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The Impact of Global Financial Crisis on Market Efficiency: An Empirical Analysis of the Indian Stock Market

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Abstract

This paper analyses the impact of the Global Financial Crisis on the informational market efficiency of the Indian Stock Market. In particular, the research focuses on analysing the stock market behaviour in three different sub-periods: Pre-Crisis, Crisis and the Recovery period. Various statistical methods, both parametric and non-parametric tests are employed to check if the market follows a random walk process. This helps in assessing the efficiency of the market. The results of the analysis show that the market is weak form inefficient in all three sub-periods. The informational market efficiency improved marginally from the Pre-Crisis period to the Crisis period and increased further from the Crisis period to the Recovery period. The informational inefficiency is an important criterion for the smooth functioning of the market because in an informationally inefficient market, the securities are not always fairly priced and this provides an incentive to traders to collect and use the relevant information to devise trading strategies which helps them in earning abnormal returns.

Keywords: Indian stock market, financial crisis, random walk process, abnormal returns, market efficiency, SEBI, statistical tests of informational inefficiency, Bombay stock market, National stock market

1. Introduction

India is one of the major emerging economies of the world. The S&P Fact book shows that the Indian stock market has the largest number of companies listed on its exchanges. The growth of the Indian economy has been coupled with the growth and integration of the stock market with the world. The Indian capital market although far less developed is an important investment destination. The investors, the traders and the policy makers all have an interest in the efficiency of the market. The efficient market hypothesis for markets is defined in terms of informational efficiency always. An efficient capital market plays an important role in a country's economy as capital allocation is a direct consequence of the efficiency. The evidence provided by past research shows that the stock markets of China, India and the other developing economies are much less developed than those of the Western world. Stock market efficiency is a widely debated subject and the researchers have been divided on the subject. The developing world stock markets deserve more attention because they are still considered far behind those of the developed world. Hence, it would be interesting to study the stock market efficiency of the Indian stock markets and more importantly the evolution of the efficiency due to the impact of the Global Financial Crisis.

Financial crisis is a situation which is associated with a bank run or investors pulling out of the bank stocks because of a fall in the valuation of banks and financial institutions. The end of 2007 and beginning of 2008 saw a liquidity shortfall in the US banking system and quite a few big banks namely Lehman Brothers, Merrill Lynch and Bear Sterns started collapsing. The problem also extended to other countries. In the UK, RBS, HBOS and Lloyds TSB had to be bailed out by the UK Government. The stock markets around the world collapsed as a result of this. The Indian stock market was not an exception. On 29 October 2007, the BSE Sensex breached the twenty thousand mark for the first time and on 27 October 2008 hit an intraday low of 7,697.30. The stock market's efficiency is the basis on which the traders and other investors invest in the stock exchange. The global financial crisis had a massive impact on the stock exchanges and their efficiency around the world. The research on this matter is very little and not up to date. This paper is an attempt to empirically check the impact of the global financial crisis on the market efficiency of the Bombay Stock Exchange.

The remaining paper has been organised as follows: Section 2 of Part I provides details about the past literature, Part II provides insights into the rationale and scope of the study and, discusses the objective and the hypothesis in detail while Part III talks about the data and the research methodology. This paves for the analysis in Part IV and the results and conclusions in Part V. The Bibliography and Appendix follow in Part VI.

1.1 Literature Review

Over the years, a lot of research has been done on the subject of stock market efficiency. There are many different studies by different researchers to examine the Efficient Market Hypothesis (EMH) and random walk characteristics of different stock markets and indices. Bachelier (1900) in his thesis first theorized the concept of market efficiency. He proposed the concept of independent and identically distributed (i.i.d) observations. He goes on to show that price changes are i.i.d because of noise trading which leads to unsymmetrical patterns and randomness of information. Kendall and Hill (1953) find that there are no predictable components in the stock market returns and therefore stock prices seem to evolve randomly. Samuelson (1965) goes on to say that in a competitive market there is a buyer for every seller and if one is sure that the price would rise, the price would have already risen and hence changes follow a random walk. Fama (1965) is the first one who triggers interest in the EMH theory when he published his paper in 1965. Fama carries out empirical testing and concludes that a financial analyst's exercise has no value as it is impossible to make abnormal profits from investment strategies. Similar observations are made by Niederhoffer and Osborne (1966). The theory of market efficiency states that in an informationally efficient market, the current prices reflect the information in the market and hence, it is not possible for an investor to make abnormal returns (1970). Following Fama (1970), returns can be denoted as

$$R_t = \phi_{t-1}(f_t^m) + \mu_t$$

Where R_t is the stock return at time t and $\phi_{t-1}(f_t^m)$ represents the equilibrium return at time t-1 while μ_t stands for the abnormal or excess component. According to Fama market uses the information to arrive at the equilibrium return. Let S_t represent the information set available at time t, then

$$\phi_{t-1}(f_t^m) = \phi(f_t^m|S_{t-1})$$

This equation implies that the market is efficient when it absorbs all relevant information quickly and this reflects in the price of the asset. In other words, we cannot use the information, S_{t-1} to make abnormal returns. Mathematically, this can be represented as:

$$\phi(f_t^m|S_{t-1}) = 0$$

1.1.1 Support for Weak Form Market Efficiency

Niederhoffer and Osborne (1966) suggest that investment strategies do not work as the stock prices are not serially correlated making it impossible to outsmart the market. As regards the emerging markets, Sharma and Kennedy (1977) are the first to check the market efficiency of the Bombay Stock Exchange in addition to the London Stock Exchange and the New York Stock Exchange. They use the time period from 1963 to 1973 and by applying the run test and spectral analysis conclude that the prices are completely random for all three stock exchanges. These early tests rely on serial analysis, runs and spectral tests to check the market efficiency but they tend to be less efficient in capturing the pattern of returns. Research based on the biggest emerging market, China by Liu, Song et al. (1997) upholds weak form efficiency of the Shanghai Stock Exchange. Yeh and Lee (2001) comes up with the same observations too. Smith (2007) looked into several middle eastern markets and concludes that Israeli, Jordanian and Lebanese markets support the Random Walk Hypothesis and are weak form efficient. Barnes (1986) has tested the weak form efficiency of the Kuala Lumper Stock Exchange and concludes that KLSE exhibits a high degree of efficiency in the weak form. He uses thirty companies and six different sectors over the time range of 1975 to 1980. efficiency of the Nigerian stock market. A correlation analysis conducted on the data from period January 1981–December 1992 reveals that the Nigerian Stock Exchange is weak form efficient. Research conducted by Samuels, Yacout et al. (1981) and Ayadi (1983) provide support for this study. Urrutia (1995) uses LOMAC's single variance ratio test for the stock exchanges of four emerging stock markets and concludes that all were weak form efficient. Rahman, Salat et al. (2004) evaluates the Dhaka Stock Exchange using the the unit root tests- Augment Dickey Fuller and Phillips-Perron test for a period from January 1990 to September 2003. The tests show the existence of a unit root, which means there is an existence of weak form efficiency of the DSE. When it comes to the Indian markets, the study conducted by Bhaumik (1997) discussing the stock index futures in India concludes that the market is weak form efficient. This is followed up by research from Ramasastri (1999) who uses unit roots on the stock returns data from the nineties to conclude that the Indian stock market is weak form efficient. Similar results were reported in another study conducted on the Indian stock exchange data from the nineties (Pant & Bishnoi, 2001). Rao and Shankaraiah

(2003) and Samanta (2004) also provide evidence to support the Random Walk Hypothesis. None of the studies previous studies look at the impact of a sudden financial crisis on the efficiency if the market. Our study therefore concentrates on this specific issue.

1.1.2 Support against Weak Form Market Efficiency

The earliest study is from Gandhi, Saunders et al. (1980) when they checked the industrial indices from the Kuwait Stock Exchange (KSE) for the period starting from December 1975 to May 1978 and found that both runs test and linear regression of lagged returns rejects the weak form efficiency hypothesis. Laurence (1986) tests both the Kuala Lumpur Stock Exchange and the Singapore Stock Exchange and concludes that both are not weak form efficient. He employs run test and the serial correlation tests to check for randomness. Worthington and Higgs (2009) performed a weak form efficiency check of the Australian stock market from February 1875 to December 2005 and conclude that the market is weak form inefficient. They use serial correlation tests, runs test and unit root tests on the daily returns from 6 January 1958 to 12 April 2006 and monthly returns from February 1875 to December 2005. The random walk model is strongly rejected by Lo and MacKinlay (1988) for the entire sample period ranging from 1962 to 1985 and for all sub periods for a variety of aggregate return indexes. They run the test by comparing variance estimators derived from data sampled at different frequencies. Mobarek and Keasey (2000) checked the weak form efficiency of the daily stock indices of the Dhaka Stock Exchange for the period of 1988 to 1997. Rahman and Hossain (2006) use both parametric and non-parametric tests on the daily stock returns of the Dhaka Stock Exchange from 1994 to 2005 to conclude that the stock market is not efficient in its weak form. Uddin and Khoda (2009) also tested the weak form efficiency of the DSE by testing twenty-three stocks of the pharmaceutical sector. Filis (2006) studies the Athens Stock Exchange from the period 2000 to 2002 and concludes that the market is inefficient due to volatility clustering. However, the FTSE/ASE 20 index showed evidence of weak form efficiency as it followed a random walk pattern. Parkinson (1987) tests the Nairobi Stock Exchange using monthly prices for the period of 1974 to 1978 and found that random walk hypothesis was rejected for NSE. Darrat and Zhong (2000) investigated the two Chinese stock exchanges-Shanghai and Shenzhen. They use two different approaches, the standard variance-ratio test of Lo and MacKinlay (1988) and a model comparison test. Both models vehemently reject the weak form efficiency of both the markets. Charles and Darné (2009) use the daily data from 1992 to 2007 from the Chinese stock exchanges and observe that the Class B shares of Chinese stock exchange do not follow the random walk hypothesis, and therefore are significantly inefficient. Paper by Hoque, Kim et al. (2007) re-examines the random walk hypothesis for eight emerging equity markets in Asia: Hong Kong, Korea, Taiwan, Indonesia, Malaysia, Singapore, Thailand and the Philippines. The variance ratio tests are employed and they show that the eight south east Asian markets do not follow random walk hypothesis with the exception of Taiwan and Korea. Awad and Daraghma (2009) examine the efficiency of the Palestine Security Exchange (PSE) at the weak-level for the thirty-five stocks listed in the market. They use some parametric tests like the serial correlation test, the ADF test and some like non-parametric tests include Phillips-Peron (PP) and runs test. All tests reveal that the market is inefficient in the weak form. Abdmoulah (2010) uses GARCH-M (1,1) approach along with state–space time-varying parameters for the 11 Arab stock markets for periods ending in March 2009. All markets are found to be weak form inefficient. Frennberg and Hansson (1992) use the monthly data for the Swedish stock exchange from 1919 to 1990 and apply variance ratio and auto-regression of multiple period returns. They found out that the Swedish market hasn't followed random walk in the 72 years of sampled data. Poshakwale (1996) examines the Bombay Stock Exchange for efficiency and day of the week effect over a period of 1987 to 1994 and concludes that the market is weak form inefficient. KS one sample test, run test and serial correlation test are used to test the daily stock returns and the day of the week effect tests show that the stock market returns on Friday are much higher than any other day of the week on an average. Guidi, Gupta et al. (2011) test the weak form efficiency of the Central and Eastern European markets for the period 1999-2009

