that if the probability of a rise is not 0.5, the random walk model best fits the data, but with leptokurtosis in the distribution of returns. This work marked the beginning of testing non-linear dependence in time series analysis.

Moore (1962) studied successive price changes of 29 stocks on the weekly basis during 1951-58 with the help of serial correlation tests and found insignificant negative correlation co-efficient (- 0.56), which suggests that previous price changes could not be

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used to predict future changes in prices and evidenced a slight positive serial correlation for the Index.

Granger and Morgenstern (1963) performed spectral analysis on NYSE in an attempt to find more complex relationships that cannot be identified by simple serial correlation techniques, generally adopted in previous studies, and found that short run movements of the series obey the simple random walk, but long-run movement did not and concluded that business cycles were of little or no importance.

Cootner (1964) edited the classic book 'The Random Character of Stock Market Prices' which comprised of a collection of papers by Robers, Bachielier, Cootner, Kendal, Osborne, Working, Cowles, Moore, Granger and Morgenstern, Alexender and others containing empirical arguments for and against the random walk in share prices and the book had the credit of being reviewed by more than five experts in the field and in all the reviews, Cootner got the credit of taking the painful exercises of coupling the work of different people of different points of time and it was the first printed material in English with respect to Bachelier's work, translated as 'Theories of speculation'. All the reviewers applauded the efforts of Cootner and suggested the book for the shelves of every stock market researcher at that time, and it continues its pivotal role even today in research and to continue to be an importance book for ever.

Fama (1965a) published his landmark empirical analysis of stock market prices, a study of the 30 stock Dow Jones Industrial Average for 5 years from 1957-1962. He found statistically significant serial correlations in 10 out of 30 shares in the one day test and when he extended the time horizon of analysis, only 5 were significant in the four day test, 2 in the nine days test and only 1 was significant in the sixteen days test. Out of 1200-1700 observations only 0.36 per cent variation in the next price was explained by the statistically significant test mean, which means the low explanatory power of the variable and that too rapidly disappeared after a few days and he concluded that there was a very little evidence of dependence.

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Fama (1965b) based on his empirical work in 1965a, published a descriptive paper in which he challenged the stand to technical analysts/chartists and fundamental analysts camp by strongly superimposing the findings of his study. He invited the chartists to show that they could consistently use the techniques to make better than chance predictions of stock predictions, and had gone further into the aspect that it was not enough for theory to talk mystically about patterns observed in the data but to make meaningful predictions of future prices, and claimed that the challenge was straight forward. The challenge posed by him to the fundamental analysts was more involved, in the scene that stock prices at any point of time represent good estimates of intrinsic or fundamental values. If they have neither better insights nor new information it is better to forget about fundamental analysis, he concluded.

Samuelson (1965) was the first to provide the formal economic argument for efficient market. He proved that prices move in a random manner in a market in which all have similar time horizons and expectations and that all information is available to all the market participants at a zero cost. He focused on the concept of a 'martingale' rather than a random walk as referred in previous studies including Fama.

Fama and Blume (1966) have studied the Dow Jones Industrial Average between 1956 and 1958 by applying the Filter rule technique developed by Alexander and compared it with the serial correlation technique results for the same data. They concluded that for measuring the director and degree of dependence in price changes, serial correlation is probably as powerful as the Alexandrian Filler rules.

Harry Robers (1967) coined the term "Efficient Market Hypothesis" and made the distinction between weak and strong form tests in his unpublished manuscript, which then became a classic testimony in all the future literature.

Fama (1970) made a clear cut distinction between weak form, semi-strong form and strong form and became the first in financial literature to consider the joint hypothesis problem.

Malkiel (1973) a chartist turned academician was of the view that in the markets in its weak form, knowledge of past stock price movements could be of no help in

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determining future stock price movements and in its strong form, he asserted that the market so efficiently digested any relevant investment information so as to eliminate the presence of any undervalued securities.

Solnik (1973) studied a sample of 234 securities form 8 major European stock markets by using serial correlation tests between 1966 to 1971 and found that all the sample correlation coefficient were quite small although only slightly larger, on average than their US equivalent and concluded that it might have been due to thinness of markets and discontinuity in trading, which resulted in taking a slightly higher time to adjust the information signals into prices.

Jenson (1978) had tested the efficient market hypothesis and found that it was consistent with the data in a wide variety of markets: the New York and American Stock exchanges, the Australian, English and German Stock Market. But the author was of the opinion that when better data become available (eg. Daily price data) and with the sophistication of econometric models increase, it would be possible to find inconsistencies that the data and techniques failed to identify in the past.

