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Working Paper

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Fractal Structure Analysis in the Indian Stock Market

Abstract

The Fractal Market Hypothesis questions the Efficient Market Hypothesis which asserts that all the available information may not be reflected in the market prices, since investors may not directly react to information, according to the information being received. Instead, investors may react after a delay, as in the case of information confirming a recent trend change. The present study has made an attempt to analyse the existence of fractal structure in the Indian Stock Market with special reference to BSE Sensex. The study found that the trend occasionally followed the random walk initially. Afterwards, the trend reveals persistent behavior. Thus the fractal structure exists in the BSE Sensex.

Key Words: Efficient Market Hypothesis, Fractal Structure, Random Walk, Persistence.

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1. Introduction

Efficient Market Hypothesis is one of the major areas of research in capital market. According to the Efficient Markets Hypothesis (EMH), an efficient capital market is one in which security prices adjust rapidly to the arrival of new information, and therefore, the current prices of securities reflect all information about the security. This implies the absence of exploitable excess profit opportunities. The EMH assumption that rational investors always make optimal decisions was questioned by various researchers. Edgar Peters (1989) proposed in his Fractal Market Hypothesis that all the available information may not be reflected in the market prices since investors stay in their 'preferred habitat' (time horizon), no matter what the market information indicates.

1.1. Fractal Market Hypothesis

Fractal Structure refers to the structure wherein the parts are in some way related to the whole. It is the irregular shape or structure formed by repeated subdivisions of a basic form, and having a pattern of regularity underlying its apparent randomness. Following Mandelbrot who discovered such fractals in the financial markets, Peters (1994) proposed a Fractal Market Hypothesis (FMH). It explores the application of chaos theory and fractals to finance. The main idea of the fractal model is that investors may not directly react to information. Instead, investors may react after a delay, as in the case of information confirming a recent trend change.

1.2. Review of Literature

H. E. Hurst (1951) discovered a biased random process, or fractional Brownian motion, as opposed to a pure random process. A biased random process means that there is a long-term

dependence, or a 'memory', between observations. The events of one period influence all the periods that follow. This dependence is called 'persistence.' Edgar E.Peters (1989) investigated to find out whether capital markets movements followed a biased random walk. The results concluded that investors' interpretation of events is not immediately reflected in price, as the Efficient Market Hypothesis suggests. Edgar E. Peters (1994) applied fractal analysis for Dow Jones Industrials Data, S&P Tick Data, Gold Prices, U.K Inflation Data and the exchanges rates of Mark/Dollar, Pound/Dollar and Yen/Dollar. He found that there will be trends and cycles at all investment horizons since the information is processed differently at various frequencies. He observed that though the exact structure of trend is predictable, it will never be perfectly predictable and this keeps the market stable. T P Madhusoodanan (1998) observed persistent behavior for both index returns and for individual stock returns and hence the random walk hypothesis was not accepted by him in the Indian Market. Chin W. Yang (1999) insisted that the abnormal profit was entirely possible for certain time intervals during a trading day. His study reveals the existence of better forecasting performance for the time intervals in which the long term memory is found. Gokala C Nath (2001) found out that the movement of stock prices does not follow a random movement and there is definite possibility for the persistence for a shorter period. But for the longer period, there is enough noise in the series and the trend is not perfectly established. Epaminondas Panas (2001) undertook the comparative analysis of the two approaches - Levy - Stable Family Distributions Methodology and Auto Regressive Fractionally Integrated Moving Average (ARFIMA) methodology. A comparative analysis of the two approaches indicates the existence of long-memory in the Athens Stock Exchange. Ashok Razdan (2001) asserted that the price movements follow a set of distributions which have high

peak and fat tails. The result shows that the market returns were correlated to multifractal features in the index data. Madhusudan (2003) found out that the behavior of speculative price is related to time varying volatility, indicating that the large changes in speculative prices have high persistence. Daniel O. Cajuerio and Benjamin (2005) presented empirical evidence of long range dependence in returns and volatility for banking indices for forty one different countries, including developed and emerging markets. The results suggested that there was strong degree of long range dependence in equity returns for emerging markets rather than for developed countries. Tran Van Quang (2005) analysed the Fractal Market Hypothesis which emphasizes the impact of liquidity and investment horizon on the behavior of investors. The result reveals that the price changes on Czech Equity Market did not follow a random walk and the market was far behind efficient. Hareesh Kumar and Malabika Deo (2007) proved that Day of the Week Effect exists in the Indian Stock Market, which affects both the stock returns and volatility and thereby proving that Indian Stock Market is efficient. Punithavathy Pandian and Queensly Jeyanthi (2008) maintain that National Stock Exchange of India is efficient in absorbing the structural changes that followed the Rolling Settlement. Chin Wen Cheong (2008) explores the Fractionally Integrated (FI) Time Series Analysis in Malaysian Stock Market. The empirical results evidenced the proxy of absolute return and ARCH-type volatility model provides better performances in both the estimation and forecasting evaluations.