2. Rationale and Objective

As mentioned before, the market efficiency can be broadly categorised into three forms- strong form efficiency, semi-strong form and weak form efficiency. Strong form efficiency is hard to test because of data unavailability. Also, it is not possible to test the semi-strong form efficiency because there is no way of knowing if some people in the market have access to some private information which is valid and useful to devise investment strategies. Weak form efficiency asserts that fundamental analysis can be used to identify stocks that are undervalued and overvalued. This analysis can help investors make their investment decisions. Weak form efficiency can be tested by checking the randomness of stock returns. Our objective is to test the weak form efficiency of the Bombay Stock Exchange and check if the Global Financial Crisis had an impact on the same. We also check if serial correlation and heteroscedasticity exists in the Indian stock market. Fundamental analysis is the cornerstone of the stock markets around the world. Valuation of securities is an important function carried out by several traders and investors which leads to the formation of trading strategies in these markets. Arbitrage is only possible in a market which is weak form inefficient. If the markets are weak form efficient, it is not possible to buy securities which are undervalued and sell them at a time or in a market where they are fairly priced or overvalued. In other words, in a weak form efficient market, the concept of value investing would not exist and the traders have no incentive to collect information and it is hard to make abnormal returns. As such, it should be impossible to outperform the overall market through expert stock selection or market timing, and that the only way an investor can possibly obtain higher returns is by purchasing riskier investments. The Global Financial Crisis had a huge impact on the stock markets and it is worth understanding if it was possible to make abnormal returns in the bear markets from 2007-2011 or if the only way of making money was through the purchase of risky assets.

The aim of this paper is to understand the informational market efficiency of the Bombay Stock Exchange by testing the randomness in the daily stock returns and to study the impact of the Global Financial Crisis on the market efficiency. Randomness is possible only if the market is weak form efficient and hence, we check if the Bombay Stock Exchange indices follow random walk. The Bombay Stock Exchange is used for the analysis because it's the oldest, the most established and widely known stock market of India.

3. Data and Research Methodology

The data for the Bombay Stock Exchange is taken from the BSE website and the specific data regarding the five indices- BSE Sensex, BSE 100, BSE 200, BSE 500 and BSE Bankex is taken from Bloomberg and FactSet database. The data consists of the daily closing prices for the above mentioned five indices from 1 December 2003 to 30 November 2015. December 2007 is believed to be the start date of the great recession and the global financial crisis while November 2011 saw the world economies establish themselves firmly on the path of recovery. Bearing this in mind the data is split into three equal sub periods- Pre Crisis period from 1 December 2003 to 30 November 2007, Crisis Period from 1 December 2007 to 30 November 2011 and Recovery Period from 1 December 2011 to 30 November 2015. The stock market efficiency is tested for all the different sub-periods for all the five indices. The tests used for the analysis are:

1) **Jarque-Bera** test to measure the normality of the distribution;
2) **Kolmogorov-Smirnov (KS)** test to check goodness of fit;
3) **Autocorrelation Function test** is used to check the correlation of series with itself;
4) **Variance ratio test** to understand structural breaks and mean reversion tendency;
5) **Engle test**;
6) **Runs test** to test the randomness of time series;
7) **Unit Root test** to measure the stationarity of time series data.

Previous research done on this topic has employed these tests and verified the effectivity. While these tests have been used to test the stock market efficiency, they have never been used in the context of an impact analysis. After careful consideration and analysis, we are using these tests to check the impact of the Global Financial Crisis on the market efficiency. While some of the tests are conducted using the daily returns the others are calculated using prices of the indices and some using the standardised daily returns. The returns have been calculated using the formula:

$$r = ln\frac{P_t}{P_{t-1}}$$

The standardised returns have been calculated using the formula:

$$\bar{r} = \frac{X - \mu}{\sigma}$$

Where X is the value from the sample, μ is the mean and σ is the standard deviation of the sample data.

3.1 Jarque-Bera Test

Jarque-Bera test is used to measure the normality of distribution. A data set has the numeric observations: y1, y2, y3, y4, y5, …, yn. The sample mean of this observation set is defined as

$$\bar{y} = \frac{1}{n}\sum_{i=1}^{n} y_i$$

and the sample variance:

$$s^2 = \frac{1}{n-1}\sum_{i=1}^{n}(y_i - \bar{y})^2$$

The Jarque-Bera Test requires two more statistics: skewness and kurtosis

Skewness is a measure of symmetry. A distribution or a data set is said to be symmetric if it looks exactly the same to the left and right of the centre point. Skewness is defined as:

$$S = \frac{1}{n}.\frac{\sum_{i=1}^{n}(y_i - \bar{y})^3}{\bar{\sigma}^{2^{1.5}}}$$

where $\bar{\sigma}^2$ stands for sample variance.

Kurtosis is a measure of the 'fatness' of tails. A high kurtosis portrays a chart with fat tails which means that the distribution is low and even. Kurtosis is defined as

$$K = \frac{1}{n}.\frac{\sum_{i=1}^{n}(y_i - \bar{y})^4}{\bar{\sigma}^{2^2}}$$

Excess Kurtosis is defined as

$$E = K - 3$$

Excess Kurtosis is commonly used because E for a normal distribution is equal to 0 and K proper is 3. This type of distribution is called mesokurtic. An estimator g2=<E> for the excess kurtosis E is given by:

$$g_2 = \frac{k_4}{{k_2}^2}$$

Where K are the k-statistics. For a normal distribution, the variance of the estimator is

$$var(g_2) \approx \frac{24}{n}$$

The Jarque-Bera test for normality uses Skewness and Excess Kurtosis measures to test the null hypothesis which is defined as:

H_0: normal distribution, Skewness is zero and excess kurtosis is zero;

against the alternative hypothesis

H1: non-normal distribution.

The Jarque-Bera test statistic is calculated as

$$JB = n.\left[\frac{S^2}{6} + \frac{EK^2}{24}\right]$$

The JB test statistic is then used to calculate the chi-square statistic (χ^2) with 2 degrees of freedom. The null hypothesis holds if the calculated JB test statistic is less than the critical value of Chi-square distribution. The critical values can be found in Table 1.

Table 1. Chi Square of JB test statistic

Probability	**Degrees of Freedom**				
	1	2	3	4	5
0.05	3.84	5.99	7.82	9.49	11.1
0.01	6.64	9.21	11.3	13.2	15.1
0.001	10.8	13.8	16.3	18.5	20.5

3.2 Kolmogorov-Smirnov Test

The KS test is one of the most commonly used goodness-of-fit tests. It assesses how closely does the observed cumulative observation agrees with a commonly specified theoretical continuous distribution which may be normal, uniform, poisson or exponential. In other words, it measures how well a random sample of data fits one of the four theoretical distributions. The distributions are regarded as empirical distribution functions in their cumulative form. The test statistic measures the maximum vertical distance between the two functions and hence is quite accurate. The other big advantage of the KS-test is that it makes no assumption of the distribution of data. In statistical terms, it is non-parametric and distribution free. Let be an ordered sample with $y_1, y_2, y_3, \ldots, y_n$ and define $S_n(y)$ as:

$$S_n(y) = \begin{cases} 0, & y < y_1, \\ k/n, & y_k \le y < y_{k+1}, \\ 1, & y > y_n \end{cases}$$

We assume that the sample comes from a population with cumulative distribution function F(y) and we define D as follows:

$$D_n = \max|F(y) - S_n(y)|$$

Dn is a random variable which is used to estimate the value of F(y). The distribution of Dn can be calculated easily but the critical values of the distribution are more important for analysis. $D_{n,\alpha}$ is a critical value if $P(D_n \le D_{n,\alpha}) = 1 - \alpha$. For completely specified continuous distributions with number of observations (n) > 35, the critical value is as follows:

$$for\ n > 35: \frac{\sqrt{-0.5.\ln(\frac{\alpha}{2})}}{\sqrt{n}}$$

Dn can be used to test the hypothesis that a random sample came from a population with a specific distribution function F(y). If $\max|F(y) - S_n(y)| \le D_{n,\alpha}$, then the sample data is a good fit with F(y). See Figure 1.

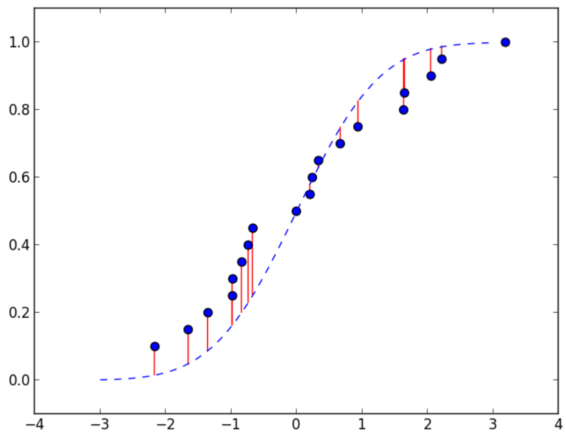

Figure 1. KS test plot

3.3 Runs Test

Runs test is an important non-parametric test of RWH. A sequence of consecutive changes in the returns time series is defined as a run. A run is zero, if there are no changes in the series. The expected returns represent the changes required if the data is generated from a random process. If the actual runs are within the α range of 0.05, it indicates that the returns are generated by a random process.

The runs test is defined as:

H_0: the sequence was generated in a random manner.

H_1: the sequence was not generated by random walk.

Z: the test statistic is $Z = \frac{R-ER}{S_R}$.

Where R is the observed number of runs and ER is the expected number of runs, and SR is the standard deviation of the number of runs. The value of ER is computed as

$$ER = \frac{Y(Y-1) - \sum_{i=1}^{3} c_i^2}{Y}$$

where Y is total number of runs, ci is number of return changes of each category of sign (i = 1, 2, 3). The ER in equation above has an approximate normal distribution for large Y. The runs test rejects the null hypothesis if

$$|Z| > Z_{1-\frac{\alpha}{2}}$$

Where α is the significance level. For a large sample runs test, the test statistics are compared to a standard normal table.

3.4 Autocorrelation

Autocorrelation is the degree of similarity between a time series and a lagged version of the same lagged time series over successive time intervals. Mathematically, it is the same as correlation, the only difference being that the same time series is used twice- once in its original form and once lagged. Autocorrelation is used to test if the process generating the observed returns is a series of i.i.d random variables. Auto-correlation can be calculated mathematically as follows:

For an observed series y1, y2, …. yT, with the sample mean of $\bar{y}$. The sample lag-h autocorrelation is given by

$$\hat{\rho}_h = \frac{\sum_{t=h+1}^{T}(y_t - \bar{y})(y_{t-h} - \bar{y})}{\sum_{t=1}^{T}(y_t - \bar{y})^2}$$

Ljung and Box's portmanteau Q-statistic is used to check for autocorrelation and goodness of fit. The test is defined as:

H_0: the sequence does not exhibit goodness of fit.