Miller (1979) was of the opinion that any non-random fluctuation in price (other than a steady upward) approximating the risk adjusted rate of returns) would be exploited by speculators who would buy before an expected fall, eliminating any predictable functions and making all price changes random and questioned the random walk approach to prove market efficiency.

Leroy and Porter (1981) compared the variance of stock market prices with the variance of ex-post present values of future dividends and identified excess volatility in U.S. stock market and concluded that the concept of market efficiency was subject to questions, since the variance bounce was violated dramatically and this study make a beginning for analyzing stock price volatility against Random walk approach.

Shiller (1981) compared the stock prices changes with price expected based on dividend expectations by taking historical growth model in dividend and found that the market showed excess volatility in terms of real prices not properly supported by the

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trend in dividends. By linking dividends and share prices to identify price volatility, it was the first work to play the trump card "volatility" against market efficiency.

Marsh and Merton (1986) showed that when managers' smooth dividends and earnings followed a geometric random walk, then the variance bounce violation in theory has been a strong support for the version of efficient market hypothesis and not against the market efficiency.

Lo and Mackinlay (1988) studied the US stock Indexes return from 1962 to 1985 by using variance-ratio rest and exploit the fact that return variances, scale linearly under the random walk hypothesis, the variance of two-week return is twice the variance of one week return and ultimately rejected the random walk hypothesis. But interestingly they found that individual stock did satisfy the random walk.

Shiller (1989) published a book on market volatility which described the sources of volatility to challenge Efficient Market Hypothesis and argued that excess volatility in stock prices and returns were the signs of market inefficiency by highlighting the papers in early 80s.

Andrew Lo (1991) developed a model to test long run memory which is robust to short range dependence and found that there was no evidence of long range dependence in stock returns on all the indexes tested.

Fama (1998) in answering the EMH critics in the form of anomalies, was of the opinion that the anomalies are chance results, apparent overreaction to information is about as common as under reaction and post-event continuation of pre-event abnormal returns is about as frequent as post event reversal and sited the methodologies used to identify the anomalies were challengeable and concluded that most long term returns anomalies tend to disappear with reasonable changes in technique.

Shleifer (2000) in his book Inefficient Markets: An Introduction to Behavioural Finance questioned the assumption of investors' rationality and perfect arbitrage by focusing on irrational behaviour of investors and tried to build some models to test the behavioral finance approach but contented that in spite of being irrational there are chances that the market can be efficient if investors mistakes are uncorrelated.

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Kian-ping Lim et al (2003) studied the weak form efficiency in Kuala Lumpur stock exchange by taking the period between 1990 and 2002 with the help of Hinich and Patterson windowed-test procedure to relate the findings with behavioural finance and found that in spite of having linear and non-linear dependencies, which supports return predictability for a brief period of time, concluded that the data by and large supported weak form efficient hypothesis and they identified irrational reactions of investors during the brief period when linearity existed.

Mohammad Musa and Mokhdum Morshed (2003) studied the efficiency of Dhaka Stock Exchange, Bangladesh between 1996-97 by taking the index closing value on daily basis and applied 'uncertain' information hypothesis (VIH) to find that the ARs and CAARs following positive events were significantly positive up to a few trading days whereas ARs and CAARs following negative events were significantly negative for only trading day +1, which was in favour of under reaction of investors to conclude that Bangladesh Capital Market could not be termed efficient in its pure theoretic form.

Bashar Abuzarour (2005) studied the market efficiency in Middle East Markets (consisted of Jordan, Egypt and Palestine) between 1992 and 2004 by applying the variance ratio test and rejected the random walk hypothesis. The author sited infrequent trading as the reason for not-having efficient markets and suggested removal of restrictions and barriers to the flow of capital in MENA régimes financial markets to improve efficiency and liquidity in Middle East Markets.

Mehmat Aga and Berna Kocaman (2008) found the weak form efficiency in Istanbul Stock Exchange by comparing the index returns with 'return index - 20,' a monthly index composed by authors. The results obtained from time series analysis showed that current time could not be explained with the past values, which supported the random walk hypothesis.

Random Walk Hypothesis on Stock Returns - India

Rao and Mukharjee (1971) were the first to attempt a study on random walk model in Indian context by taking the weekly average prices of the Indian Aluminium company for a period of 15 years from 1955 to 1970 by applying spectral analysis and a

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large number of spectral estimates were found to fall within the appropriate 95% confidence level, which supported the random walk hypothesis to conclude the weak form efficiency. Since the study was pertaining to only one company, no concrete conclusion has been made towards the efficiency of the market.