The above studies analysed the fractal structure in various developed and developing countries. However, only few studies have been made in India for analyzing the fractal structure. Hence the present study has made an attempt to analyse the presence of fractal structure in the Indian Stock Market.

1.3. Statement of the Problem

Efficient Market Hypothesis assumes that the investors are rational within the same unique time horizon. Every investor would respond to the same information at the same time and it resulted in linear reaction. Fractal Market Hypothesis revisits such linear reaction because investors' behavior assumed by Fractal Market Hypothesis is a non-linear reaction. The Fractal Model accounts for markets that consist of many irrational investors trading at different investment horizons. If each individual may intercept information in different ways at different times, it would lead to long range dependence or long memory and persistence behavior. In this study, the existence of fractal structure in BSE was examined.

1.4. Need of the study

The regulatory changes in India have made the capital market more efficient with respect to the price discovery mechanism and helped the market to grow exponentially. The transparency and liquidity also increased the number of investors. The substantial increase in Foreign Investors has also helped in increasing liquidity. The better dissemination of information increased the level of efficiency in asset prices. The level of such efficiency in prices needs to be tested with various models that exist in the literature.

1.5. Objectives of the Study

The following are the important objectives of the study:

- To assess the randomness and normality of sample index returns.
- To analyze the existence of fractal structure in BSE Index.
- To examine long range dependence of daily returns of Sensex during the study period.

1.6. Hypotheses of the Study

The following hypotheses were tested,

NH1 : The Sensex returns are non-stationary

NH2 : The Sensex returns are not normally distributed.

NH3 : The Sensex returns have no long range dependence.

1.7. Methodology of the Study

1.7.1. Sample Selection

The main aim of this study was to analyse the existence of fractal structure in BSE. The daily index returns of BSE Sensex were used to check the evidence of fractal structure in the BSE.

1.7.2. Sources of Data

The daily index returns of BSE Sensex were collected from the Prowess Corporate Database. The other required data were obtained from Journals and Websites.

1.7.3. Period of the Study

The Study covered a period of five years from 1 January, 2005 to 31 December 2009.

1.7.4. Tools used for analysis

The daily index returns of Sensex were analysed by using Mean, Median, Standard Deviation, Skewness, Kurtosis, Augmented Dickey Fuller Test, Jarque-Bera Test and Rescaled Range Analysis with the help of SPSS, Unit Root ADF Software, E-views and KaotiXL Software.

2. Analysis of the Study

In order to know the existence of fractal structure the analysis of this Study has been arranged as follows:

2.1. Descriptive Statistics of BSE Sensex

2.2. Augmented Dickey-Fuller (ADF) on BSE Sensex Returns

2.3. Jarque-Bera Test on BSE Sensex Returns

2.4. Estimating the Hurst Exponent using Rescaled Range Analysis on BSE Sensex Returns

2.5. Estimating the Hurst Exponent for non-periodic cycles on Sensex

2.1. Descriptive Statistics of BSE Sensex

The mean, standard deviation, skewness and kurtosis of BSE Sensex are displayed in **Table – 1**. The Sensex has a positive average returns at 0.0976 and it implies that the returns series have slowly increased over a period of time. The standard deviation, which is considered to be a measure of volatility of Sensex, was 1.9613. Further, it is to be noted that the Sensex recorded positive skewness at 0.3125. This indicates the probability of getting more positive returns and less negative returns over the study period. The value of the kurtosis (9.8305) was greater than three in the series and revealed a heavier tail than standard normal distribution. Hence the Sensex returns were not normally distributed.

2.2. Augmented Dickey-Fuller (ADF) on BSE Sensex Returns

Table - 2 reveals the empirical results of the Augmented Dickey-Fuller Test (ADF) for the Sensex Returns. According to the above Table, the statistical value of Augmented Dickey-Fuller (ADF) Test for Sensex Returns was -12.2593 and probability was 0.0000. From the analysis of the above Table, it is to be noted that the index returns of Sensex were discovered to

be stationary during the study period. Hence the null hypothesis, NH1 **'The daily index returns are non stationary'** is rejected**.**

2.3. Jarque-Bera Test on BSE Sensex Returns

The results of the Jarque Bera Test (JB) for the Sensex returns during 1.1.2005 to 31.12.2009 are given in Table-3. It is inferred that the statistical value of the Jarque Bera Test (JB) was 2428.7924 and probability was 0.0000. It is clear that the JB test value was greater than the critical value of 9.2103 at 1 per cent level and 5.9911 at 5 per cent level. It indicates the fact that the series were not normally distributed. According to the above Table, the kurtosis value (9.8305) ranged around the mean while the skewness was 0.3125 which reveals asymmetry in the distribution of index returns. From the overall analysis of the above Table, it is asserted that the Sensex was not normally distributed during the study period. Hence the null hypothesis, NH2 **'The daily index returns are not normally distributed'** is accepted.