H_1: the sequence exhibits goodness of fit.

Q: the test statistic is $Q = n(n+2)\sum_{k=1}^{m}\frac{\hat{r}_k^2}{n-k}$.

where $\hat{r}_k^2$ is the estimated autocorrelation of the series at lag k and m is the number of lags being tested.

The Box-Ljung test rejects the null hypothesis if

$$Q > \chi^2_{1-\alpha,h}$$

where $\chi^2_{1-\alpha,h}$ is the chi-square distribution table value with significance level α and h degrees of freedom.

The distribution of Q(m) has two possible cases:

1) If the r_k are sample autocorrelations for residuals from a time series model, the null hypothesis distribution of Q(m) is a chi-square distribution with df=m-n, where n is the number of coefficients in the model
2) If ACF is for raw data, n is equal to 0 and hence, the null hypothesis distribution of Q(m) is a chi-square distribution with df=m.

3.5 Variance Ratios

Net return on the asset between two dates, t-1 and t is expressed mathematically as:

$$R_t = \frac{P_t}{P_{t-1}} - 1$$

Gross return is defined as:

$$R_t + 1 = \frac{P_t}{P_{t-1}}$$

The natural logarithm of gross return is defined as the continuously compounded return rt and is mathematically represented as:

$$r_t = \ln(R_t + 1) = \ln(\frac{P_t}{P_{t-1}})$$

Continuously compounded multi-period returns is expressed as:

$$r_t(k) = ln[(R_t + 1).(R_{t-1} + 1) \ldots .(R_{t-k+1} + 1)] = r_t + r_{t-1} + \cdots . + r_{t-k+1}$$

The random walk increments are linear function of time variable and this property is used and exploited for all the variance ratio tests designed to check the randomness of a time series.

3.5.1 Lo and MacKinlay Variance Ratio Test

Lo and MacKinlay is a variance ratio test, which is used to distinguish between different stochastic processes. If the stock prices are generated randomly, then the variance of weekly sampled returns should be five times the variance of daily returns and also the monthly sampled log-price relatives must be four times as large as the variance of weekly returns. Mathematically, this means that

$$V(X_t, X_{t-q}) = q.V(X_t - X_{t-1})$$

Variance Ratio has the following form:

$$V(2) = \frac{V[r_1(2)]}{2\,V[r_t]} = \frac{V[r_t + r_{t-1}]}{2V[r_t]} = \frac{2V[r_t] + 2\,Cov[r_t, r_{t-1}]}{2V[r_t]}$$

and it follows that

$$V(2) = 1 + \gamma(1)$$

where $\gamma(1)$ stands for the autocorrelation coefficient of the first order for the time series denoted by $\{r_t\}$. Random walk hypothesis holds only if the autocorrelations are zero and if V (2) is 1. The V (2) can be extended to any number of periods, q and in that case the variance ratio satisfies the following equation:

$$V(q) = \frac{V[r_t(q)]}{q.V[r_t]} = 1 + 2.\sum_{k=1}^{q-1}(1 - \frac{k}{q})\gamma^k$$

where $r_t(k) \equiv r_t + r_{t-1} + \cdots + r_{t-k+1}$ and γ^k is the kth order autocorrelation coefficient of the time series $\{r_t\}$.

Lo-MacKinlay proposed a test statistic under the null hypothesis of the homoscedastic increments and with V(q) = 1.

Z: the test statistic is:

$$Z = \frac{V(q) - 1}{\theta(q)^{1/2}}$$

which is asymptotically distributed as N (0,1). The asymptotic variance can be defined as:

$$\theta(q) = \left(\frac{2(2q-1)(q-1)}{3q}\right)^2$$

There is a slight problem with this test statistic, the RWH can be rejected because of heteroscedasticity, which is a common feature of financial returns. Lo-MacKinlay rectified this by creating a heteroscedastic robust test statistic which can be defined as follows:

Z0: the robust test statistic is:

$$Z_0 = \frac{V(q) - 1}{\theta_0(q)^{1/2}}$$

Which follows standard normal distribution asymptotically. The asymptotic variance $\theta_0(q)$ is

$$\theta_0(q) = \sum_{j=1}^{q-1}\left(\frac{2(2q-1)}{q}\right)^2 \rho(j)$$

where

$$\rho(j) = \frac{\sum_{t=j+1}^{nq}(r_t - \bar{v})^2.(r_{t-j} - \bar{v})^2}{\left(\sum_{t=j+1}^{nq}(r_t - \bar{v})^2\right)^2}$$

According to variance ratio test, if the variance ratio at holding period q is equal to unity, the returns time series is a random walk. If it is greater than unity, it shows positive autocorrelation and reflects negative autocorrelation if it is less than unity.

3.6 Unit Root Tests

Let us consider a simple AR (1) model, which will have the following equation:

$$y_t = \phi y_{t-1} + \varepsilon_t$$

where $\varepsilon_t \sim WN\ (0, \sigma^2)$.

The unit root hypothesis can be defined as follows:

H_0: there exists a unit root, in other words, $\phi = 1 \Rightarrow y_t \sim I(1)$.

H_1: the unit root does not exist, $|\phi| < 1 \Rightarrow y_t \sim I(1)$.

Z_0: the test statistic is defined as: $Z_{\phi=1} = \frac{\hat{\phi}-1}{EE(\hat{\phi})}$.

where $\hat{\phi}$ is the least squares estimate and $EE(\hat{\phi})$ is the standard error estimate. In the unit root process, y_t is not stationary but Δy_t is stationary. Hence, we denote yt as a difference stationary process. A process is integrated of order d, I(d), if it contains d unit roots.

3.6.1 Augmented Dickey Fuller Test

The unit root test described above is the DF test which can be extended to an AR(p) model.

$$y_t - y_{t-1} = (\theta_1 - 1)y_t - 1 + \theta_2 y_t - 1 + \theta_3 y_t - 3 + \varepsilon_t$$

$$y_t - y_{t-1} = (\theta_1 - 1)y_t - 1 + (\theta_2 + \theta_3)y_{t-2} + \theta_3(y_{t-3} - y_{t-2}) + \varepsilon_t$$

$$y_t - y_{t-1} = (\theta_1 + \theta_2 + \theta_3 - 1)y_{t-1} + (\theta_2 + \theta_3)(y_{t-2} - y_{t-1}) + \theta_3(y_{t-3} - y_{t-2}) + \varepsilon_t$$

$$\Delta y_t = \pi y_{t-1} + c_1 \Delta y_{t-1} + c_2 \Delta y_{t-2} + \varepsilon_t$$

where

$$\pi = \theta_1 + \theta_2 + \theta_3 - 1 = -\theta\ (1)$$

$$c_1 = -(\theta_2 + \theta_3)$$

$$c_2 = -\theta_3$$

The hypothesis $\theta(1) = 0$ corresponds to

H_0: $\pi = 0$ against.

H_1: $\pi < 1$.

3.6.2 Phillips-Perron (PP) Test

The Dickey Fuller test involves fitting a regression model by ordinary least squares but serial correlation will present a problem. To account for this, the Augmented Dickey Fuller test's regression includes lags of first differences of y_t. The PP test involves fitting the following regression model:

$$\Delta y_t = \pi y_{t-1} + c_1 \Delta y_{t-1} + \varepsilon_t$$

And the results are used to calculate the test statistics. The PP tests correct for any serial correlation and heteroscedasticity in the errors ε_t non-parametrically by modifying the Dickey Fuller test statistics. Under the null hypothesis that $\pi = 0$, the PP t-statistic has the same asymptotic distribution as the ADF t-statistic. The biggest advantage of the PP test over the ADF test is that it is robust to general forms of heteroscedasticity in the error term ε_t. Another big advantage is that the user does not have to calculate the suitable lag length for the test regression.

4. Analysis and Findings

The results of various tests conducted have been discussed in this section.

4.1 Jarque-Bera Test

The JB test is used to check if the stock returns are normally distributed around the mean. Skewness and Kurtosis are used as measures in addition to the JB test statistic. For a normal distribution, the JB test statistic should be greater than 0.05 at 5% level of significance and the skewness and kurtosis are zero and three respectively. As can be seen from the table below, the null hypothesis is rejected for all five indices in all the periods. The value of the JB test is less than 0.05 in all instances at the 5% significance level. Hence, from this analysis it can be concluded that the stock markets during the Pre-Crisis period, the Crisis period and the Recovery period did not follow normal distribution. The significant kurtosis indicates that the distribution has sharper peaks than a normal distribution. The negative skewness figure proves that the returns are flatter to the left compared to a normal distribution. To verify this analysis, the Histogram and QQ plots were plotted for all the indices during all the different periods. The BSE Sensex plots illustrate the change in behaviour seen during the different periods. In the Pre-Crisis period, the skewness is negative and we can see from the histogram that the left tails are fatter and the scale goes till -0.12% against the 0.08% on the right. The kurtosis figure is high and hence we can also see the sharper peak in the histogram. The inverted S-shape of the QQ plot confirms the existence of fatter tails. In the Crisis period, the situation is different as the skewness is positive and the tail is slightly fatter on the right. Again, the extremely high Kurtosis value justifies the peak. In the Recovery period, the distribution moves closer to a normal one. The skewness although slightly negative is closer to zero and the kurtosis value is closer to three. The same is reflected in the histogram and in the QQ plot where the blue line seems much more aligned to the red one. Similar analysis can be done for all the indices. The other index which stands out is the BSE Bankex. The Skewness and the Kurtosis figures for the Crisis period and the Recovery period show that the distribution was really close to the normal distribution. As the global financial crisis is associated with the banking and financial institutions, this is an important observation for the other analysis carried out in the paper. Table 2 gives the descriptive statistics from the JB Test. Figures 1 to 7 give the QQ plots and histograms for the three periods.

The QQ plots and Histograms for all indices have been attached in Appendix 6A, 6B, 6C and 6D.