Ray (1976) conducted a study on seven daily index series between 1966 and 1972 by applying runs test, serial correlation test and spectral analysis and found that the random walk model traced only for iron and steel and cement industries among the industries studied at that time. The study has been an improved one from the Rao and Mukharjee for having considered seven Industry stocks.

Sharma and Kennedy (1977) studied the behaviour of stock market indices of Bombay, London and New York stock exchanges for a period of 11 years from 1963-1973 by using runs test and spectral analysis techniques on the monthly data and found that BSE stock obey random walk model, spectral densities estimated for all the exchanges used confirmed randomness of the series and no systematic cyclical component or periodicity was present in the study.

Barua (1981) scrutinized the daily price changes of 20 securities from July 1977 to June 1979 by applying runs test and auto correlation tests and found serial independence of price changes of securities but the market index exhibited significant serial dependence in both the tests. This phenomenon can be explained by the argument suggested by Moore that since the market is supported to reflect the impact of changes in the context of overall economic environment, if the changes in the economy show a definite trend there are chances that the market could behave non-randomly.

Sharma (1983) studied the randomness of 23 actively traded stocks at the BSE for a period of 6 years from 1973 to 1978 by taking 288 weakly observations made at each Friday closing price. The Integrated Moving Average (IMA) form of the random walk model, as suggested by Box and Jenkins was used for testing the hypothesis and the model was found to be an adequate representation of price changes except for two stocks for which no adjustment was made for rights and bonus issues.

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Ramachandran (1986) tested the weak form efficiency by considering week end prices of 60 scripts between 1976 and 1981 through the application of runs test, serial correlation and filter rules ranging from 1% to 49% with an assumed transaction cost of 2.5% and carry forward charges of 20% per annum and found support for weak form EMH. Assuming that the investor utilized the carry forward facility, the author compared the filter returns from a buy and hold strategy to find inferior returns in filter rule strategy, which endorsed the view of Fama that if transaction costs are considered, the excess returns earned by using filter rules fades away.

Rao (1988) conducted serial correlation test, runs test and filter rules technique on the sample data covering 10 blue chip companies for a period of 6 years from July 1982 to June 1987, using weak end prices in BSE and found weak form efficiency of the EMH in all the tests even without having transaction costs assuption, the buy and hold strategy outperformed the trading strategy.

Obaidullah (1990) examined the randomness of successive price changes among 36 active scripts traded on the BSE for a period of 4 years from 1985 to 1988 by applying serial correlation and runs test and found support for weak form efficiency of the market.

Chaudhuri (1991) studied the short run price behaviour of Indian Stock Market with particular reference to testing the weak form efficiency to test the randomness of returns by taking 93 actively traded stocks in Bombay Stock Exchange over the period January 1988 to April 1990 on a daily basis. By using serial correlation test and the runs test to daily log price changes the author concluded that the study did not support the serial independence of daily log price changes and it did not seem to be efficient even in its weak form.

Barman and Madusoudanan (1993) analysed the permanent and temporary components of Indian Stock Market returns by taking sensex data by using unit root test and variance bounce ratios and concluded that the fluctuations in returns was permanent in the long run, while for short and medium term they were temporary, which is an indication of lack of market efficiency.

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Ranganatham and Subramanian (1993) studied the Indian Stock Market efficiency by using frequency domain approach of spectral analysis and found some periodic cycles in the price movements which run counter to the argument of weak form market efficiency. They used ARIMA (Auto Regressive Integrated Moving Averages) Model, which gives an algebraic statement tracing how one thing is statistically related to one or more other things and it states how observations on a variable are statistically related to past observations on the same variable.

Vaidyanathan and Kumar Gali (1994) studied the randomness of Indian stock market by taking the closing prices of ten actively traded shares in the Bombay Stock Exchange over four different periods of time through runs test, serial correlation and filter rules and concluded that the results provided supportive evidence for the weak form efficiency of the Bombay Stock Exchange.

Belgaumi (1995) studied the share price data of 70 listed companies on the BSE by using run test and serial correlation test and the results of the analysis supported the view that Indian capital market follows random walk and hence efficient in its weak form.

Ramasastri (2000) enquired into the randomness of Indian stock market by taking BSE sensex closing data for a period of 8 years from January 1991 to December 1998 dividing the sample data into three sub-period and explored the tests of unit roots to conclude that sensex data followed random walk in all the sub periods which is an indication of market efficiency in its weak form.