2.4. Estimating the Hurst Exponent using Rescaled Range Analysis on BSE Sensex Returns

If Hurst Exponent value H is close to 0.5, it indicates a random walk. In a random walk, there is no correlation between previous value and its future value and there is a 50 per cent probability that future returns values will go either up or down. If Hurst Exponent value H lies between 0.0000 and 0.5000, it means that time series exhibits 'anti-persistent behavior'. It indicates that the increasing trend in the past implies decreasing trend in the future. If Hurst Exponent value H lies between 0.5000 and 1.0000, it means that the time series has 'persistent behavior'. It reveals that the increasing trend in the past implies increasing trend in the future also. The fractal dimension of time series was calculated according to formula D=2-H. If this value lies between 1.0000 and 2.0000, it reveals that there is greater opportunity to earn profit.

Table - 4 reveals Hurst Exponent estimation results for Sensex. During the study period, the value of R/S analysis for the Sensex was 0.62047. The critical values at 1 per cent, 5 per cent and 10 per cent were - 0.6484, - 0.6204 and -0.6066 respectively. It provides the evidence of persistence in the daily index return and it is significant at 10 per cent level. Hence the null hypothesis, NH3 **'The daily index returns have no long range dependence'** is rejected. From the overall analysis of the Table, the daily index returns of Sensex were discovered to have long memory during the study period. Further, the fractal dimension of time series of stock returns for Sensex (1.4753) confirms that they did not follow a random walk.

2.5. Estimating the Hurst Exponent for non-periodic cycles on Sensex

The estimation of Hurst Exponent for non periodic cycles of Sensex is given in **Table – 5**. None of the values for the time lags is equal to 0.5000, indicating that the Indian Stock Market did not follow random walk in so far as the daily returns were concerned. This shows that there was a definite possibility for persistence in the Sensex returns but the values for time lags above 20 days were close to 0.5000, indicating that the trend was not perfectly established. However, for the longer period, the values were reasonably higher than 0.5000, indicating the persistence behavior.

3. Findings and Suggestions

The following are the major findings of the present Study.

- It is clearly understood that the stock prices did not reflect the information in the past series of stock prices. In addition to that, the daily index returns did not follow a random walk and it is possible to gain more returns by observing the patterns in historical stock prices.

- The information is assimilated differently by different investment horizons. Information did not have uniform impact on prices.
- **Augmented Dickey-Fuller Test** shows that the daily index returns of Sensex were reported to be stationary at 1 per cent, 5 per cent, 10 per cent significant levels. Its't' value was negative, which indicates stronger rejection of null hypothesis.
- **Jarque Bera Test** reveals that the daily index returns of Sensex was not symmetrically distributed over a period of five years. The probability value of JB test was 0.0000. It reveals the confidence level at 100.0000 per cent
- **According to Hurst Exponent** the BSE Sensex returns did not follow random walk during the study period. In the initial period, the trend occasionally followed the random walk. Afterwards, the trend revealed persistent behavior but the values indicate that there was either an increasing trend or a decreasing trend

Based on the findings of the Study, certain suggestions have been offered.

- The prices may not reflect all available information, but only the information important to the particular investment horizon. Hence investors should take their investment decision based on important information.
- The regulatory authorities should monitor the reliability of the truth in the information released, because it would reflect the share prices.

3.1. Conclusion

This Study has made an attempt to examine the presence of fractal structure in Indian Stock Market by using Sensex. ADF and JB Tests show the evidence of stationary and non

normality. The empirical results suggest that there was a stronger degree of long range dependence in the daily index returns of Sensex. A fractal approach leads to the Heterogenous Market Hypothesis (HMH) and Coherent Market Hypothesis (CMH) where further studies could focus on these areas.

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Table - 1

Descriptive Statistics of Sensex Returns

Descriptive Statistics	BSE
Mean	0.0976
Maximum	17.3410
Minimum	-10.9621
Standard Deviation	1.9613
Skewness	0.3125
Kurtosis	9.8305
Number of observations	1239

Source: Computed from Prowess

Table – 2

Augmented Dickey-Fuller Test Results for Sensex Returns

		t-Statistic	Probability*
Augmented Dickey-Fuller test statistic		-12.2593	0.0000
Test critical values:	1% level	-3.4908	
	5% level	-2.8879	
	10% level	-2.5809	

Source: Computed from Prowess

*MacKinnon (1996) one-sided p-values

Table – 3

Jarque Bera Test Results for Sensex

		t-Statistic	**Probability**
Jarque-Bera test statistic		2428.7926	0.0000
Skewness		0.3125	
Kurtosis		9.8305	
Test critical values:	1% level	9.2103	
	5% level	5.9911	

Source: Computed from Prowess

Table – 4

Hurst Exponent Estimation Results for Sensex

Hurst exponent	**Statistic value**
Rescaled Range Analysis	0.6204
Fractal dimension	1.4753
Number of Observations	1239
Degrees of Freedom	2

Source: Computed from Prowess

Table - 5

Hurst Exponent for Non Periodic Cycles of Sensex

Period, N	**20 days**	**40 days**	**80 days**	**160 days**	**310 days**	**620 days**	**1239 days**
Hurst	0.5321	0.5417	0.5733	0.5879	0.6324	0.6883	0.7876

Source: Computed from Prowess