Table 2. Descriptive statistics

INDEX		**Trading Days**	**Mean**	**Standard Deviation**	**Skew**	**Kurtosis**	**JB Test Statistic**	**χ2 (JB Statistic)**
BSE	Pre Crisis	1006	0.1314%	1.4718%	-0.7827	6.6996	1984.1172	0.0000
SENSEX	Crisis	986	-0.0186%	1.9805%	0.2774	6.6846	1848.4119	0.0000
	Recovery	992	0.0487%	0.9841%	-0.3040	2.3277	239.2389	0.0000
BSE 100	Pre Crisis	1006	0.1358%	1.5011%	-0.9023	6.9022	2133.4330	0.0000
	Crisis	986	-0.0224%	1.9600%	0.0893	6.7880	1894.3106	0.0000
	Recovery	992	0.0519%	1.0018%	-0.4157	2.4789	282.5651	0.0000
BSE 200	Pre Crisis	1006	0.1308%	1.5186%	-1.1378	8.3116	3112.7794	0.0000
	Crisis	986	-0.0232%	1.9277%	0.0353	6.7516	1872.9723	0.0000
	Recovery	992	0.0549%	0.9831%	-0.5037	2.8222	371.1636	0.0000
BSE 500	Pre Crisis	1006	0.0723%	1.4172%	-1.8844	9.4454	4274.6565	0.0000
	Crisis	986	-0.0255%	1.8921%	-0.0447	6.6966	1842.6922	0.0000
	Recovery	992	0.0552%	0.9694%	-0.5846	3.1278	460.8773	0.0000
BSE	Pre Crisis	1006	0.1501%	1.9029%	-0.6390	6.3064	1735.5235	0.0000
BANKEX	Crisis	986	-0.0100%	2.5065%	0.1878	4.4844	831.9803	0.0000
	Recovery	992	0.0710%	1.5499%	0.0651	2.4494	248.6852	0.0000

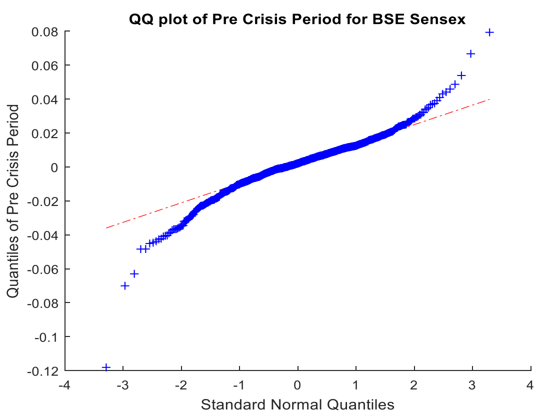

Figure 2. QQ plot, pre crisis- BSE sensex

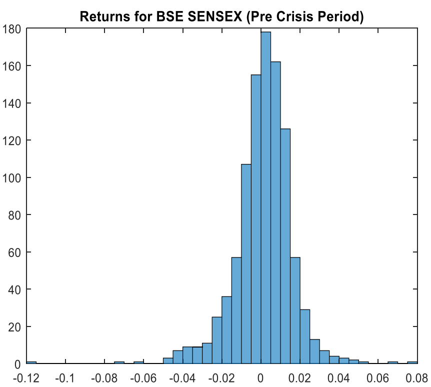

Figure 3. Histogram, pre crisis- BSE sensex

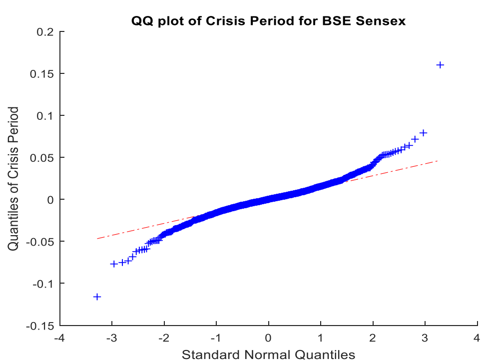

Figure 4. QQ plot, crisis- BSE sensex

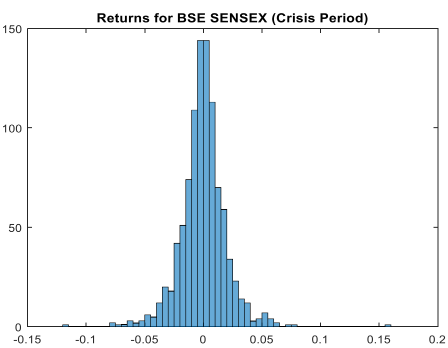

Figure 5. Histogram, crisis- BSE sensex

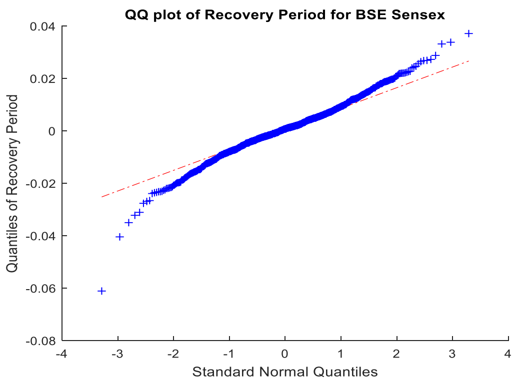

Figure 6. Histogram, recovery-BSE sense

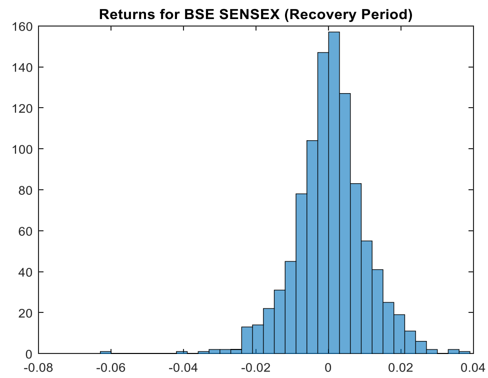

Figure 7. QQ plot, recovery- BSE sensex

4.2 Kolmogorov-Smirnov Test

The KS one sample test compares the cumulative distribution function against a specified distribution which is in our case the normal distribution. Table 3 shows the results of the KS test and as the test result value shows the KS test rejects the normal distribution of the empirical CDF for all indices in all periods. An important observation here is that the KS statistic which is a measure of the difference between the empirical CDF and the normal CDF is the lowest in the Recovery period. Hence, in the Recovery period the distribution of stock returns resembled much more to the normal distribution than in the Pre-Crisis and the Crisis period. Also, except the BSE Bankex, the goodness of fit with the normal distribution has gone up in all indices over time. In other words, the stock returns distribution seems to be slowly moving towards a normal distribution.

The KS test plots mapped against the normal distribution for all indices during the three different periods can be found in Appendix 6E, 6F and 6G.

Table 3. KS test statistics

INDEX		Test Result	p-value	KS Test Statistic	Critical Value
BSE SENSEX	Pre-Crisis	1	1.49E-04	0.066	0.0384
	Crisis	1	7.59E-05	0.0692	0.0388
	Recovery	1	0.0221	0.0437	0.0387
BSE 100	Pre-Crisis	1	2.74E-05	0.0721	0.0384
	Crisis	1	5.00E-05	0.0707	0.0388
	Recovery	1	0.0284	0.0422	0.0387
BSE 200	Pre-Crisis	1	3.82E-05	0.0709	0.0384
	Crisis	1	1.12E-04	0.0677	0.0388
	Recovery	1	0.0283	0.0422	0.0387
BSE 500	Pre-Crisis	1	0.0103	0.0475	0.0384
	Crisis	1	2.82E-04	0.0642	0.0388
	Recovery	1	0.0445	0.0394	0.0387
BSE BANKEX	Pre-Crisis	1	0.0032	0.0532	0.0384
	Crisis	1	0.0026	0.0548	0.0388
	Recovery	1	0.0015	0.0572	0.0387

4.3 Autocorrelation/Serial Correlation (ACF Tests)

The autocorrelation analysis provides some great insights into the functioning of the Bombay Stock Exchange in the short and the long run. Figure 8 shows the autocorrelation of the BSE Sensex over the complete time period of twelve years. As is evident from the figure, the autocorrelation is really small and the plot shows that the autocorrelation function is a Moving Average function. We see a "spike" at lag 1 followed by generally non-significant values for lags past 1. Theoretically, for the MA (1) function, all autocorrelations for lags past 1 should be zero but that is not the case in practice. The figure shows that all values are not significant after the first lag.

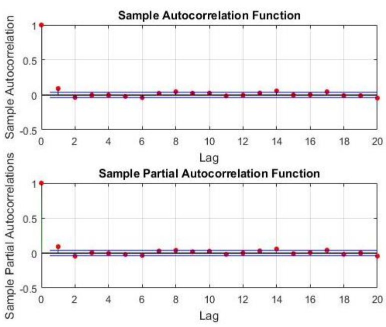

Figure 8. Autocorrelation, all periods: BSE sensex

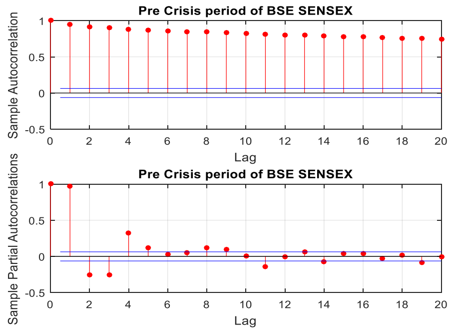

Figure 9. Autocorrelation, pre crisis: BSE sensex

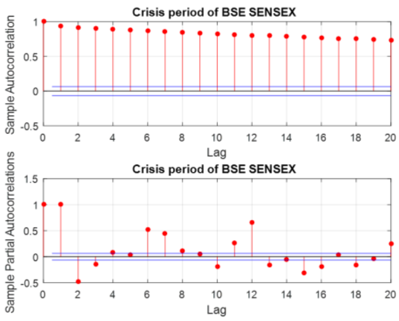

Figure 10. Autocorrelation, crisis: BSE sensex

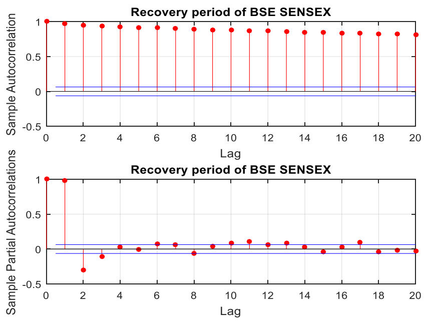

Figure 11. Autocorrelation, recovery: BSE sensex

The case for the shorter time periods is completely different. If we plot the BSE Sensex autocorrelation for the Pre-Crisis, Crisis and Recovery period, we can observe that the serial correlation (autocorrelation) is high. Figures 9, 10 and 11 show that the autocorrelation gradually decreases as the number of lags increase but it is over the significance level for all observed lags. The plot shows that the autocorrelation function of the Pre-Crisis, Crisis and Recovery period is an AR (1) model.

This shows that over the long run, it can be proved that the BSE Sensex follows a random walk but the same cannot be said when we observe the log returns over shorter durations. The same observations can be drawn from the plots of all other indices. The graphs for autocorrelation and partial autocorrelation for the other four indices are in Appendix 6H, 6I and 6J. The graphs provide interesting insights but do not provide conclusive evidence of the autocorrelation of stock returns for the different indices. Table 4 shows the Ljung-Box statistics for different indices. It is clear from the test statistics that the null hypothesis of no serial correlation can be rejected at any conventional significance level for all indices during any of the time periods.

The Ljung-Box statistics are calculated for the fifteenth order autocorrelation for series. The values for the null hypothesis are rejected at 5% significance level.