Barman and Samanta (2001) studied the monthly price data for 15 years from April 1984 to March 1997 on BSE sensex by applying Martingale test, volatility test and co-integration test between real price index and real dividend to test the efficient market hypothesis in Indian Capital Market and their results supported the view that Indian Capital Market was weak form inefficient.

Parimal Jayanth (2001) studied both the inter-day and Intra-day volatility in stock prices by taking the daily returns of 4 indices – BSE sensex, BSE 100, Nifty and NASDAQ to test the randomness through the non-parametric tests such as signs test and

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rank correlation test. The author found inter day as well as intra day volatility as non-random and concluded that the market was not efficient due to day of the weak effect on the daily returns depending upon the trading cycles of the respective bourses.

Guptha (2001) studied the randomness of BSE stocks by using daily price data of 41 actively traded stocks for a period of 10 years from January 1986 to December 1995 and concluded that the market is weak form efficient.

Ramasastri (2001) analysed the daily sensex returns for a period of 3 years from January 1996 to December 1998 by applying correlogram and spectral analyses to conclude that Indian capital market is efficient in its weak form.

Deb (2003) enquired into the randomness of BSE sensex, BSE 100, BSE 200, Nifty and Junior Nifty by applying parametric and non-parametric tests on daily closing values and observed that all these indices showed non-stationary (random walk) but their returns were stationary when ADF unit root test was applied.

Debasish and Mishra (2003) analyzed the existence of random walk hypothesis in the Indian Stock Market by taking the adjusted daily returns, weekly returns and monthly returns for 6 stock indices, BSE (sensex, 100, 200) and NSE (Nifty, Junior and Defty) and two non-parametric tests namely runs tests and spearman's rank correlation tests were applied. The empirical results were in support of informational efficiency and random walk hypothesis in the case of daily and weekly returns but contradictory results were found in case of monthly returns.

Alimov et al (2004) studied the daily closing values of BSE 100, BSE 500 and the daily closing prices of 14 stocks from July 2001 to October 2003 by employing ADF test for unit roots and concluded that the data was non-stationary at 5% significant level, and hence the market followed a random walk. The authors substantiated their conclusion by applying Lo and Mackinlay's variance ratio test.

Suyash Goswami and Gokaka Nath (2005) studied market efficiency and linkage dynamics of Indian Stock Market (Nifty) with other leading international markets for a period between January 1994 and April 2004 by applying auto correlation and stationery test for checking the randomness and co-integration tests to test the inter linkage

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dynamics of Indian Market with the other markets. Their findings supported the view that Indian Stock Market was weak from efficient and the returns were linked with the returns of U.S. and European markets and not with Asian Markets.

Bodla (2005) tested the weak form efficiency of Indian Stock Market with the help of daily price data of 47 Nifty companies for 3 calendar years (January 2001 to December 2003) by applying runs test and serial correlation test to find support for the hypothesis that Indian capital market was efficient in its weak form.

Panda and Narasimhan (2005) studied the daily log returns of Sensex data for a period 11 years from January 1994 to December 2004 by using ADF unit root test at 1%, 5% and 10% levels to find the data was stationary. The weakly log returns had also found to be stationary and the authors suggested that Artificial Neural Network Model performs better with regard to prediction of daily stock returns then the linear Auto regression (LAR) and Random Walk (RW) models in terms of root mean square error and sign forecasting of daily stock returns. The findings of the study strongly challenged the weak form efficiency of the market in Indian context.

Maynak Bhatt et.all (2010) attempted to frame a forecasting model for different sectors by taking all the 30 companies, which constituted sensex for the period between 2008 and 2009. Applying Autoregressive Moving Average (ARIMA) model for the closing values of the indices and after testing for the accuracy it was concluded that it is very difficult to develop a common model for a particular sector, which can be applied to any company that exits in the sector and the authors admitted that the prediction of share prices can not be made.

Rajagopalan (2011) studied the daily log returns of Bombay Stock Exchange BSE 100 Index for a 10 years period from 2001 to 2010 by applying ADF Unit root test and found that historical prices/ returns do not explain current or future prices/returns. This strongly supports the random walk hypothesis but with a drift, which can be used to make any meaningful predictions and concluded that the market was weak form efficient.