Table 4. Ljung-box test statistics

INDEX		Test Result	LB Q Statistic	Q Significance
BSE SENSEX	Pre-Crisis	1	37.5300	0.0011
	Crisis	1	31.5600	0.0011
	Recovery	1	34.4500	0.0011
BSE 100	Pre-Crisis	1	91.8400	0.0000
	Crisis	1	90.7200	0.0000
	Recovery	1	101.4200	0.0000
BSE 200	Pre-Crisis	1	572.5500	0.0000
	Crisis	1	467.0000	0.0000
	Recovery	1	591.2140	0.0000
BSE 500	Pre-Crisis	1	60.6600	0.0000
	Crisis	1	56.1200	0.0000
	Recovery	1	68.1000	0.0000
BSE BANKEX	Pre-Crisis	1	70.8900	0.0000
	Crisis	1	65.1280	0.0000
	Recovery	1	78.1241	0.0000

4.4 Variance Ratio Tests

Lo and MacKinlay (1988) test is carried out and variance ratios and corresponding homoscedastic increments and heteroscedasticity robust tests statistic for each index returns at various investment horizons like 2, 4, 8, and 16 are calculated. The Variance Ratio test rejects that the series is a random walk at a significance level of 5% for some values and accepts it for some others. The figures in red show the values at which the null hypothesis of random walk is rejected. The significant homoscedastic and heteroscedastic statistics reject the random walk hypothesis for the index returns for the different indices during the different time periods. The mixed results from the LMVR do not give consistent evidence at different holding periods, since the null of random walk hypothesis stands if the variance ratio is unity. A very high positive variance ratio shows high positive autocorrelation. The rejection of the null hypothesis could possibly be because of heteroscedasticity and the next test checks the stock market returns over different periods for heteroscedasticity. See Table 5.

Table 5. Variance ratio test statistics

INDEX		Homoscedastic Statistic				Heteroscedastic Statistic				Variance Ratio			
		2	4	8	16	2	4	8	16	2	4	8	16
BSE SENSEX	Pre Crisis	-41.0890	-20.9120	-12.4753	-7.2319	-0.5830	-0.4290	-0.3531	-0.3320	0.7560	0.6194	0.4022	0.2956
	Crisis	-51.0890	-26.1390	-15.2170	-9.0570	3.0190	2.3760	1.7830	1.6090	0.6954	0.6114	0.5740	0.5373
	Recovery	-34.4150	-13.3250	-6.5730	-4.7720	-0.3110	-1.0370	-0.6710	-0.4490	0.8770	0.6683	0.5565	0.3854
BSE 100	Pre Crisis	-39.0070	-18.2110	-10.3590	-6.9780	-12.7920	2.2120	0.7590	0.0220	0.6456	0.6743	0.3888	0.3001
	Crisis	-44.4960	-22.7340	-13.3420	-8.5330	-0.7400	-0.5020	-0.2470	0.0190	1.3386	1.3013	1.1532	1.0812
	Recovery	-45.4380	-23.5730	-14.0510	-8.9970	-1.3940	-0.6950	-0.6320	-0.5550	0.8465	0.6449	0.4815	0.3551
BSE 200	Pre Crisis	-39.0070	-23.2800	-13.9650	-8.7050	-12.7920	-0.0220	0.0080	-0.0240	1.2134	1.0950	0.6981	0.5024
	Crisis	-24.3740	-12.6330	-8.3340	-5.9190	-14.7970	-2.0620	-1.2730	-1.0490	1.4708	1.4622	1.3595	1.2231
	Recovery	-32.8070	-17.0820	-10.4990	-7.1260	-3.8530	-1.8940	-1.4130	-1.0580	0.7708	0.5313	0.3730	0.2851
BSE 500	Pre Crisis	-24.1820	-14.2810	-8.9880	-6.3360	-0.7230	-0.3110	-0.2560	-0.2210	1.2845	1.2059	0.8106	0.5865
	Crisis	-45.0290	-22.0990	-12.5910	-7.7770	-1.0320	-0.4990	-0.5880	-0.4200	1.4207	1.3946	1.3946	1.2412
	Recovery	-45.9970	-23.1170	-13.9940	-9.0570	1.0240	-0.3990	-0.2740	-0.1590	0.7470	0.4642	0.3122	0.2451
BSE BANKEX	Pre Crisis	-30.9780	-16.3490	-11.0590	-7.8730	0.5090	-0.1210	0.0400	0.0490	1.3271	0.8102	0.5878	0.4678
	Crisis	-18.7120	-12.7900	-8.7880	-6.6030	-0.0410	-0.6940	-0.8600	-0.9650	0.8745	0.6626	0.6874	0.6876
	Recovery	-42.3090	-21.5830	-12.0230	-7.6330	-0.8160	-0.7320	-0.5600	-0.3900	0.7889	0.9548	1.0844	1.0720

4.5 Engle Test

The Engle Test is used to check for residual and conditional heteroscedasticity. To conduct the test properly, it is important to determine the suitable number of lags for the model. We do this by fitting the model over a range of plausible lags and comparing the fitted models and then choosing the number of lags with the best fit for the test. See Table 6.

Table 6. Engle test statistics

INDEX		Test Result	Engle Test Statistic	Critical Value
BSE SENSEX	Pre-Crisis	1	761.1876	3.8415
	Crisis	1	608.8565	3.8415
	Recovery	1	876.5233	3.8415
BSE 100	Pre-Crisis	1	781.2455	3.8415
	Crisis	1	627.0003	3.8415
	Recovery	1	855.0271	3.8415
BSE 200	Pre-Crisis	1	878.9127	3.8415
	Crisis	1	646.7614	3.8415
	Recovery	1	803.1169	3.8415
BSE 500	Pre-Crisis	1	898.2623	3.8415
	Crisis	1	662.0497	3.8415
	Recovery	1	761.685	3.8415
BSE BANKEX	Pre-Crisis	1	770.2103	3.8415
	Crisis	1	800.3989	3.8415
	Recovery	1	904.0601	3.8415

The analysis reveals that it is logical to conduct the ARCH test using one lag. On conducting the ARCH test using one lag we find that the null hypothesis of no conditional heteroscedasticity is rejected for all indices during all time periods. Moreover, the pValue which for all instances is zero which suggests that the evidence for the rejection of the null is really strong. A normal scatter plot of the returns shows that the variance of the returns differs over time and is quite strong in a few places. The volatility in returns is linked to some major events in the Indian and the global markets.

As an example, the extreme volatility around April and May 2004 is associated with the political uncertainty in the Indian markets. Similar conclusions can be drawn throughout the twelve years and the events have been discussed in detail below:

2003-2004

The Indian Equity market saw a boom during the time registering returns of a little over 80% which was the highest in any of the emerging markets. According to the Reserve Bank of India the market was rallying on strong fundamentals and was driven by active trading of derivatives. There was a substantial change in the margin trading facility by the SEBI. The period of January to March 2004 was marked by political uncertainty.

2004-2005

The political uncertainty continued to effect the market till May 2004 and had a negative impact on the market. The Sensex saw its lowest point on May 17 2004. During the next three quarters though the market recovered and registered strong returns

2005-2006

The fall in the global crude prices and the turmoil in the international stock markets had its toll on the Indian stock market. Strong domestic conditions and the rise in the inflation rate in India led to the corrections from October 2005 to December 2005. The proposals of the Union Budget of 2006-2007, including the increase in Foreign Indirect Investment limit led to the rally in the stock markets.

2006-2007

The Reserve Bank of India hiked the Cash Reserve Ratio and the bank rate in October 2006. The impending recession in the US and the effects of the subprime mortgage banking had a negative impact on the stock markets around the world including India.

2007-2008

The financial year of 2007-2008 was the most volatile period for the BSE. The Sensex reached its peak of 20,000 and then also it lowest of less than 8,000. The May to August 2007 period was associated with unprecedented buoyancy in the markets. October to December 2007 saw the raising of alarms over the US subprime mortgage crisis as several financial institutions came close to bankruptcy. The period of December 2007 to March 2008 saw the start of the global financial crisis, global crisis, a severe credit crunch and unstable domestic conditions.

2008-2009

The situation only worsened between April to June 2008 and July 2008 saw the crisis deepen further. Fannie Mac and Freddie Mac reported a drop in fair value assets. On September 15, 2008, Lehman Brother filed for bankruptcy while Merrill Lynch was saved by Bank of America. In January 2008, the Northern Rock Bank crisis only aggravated the problems and the recession was at its peak. The global economy was reeling and the situation in India was worsened by the Satyam scam. The IT sector stocks took a beating during this time.

2009-2010

At the London G20 summit on 2 April 2009, world leaders committed themselves to a $5trillion fiscal expansion, an extra $1.1trillion of resources to help the International Monetary Fund and other global institutions boost jobs and growth, and to reform of the banks. The global economy was a turn but unfortunately instead of a coordinated effort to revive the world economy, individual economies followed their own personal agenda exacerbating the situation around the world.

2010-2011

The focus soon shifted from the private sector to the public sector and the spotlight shifted from the solvency of banks to the solvency of governments like Greece. Budget deficits had gone out of hand during the crisis and the sovereign debt crisis started.

2011-2012

The Eurozone debt crisis only worsened during this time and America's debt was no longer classified as the top notch A class debt. The European economies continued to contract during 2012 but the American economy showed some signs of recovery.

2013-2015

With the Eurozone still on sticky ground, the world economy in general started to recover. The prices of the commodities were going up rapidly and the credit crunch was finally reducing. With signs of inflation and increase in consumer spending, the world economy was firmly on the path of recovery. The real disposable income per household was on the rise and this strengthened the services and the manufacturing sector and has led to the recent rally in the stock market. On 16 December 2015, the Federal Reserve hiked its interest rate for the first time in 7 years which is considered to be an official signal that the American economy is finally out of the Global Financial Crisis.

For scatter graphs of all indices over the three different periods, please refer to Appendix 6K, 6L, 6M and 6N.

4.6 Runs Test

The study also employs the runs test which is a non-parametric test. In the light of the observation that the distribution of stock returns is not normal for all indices during all periods, it is logical to use a non-parametric test like the runs test for a deeper analysis. Actual runs are the number of changes in the returns, positive or negative and the expected runs are the number of changes in the returns required for the returns to follow a random walk process. It can be seen from the table that the actual runs are less than the number of expected runs in most instances. If the actual number of runs are close to the expected runs, it implies that the data is generated by a random process. A high negative Z statistic shows that there is a high degree of positive correlation. During the Pre-Crisis period, the BSE Sensex and the BSE Bankex the expected number of runs are lower than the actual runs and the Z statistic is positive which suggests that there is a negative correlation. Similar results are shown by the BSE Bankex in the Recovery period. This just goes to show that the bank stocks rightly behaved much differently during the financial crisis because of the shocks felt in the US market and other global stock markets. All in all, the behaviour of the Bombay Stock Exchange cannot be explained by the random walk theory based on these results. See Table 7.

Table 7. Runs test statistics

INDEX		Test Result	Expected Runs	Actual Runs	Z statistic
BSE SENSEX	Pre-Crisis	1	476	530	31.6385
	Crisis	1	503	483	-31.321
	Recovery	1	507	485	-31.4166
BSE 100	Pre-Crisis	1	544	462	-31.6382
	Crisis	1	519	467	-31.3208
	Recovery	1	507	485	-31.4166
BSE 200	Pre-Crisis	1	552	454	-31.6381
	Crisis	1	522	464	-31.3208
	Recovery	1	518	474	-31.4165
BSE 500	Pre-Crisis	1	559	447	-31.6379
	Crisis	1	520	466	-31.3208
	Recovery	1	525	467	-31.4164
BSE BANKEX	Pre-Crisis	1	514	492	31.6386
	Crisis	1	503	483	-31.321
	Recovery	1	491	501	-31.4166

4.7 Unit Root Test

The unit root test is commonly used to test the existence of non-stationarity in the time series data. In level form, the series should be non-stationary and in difference form, it needs to be stationary which would show the possibility of a unit root. Two tests are commonly used for the unit root analysis. The two tests are namely, Augmented Dickey Fuller and Philipps-Perron test. A great advantage of Philips-Perron test is that it is non-parametric, i.e. it does not require to select the level of serial correlation as in ADF. It rather takes the same estimation scheme as in DF test, but corrects the statistic to conduct for autocorrelations and heteroscedasticity.

The biggest disadvantage of the PP test however is that it is based on the asymptotic theory. Therefore, it works well only on large samples. The large sample size is generally considered to be around two thousand observations. We first discuss the results of the ADF test from Table 8. The ADF test rejects the null for all indices during all periods. Hence, it shows that the time series data contains a unit root which implies that the market does not follow random walk and is considered to be weak form inefficient before, during and after the crisis period.

Table 8. ADF test statistics

INDEX		**Test Result**						**P-Value**						**ADF Statistic**					
		1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
BSE SENSEX	Pre Crisis	0	0	0	0	0	0	0.9990	0.9990	0.9990	0.9990	0.9990	0.9990	3.8400	8.1097	3.4655	3.7854	3.7161	4.1585
	Crisis	0	0	0	0	0	0	0.9990	0.9990	0.9990	0.9990	0.9987	0.9789	5.1586	4.7536	4.7656	4.3217	2.7961	1.7055
	Recovery	0	0	0	0	0	0	0.9853	0.9990	0.9990	0.9990	0.9990	0.9990	1.8624	2.9114	2.9751	5.4783	4.1715	3.9657
BSE 100	Pre Crisis	0	0	0	0	0	0	0.9600	0.9990	0.9990	0.9990	0.9990	0.9990	1.3998	6.3503	6.6849	5.1649	3.5829	3.9251
	Crisis	0	0	0	0	0	0	0.9990	0.9990	0.9990	0.9990	0.9990	0.9990	3.6111	4.2624	5.9229	4.7393	3.7615	3.1949
	Recovery	0	0	0	0	0	0	0.8415	0.9389	0.9990	0.9990	0.9990	0.9990	0.5811	1.1768	3.8775	3.9576	0.6087	4.4953
BSE 200	Pre Crisis	0	0	0	0	0	0	0.9990	0.9990	0.9990	0.9990	0.9990	0.9990	5.7118	5.8879	4.9449	3.7571	3.9734	4.6061
	Crisis	0	0	0	0	0	0	0.9990	0.9990	0.9990	0.9990	0.9990	0.9990	3.5403	4.4622	4.4875	4.8340	3.8916	3.4224
	Recovery	0	0	0	0	0	0	0.8464	0.8951	0.9990	0.9990	0.9990	0.9990	0.6031	0.8600	3.3091	3.7973	4.9258	4.9590
BSE 500	Pre Crisis	0	0	0	0	0	0	0.9990	0.9990	0.9990	0.9990	0.9990	0.9990	5.4838	6.5183	5.0802	4.1888	4.6226	5.0747
	Crisis	0	0	0	0	0	0	0.9990	0.9990	0.9990	0.9990	0.9990	0.9990	3.0049	4.4923	3.7456	4.3086	4.2021	3.8570
	Recovery	0	0	0	0	0	0	0.8464	0.8951	0.9990	0.9990	0.9990	0.9990	0.6031	0.8600	3.3091	3.7973	4.9258	4.9590
BSE BANKEX	Pre Crisis	0	0	0	0	0	0	0.9715	0.9990	0.9990	0.9990	0.9990	0.9990	1.5662	4.3810	3.7930	4.7152	3.9081	5.0991
	Crisis	0	0	0	0	0	0	0.9990	0.9990	0.9990	0.9990	0.9990	0.9990	7.2389	5.2352	4.5072	3.5003	3.5880	3.5148
	Recovery	0	0	0	0	0	0	0.9990	0.9990	0.9990	0.9990	0.9990	0.9990	6.2826	4.4479	5.1996	5.4634	4.1933	3.0604

The PP test is conducted first for the different time periods and then for the whole duration of the research. As mentioned before, the PP test works well only for large samples of data (ideally over two thousand). When the stock returns are classified into the three time periods, the maximum number of observations in a time period is 1003 and hence, the PP test is not the most conclusive test. Nevertheless, the findings from the test from Table 9 show that the unit root null hypothesis is not rejected only during the Crisis period for all the indices. This goes to show that according to this analysis, accounting for the heteroscedasticity of returns, the market was weak form inefficient during the crisis and weak form efficient before the crisis and during the recovery period.

We conduct the same test for the complete duration of analysis and the results are shown in Table 10.

Table 9. PP test statistics- period classification

INDEX		Test Result	p-value	PP Test Statistic
BSE SENSEX	Pre-Crisis	1	0.0010	-6.8270
	Crisis	0	0.9248	1.0598
	Recovery	1	0.0010	-6.5825
BSE 100	Pre-Crisis	1	0.0010	-7.3208
	Crisis	0	0.8527	0.6329
	Recovery	1	0.0010	-7.5070
BSE 200	Pre-Crisis	1	0.0010	-9.4490
	Crisis	0	0.8742	0.7399
	Recovery	1	0.0010	-7.8308
BSE 500	Pre-Crisis	1	0.0010	-9.4714
	Crisis	1	0.8525	0.6319
	Recovery	1	0.0010	-8.1363
BSE BANKEX	Pre-Crisis	1	0.0010	-5.1572
	Crisis	0	0.9791	1.7086
	Recovery	1	0.9569	1.3626

Table 10. PP test statistics

INDEX	Test Result	p-value	PP Test Statistic
BSE SENSEX	0	0.9876	1.1294
BSE 100	0	0.8189	0.6365
BSE 200	0	0.8523	0.7312
BSE 500	0	0.8908	0.6323
BSE BANKEX	0	0.9777	1.7123

The test shows that when the number of observations are suitable, the PP test fails to reject the unit root null hypothesis against the trend stationarity alternative and indicates towards the presence of a unit root in all indices. Hence, over a longer period of time, from December 2003 to November 2015, all indices have been weak form inefficient.

5. Results

On the basis of empirical results given by various tests in previous section, we can conclude that the BSE does not exhibit weak form market efficiency and thus does not follow random walk in Period-I, Period-II and Period-III. The recent financial crisis did not impact the behaviour of Indian stock markets to a great extent. There is no significant difference in market efficiency in the three periods however the efficiency has improved marginally in Period-III and Period-II compared to Period-I. Thus, there are possibilities of earning extra income in Indian markets because abnormal returns are possible only when the market is inefficient as the future prices can be predicted using the past information. Thus, observation and the use of the past behaviour of stock price movement may help investors in generating excess profits. The findings have been summarised in Table 11. As seen from the summary, the JB Test and the KS test firmly reject the normality of the stock returns. The Ljung-Box test and the Engle test point towards high serial correlation or autocorrelation. The ACF test functions provide further insights into the autocorrelation of the stock returns for all indices during all periods. The runs test and the unit root test reject the random walk hypothesis and provide evidence in support of the weak form inefficiency of the market.

There are obviously some limits and boundaries to the analysis which was conducted for this research. Some of the empirical anomalies which cannot be accounted for in our analysis but have an impact on the stock market efficiency have been discussed in the next section.

Table 11. Summary of tests

INDEX		Rejection of Normality				Rejection of Random Walk Theory			
		JB Test	**KS Test**	**LB Test**	**Engle Test**	**VR Test**	**Runs Test**	**ADF Test**	**PP Test**
BSE SENSEX	Pre Crisis	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Crisis	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
	Recovery	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
BSE 100	Pre Crisis	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Crisis	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
	Recovery	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
BSE 200	Pre Crisis	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Crisis	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
	Recovery	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
BSE 500	Pre Crisis	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Crisis	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
	Recovery	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
BSE BANKEX	Pre Crisis	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Crisis	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
	Recovery	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 12. Detailed overview of tests

INDEX		Normal Distribution?		Serial Correlation?		Hetero -scedasticity?		AR=ER?	Stationary?
		JB Test	KS Test	LB Test	Engle Test	VR Test	Runs Test	ADF Test	PP Test
BSE SENSEX	Pre Crisis	No	No	High	High	Yes	No	No	No
	Crisis	No	No	Very High	Very High	Yes	No	No	Yes
	Recovery	No	No	High	High	Yes	No	No	No
BSE 100	Pre Crisis	No	No	High	High	Yes	No	No	No
	Crisis	No	No	Very High	Very High	Yes	No	No	Yes
	Recovery	No	No	High	High	Yes	No	No	No
BSE 200	Pre Crisis	No	No	High	High	Yes	No	No	No
	Crisis	No	No	High	High	Yes	No	No	Yes
	Recovery	No	No	High	High	Yes	No	No	No
BSE 500	Pre Crisis	No	No	Medium	High	Yes	No	No	No
	Crisis	No	No	Very High	Very High	Yes	No	No	Yes
	Recovery	No	No	High	High	Yes	No	No	No
BSE BANKEX	Pre Crisis	No	No	High	High	Yes	No	No	No
	Crisis	No	No	Very High	Very High	Yes	No	No	Yes
	Recovery	No	No	Very High	High	Yes	No	No	No

5.1 Selected Empirical Anomalies

Small firm effect

The small firm theory asserts that companies with smaller market capitalisation outperform companies with bigger market capitalisations. This market anomaly contributes to Fama and French (1993) proposed three factor model. According to the paper published by them, smaller companies have a bigger chance to grow and also their business is more volatile which promises better returns at a higher risk. Schwert (1983) is another study that contributes to the concept of size irregularity in the stock returns. Jensen's alpha is a measure which is used to determine the average return on a portfolio over and above that predicted by the Capital Asset Pricing Model (CAPM). The Jensen's alpha can be calculated using the following equation:

$$\boldsymbol{\alpha_p = \overline{r_p} - \left[r_f + \beta_p\left(\overline{r_m} - r_f\right)\right]}$$

Value Effect

There are also studies which show that the firms with high earnings-to-price ratio earn abnormal positive returns relative to the Capital Asset Pricing Model. Many subsequent studies also suggest that companies with higher dividend-to-price ratios and book-to-market values have higher positive returns. Ball (1992) suggests that the abnormal returns generated because of the value effect are more likely to be recorded because of problems in CAPM rather than the value effect.

Weekend Effect

This theory was proposed by French (1980) in his paper on Stock returns and the weekend effect. He observed that the average returns of S&P Composite Portfolio was mostly negative over the weekends when he analysed stock returns from 1953-1977. He defines a coefficient which measures the difference between the average daily returns on the weekdays and on the weekend. Interestingly, research conducted on stock returns on data from 1978 show that the average daily returns on the weekdays are almost equal to the returns on the weekend. The estimate of the average returns over the weekends is essentially zero for the period 1978-2002 which is the same as the average stock returns on the weekdays.