Rajagopalan in his consecutive studies on the first decade of 21st century of random walk by taking BSE 500 (2012), SENSEX (2015), Nifty index (2019^{a}) and S&P

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CNX 500 Index (2019[b]) found similar support for weak form efficiency by applying ADF Unit root test to conclude the markets do not offer arbitrage opportunities among them and the past prices/ returns are useless estimates of future prices in spite of the fact that on an average previous stationary nature of returns hold approximately 45 percent of return explanation for future but, of no practical implication as the relationship existed only for historical returns and not helpful in return prediction exercise. These studies questioned the pure form of random walk or exact random walk, but still in favour of weak form efficiency due to poor return prediction capacity in the short run.

Methods and Tools Applied

The above detailed review of random walk approach to share prices showed the quantum and depth of research conducted in stock markets internationally and nationally. While the developed west started concentrating on Random Walk from the beginning of 20th Century, the empirical works in India got started from the 7th decade of the previous Century. Method of dealing with data saw a sea change as initially the monthly and weekly price averages dominated the empirical research and later on prices on daily basis assumed concentration. In recent times, daily log returns are considered to facilitate convenient data handling running to thousands. The results of different method of using data with similar tools gave different results, as price dependence was reported in studies considered monthly and weekly average price data while pure random nature of prices was observed on daily data. Even with daily data methods, shares with high frequency of trading supported random walk while price dependence was there when the shares are not frequently traded. It made frequency of trading as one of the basic conditions of random walk and resultant market efficiency.

Tools like random numbers, run test, serial correlation, and Spectral Analysis dominated analysis part and later on Augmented Dickey Fuller Unit Root Test (ADF) was used to verify nature of price series data. Thereafter, the data based on first order difference in the form of stock returns started dominating the prediction exercise to identify the nature of predictability. Researchers who opposed the market efficiency started using variances of different aspects including dividends and earnings and

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compared with variance in prices and returns which found to be differing heavily and it was termed as Variance Bounce. This variance aspect itself claimed to be a support for market efficiency by proponents of market efficiency instead of working against market efficiency, since the random shocks would give differing impacts on prices and ultimately returns. But, the variance bounce formed the basis for anomalous price behavior observed not very frequently and lead to a new school of thought called behavioural finance in the last decade of 21st Century. Moreover, the development in analytical tools likes Auto Regressive Integrated Moving Average (ARIMA), Vector Auto Regression (VAR), Auto Regressive Conditional Heteroscedasticity (ARCH), and Generalised Auto Regressive Conditional Heteroscedasticity (GARCH) helped in making forecasting macroeconomic time series data other than stock prices to a meaningful planning.

Pure Random Walk to Random Walk with Drift

It is already observed in studies by Rajagopalan for 10 years data that the random walk with drift for different stock indices traced a 45 percent explanatory power with past returns to predict future returns. Let us assess the usefulness of such return explanation for practical purposes. Can an investor be ready to observe the 10 years daily data to capture the 45 per cent of explanation of return in the next period? There are two possible explanations for the above question. First one being that, if the investor is ready as well as competent in these tools to capture the explanatory power of 45 per cent in returns, with 55 per cent of unknown, how can he beat the market which is supposed to offer a return for the known as well as the unknown? The main point to be noted here is the unknown may be negative or positive based on the information signals.

The second one is that if the investor is ready and not competent, he/she can appoint a person(s) who is competent by whatever name they may be called. If they trade with 45 per cent explanatory power of the previous return data on the future returns, still 55 per cent part remains to be unexplained in an efficient market. If the person appointed by him is assumed to be more competent to capture some portion of the unexplained 55 per cent by whatever means, there is no assurance that he can beat the market consistently and naturally the transaction cost component wipes off the additional returns earned by the expertise. Even if

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the additional returns exceed transaction costs in some instances (by chance and not by choice), it does not mean that there are possibilities of getting the same forever and the financial advisors in that case had an escape route called 'subject to market risks' for not able to earn assured returns. The random walk model with drift, as an estimator does the same it had done earlier in return prediction when it was in pure form. The form has changed, but, the purpose is not accomplished as stock market prices are still unpredictable.

Conclusion

A nearly 120 years of Random Walk Approach to stock market prices have undergone many attacks empirically. Research made and models developed during this period questioned the classical approach of random walk or Stochastic process to make the random walk model to accommodate different variants of the original model to accept some level of predictability but not for the short run. As a result, long run return predictability models were developed based on variances in returns. Since, the prices and returns are supposed to be on increase during long run, the purpose of making stock market prediction has failed because, it is already an established stock market theory that having a long run perspective is always better to earn a return in line with the market.

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