Turn of the year effect

Roll (1983) and Reinganum (1983) extensively study the subject of abnormal returns of small firms during the first two weeks of January. Roll (1983) puts forward a theory that small firms are highly volatile and they might experience capital short term losses which the investors might wish to realise in order to gain on some income tax benefits. This creates a selling pressure on the stocks in December and they rebound in January as investors try to rebalance their portfolios and take up new positions. Unlike the other effect mentioned above, the turn of the year effect hasn't disappeared completely. It has been dropping for a while but the returns in the first fifteen days of January are on an average 0.4% more than that during any other time of the year for data for the years 1991-2011.

Momentum effect

The continuation or the momentum effect is defined as the concept in which the recent "past winners" outperform the recent "past losers". Bondt and Thaler (1985) come up with a counter-argument. The research conducted by them shows that the stocks which were poor performers in the last three to five years have higher average returns than the stocks which registered higher returns in the last three to five years.

5.2 Fama and French Three Factor Model

Fama and French (1992) in their research paper proposed a factor model that expands on the Capital Asset Pricing Model (CAPM). It adds the size factor and the value factor to the CAPM which accounts for the fact that value and small stocks show greater volatility than other stocks in the markets. The research done by the two showed that value stocks and small cap stocks consistently generate higher returns that their counterparts. The outperformance can be explained by higher risk carried and the underperformance can be explained by the mispricing by market participants. The model can be represented mathematically as:

$$R_{it} - R_{ft} = \alpha_i + \beta_i(R_{mt} - R_{ft}) + s_i SMB_t + h_i HML_t + \varepsilon_{it}$$

Where α_i represents abnormal performance. SMB stands for the difference in returns of the small cap portfolio and the large cap portfolio keeping the book-to-market ratio constant and HML measures the difference in returns of high and low Book-to-market ratio firms keeping the market capitalisation constant. Hence, s_i and h_i represent regression coefficients which measure the exposure to size and value risk just like β_i measures the market risk. Fama and French (1993) use this model to verify the various anomalies which were discussed in the section above. They basically tested to see if $\alpha_i = 0$ for the various anomalies stated. They classified stocks based on equity capitalisation, earnings-to-price ratio, dividend-to-price ratio and book-to-market values and discovered that in most cases the value was very close to zero. This goes to show that their model seems to work well for the time period they tested. The paper published by Fama and French (1996) and Fama and French (1998) provides further evidence in support of the three factor model. Although this model does well to identify and justify most anomalies in the weak form efficiency theory there are still some outliers and these outliers make the markets informationally inefficient.

5.3 Summary

A detailed analysis of the three different periods reveals that the market efficiency was highest during the Crisis period, a little less during the Recovery period and the least during the Pre-Crisis period. Table 12 provides a detailed summary of the results from all the different statistical tests conducted on the data collected from the BSE. All the important and relevant statistical methods have been used to measure the informational efficiency of the Indian stock market and the impact of the Global Financial crisis. The findings add to the research of the previous papers and shed some light on the evolution of the stock market of one of the biggest emerging economies of today.

6. Conclusions

The informational efficiency of the stock markets is an important concept as it defines the functioning of the stock markets around the world. Relevant trading strategies can be designed only after understanding the behaviour of the stock market. On the basis of the research conducted and the empirical results given by the various statistical tests, we can conclude that the Bombay Stock Exchange does not follow the random walk process and hence is informationally inefficient in the weak form. The market was inefficient before the crisis, during the crisis and post the crisis. There is no significant difference in the market efficiency but it has gone up slightly from the Pre-Crisis period to the Crisis period and to the Recovery period. The findings show that it is possible to have abnormal returns in the Bombay Stock Exchange because abnormal returns are possible only when the markets are inefficient. Market inefficiency provides an incentive to the traders to collect information and make trading decisions based on the superior knowledge and information that they can gather. The practical implication of this is that there is a variation in the expected returns of the securities and the markets respond differently to different pieces of information. EMH should not be misinterpreted into thinking that there is no point of devising portfolio strategies. It is important to make a decision about the risk and return profile that suits the investor the most. The share prices do not represent the fair value of the stocks and hence, it is possible to buy undervalued securities and sell them when they are fairly priced or overvalued. Weak form market inefficiency also promotes financial innovation and leads to the growth and development of not only the stock market but also the economy as a whole. Corporates make an effort to maximise the shareholder value but might not always make the right decisions. Traders make an effort to collect the information which is not easily available to everyone in the market. This leads to the overall growth of the market and improves the efficiency of the market. The stock market efficiency is a subject which has been studied for long and will continue to be the subject of research in the future. This research might be useful for the researchers who wish to work on the same subject in the future. The analysis and the observations from these time periods can be used to justify the studies of future research. The impact of the Global Financial Crisis on the informational efficiency of the markets adds an interesting dimension to the research. It helps us to understand the behavioural, structural and systemic changes in the market arising from such crises.

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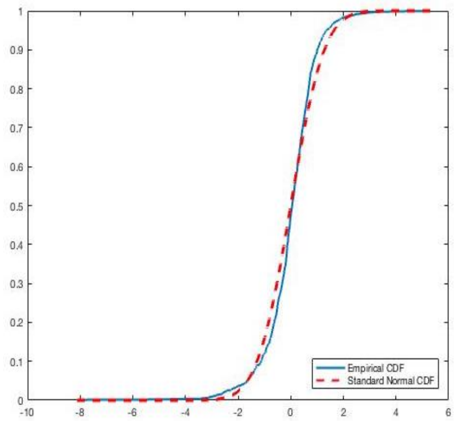
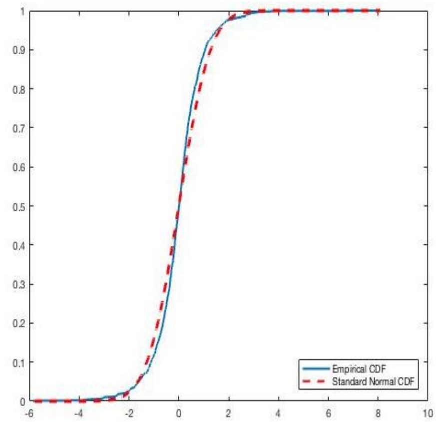
Appendix

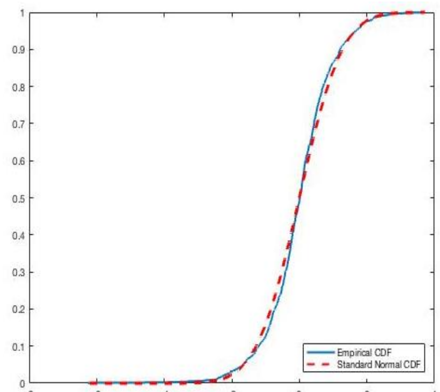
Appendix 6E. Kolmogorov Smirnov Tests- BSE Sensex & BSE 100



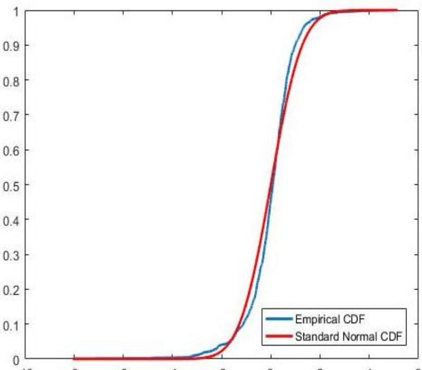
BSE Sensex: Pre- Crisis



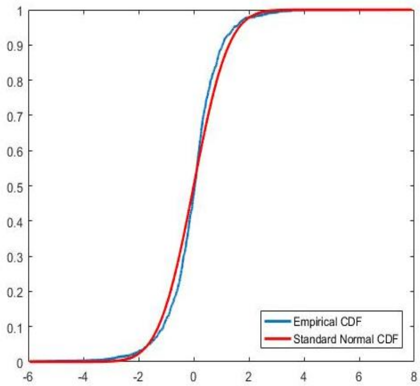
BSE Sensex: Crisis



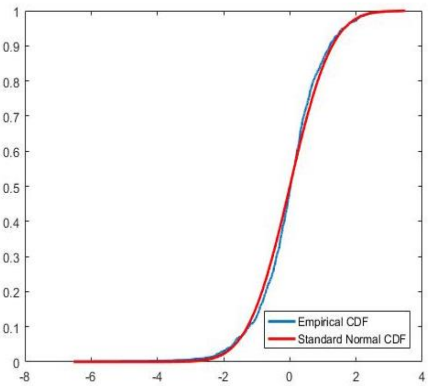
BSE Sensex: Recovery



BSE 100: Pre Crisis

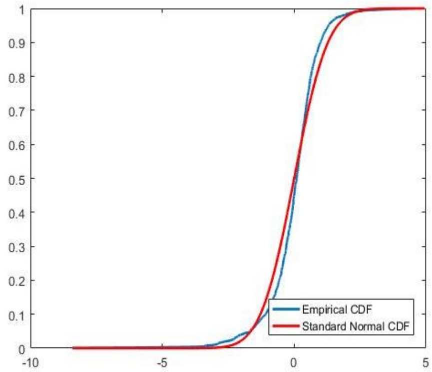


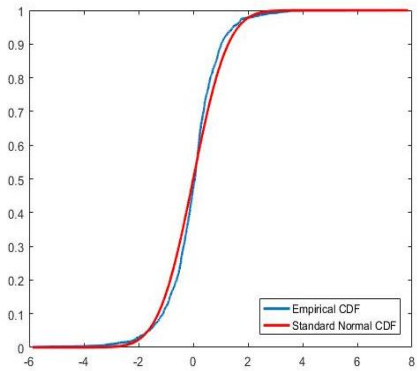
BSE 100: Crisis



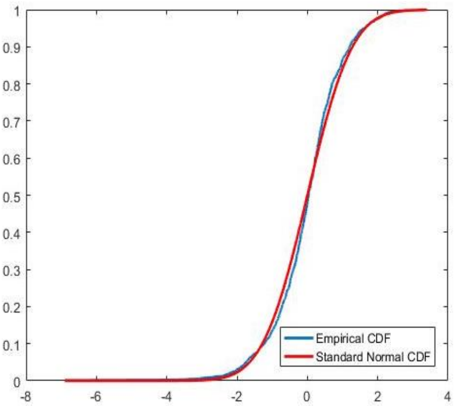
BSE 100: Recovery

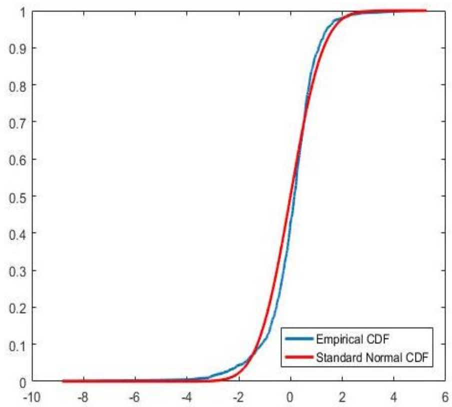
Appendix 6F. Kolmogorov Smirnov Tests- BSE 200 & Bse 500



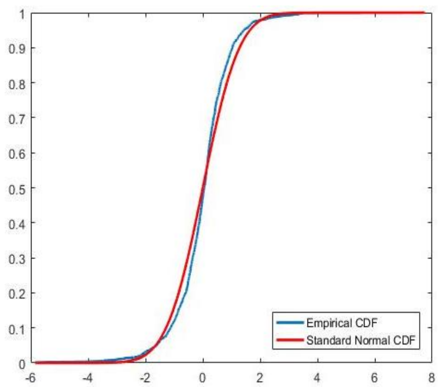


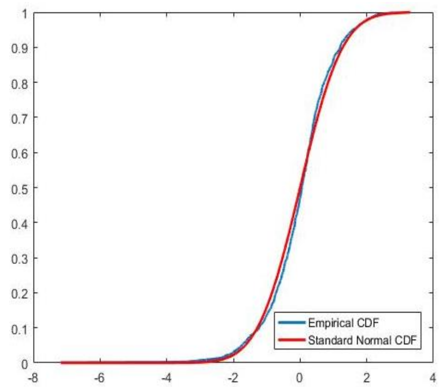
BSE 200: Pre Crisis **BSE 200: Crisis**





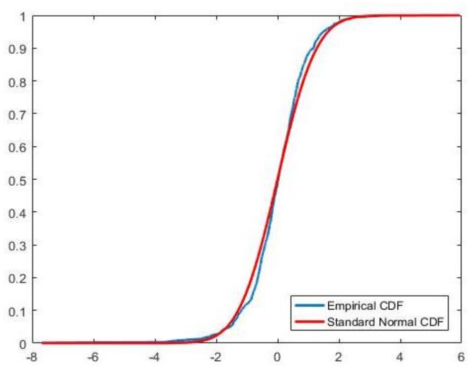
BSE 200: Recovery **BSE 500: Pre Crisis**

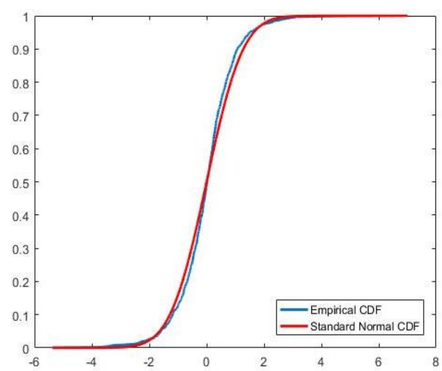




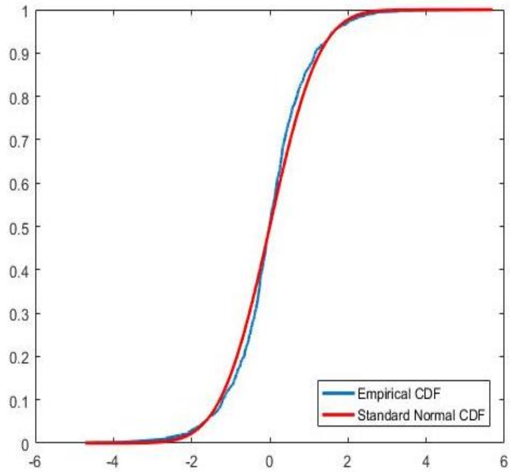
BSE 500: Crisis **BSE 500: Recovery**

Appendix 6G. Kolmogorov Smirnov Tests- BSE Bankex



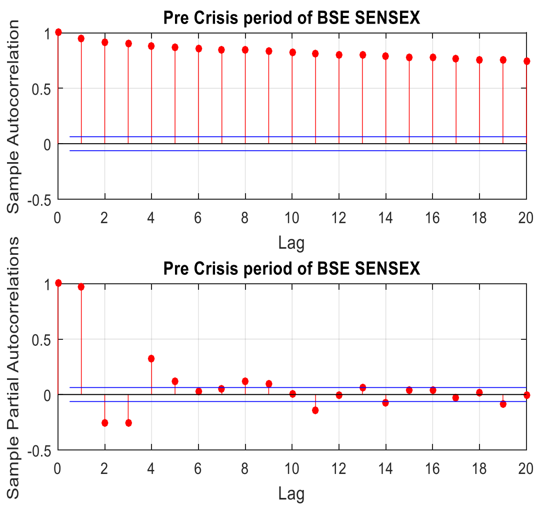


BSE Bankex: Pre Crisis **BSE Bankex: Crisis**

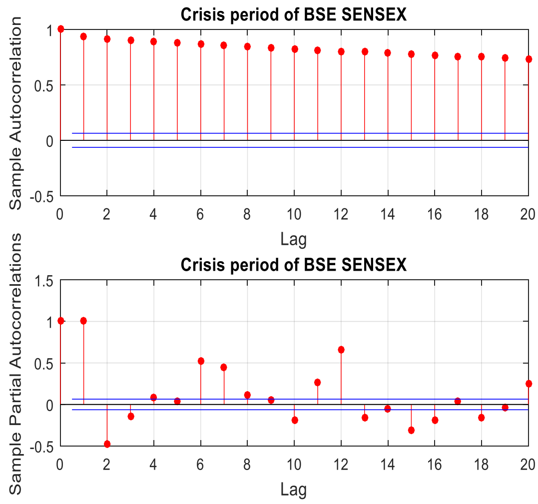


BSE Bankex: Recovery

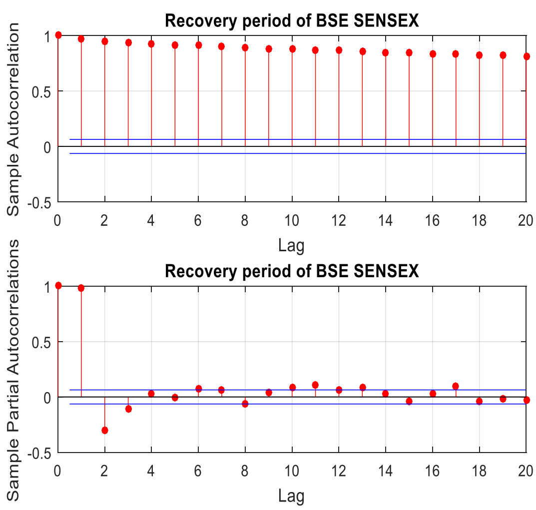
Appendix 6H. Autocorrelation Funciton (ACF) Graphs- BSE Sensex and BSE 100



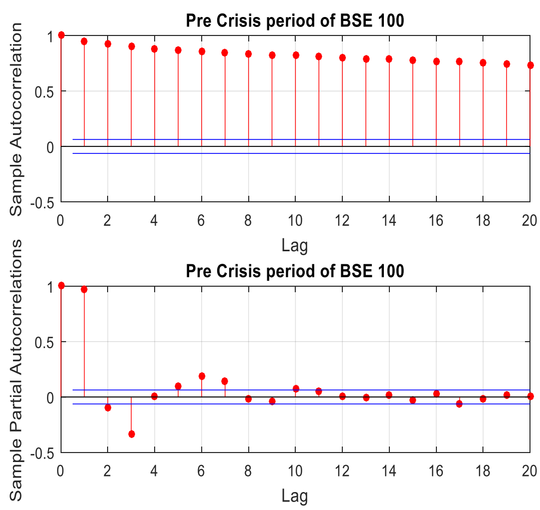
Autocorrelation, Pre Crisis: BSE Sensex



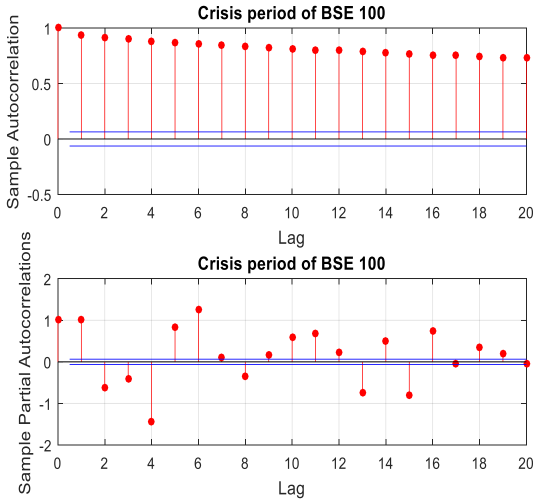
Autocorrelation, Crisis: BSE Sensex



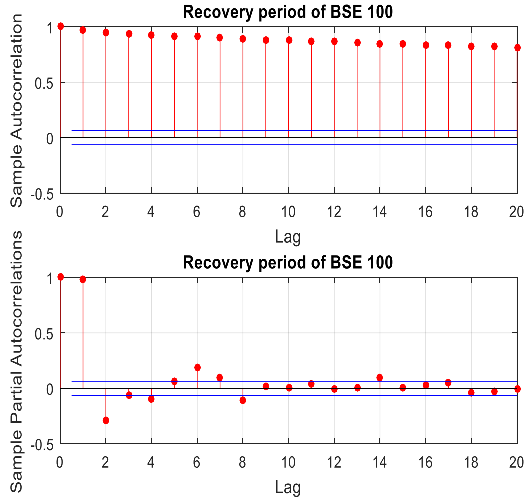
Autocorrelation, Recovery: BSE Sensex



Autocorrelation, Pre Crisis: BSE 100

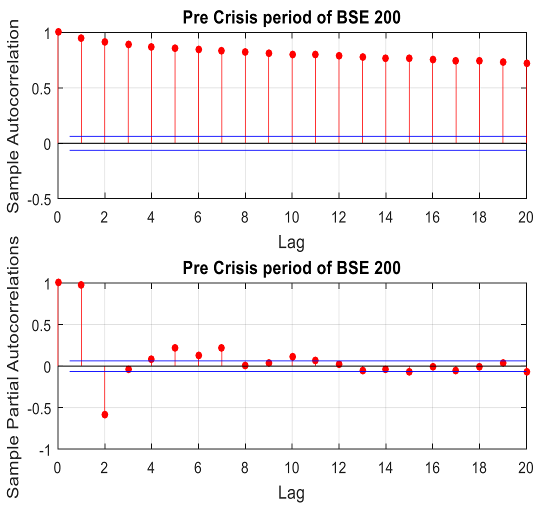


Autocorrelation, Crisis: BSE 100

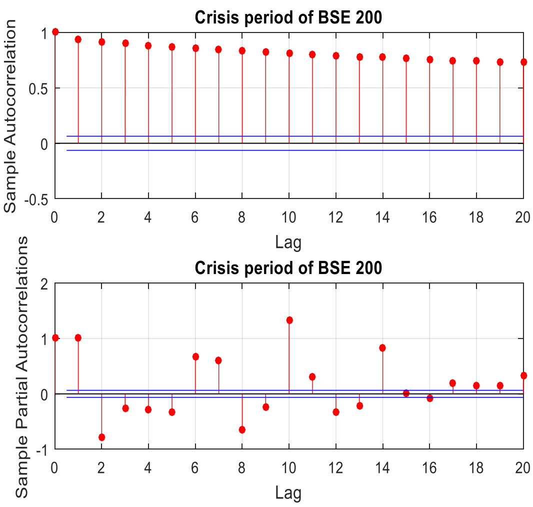


Autocorrelation, Recovery: BSE 100

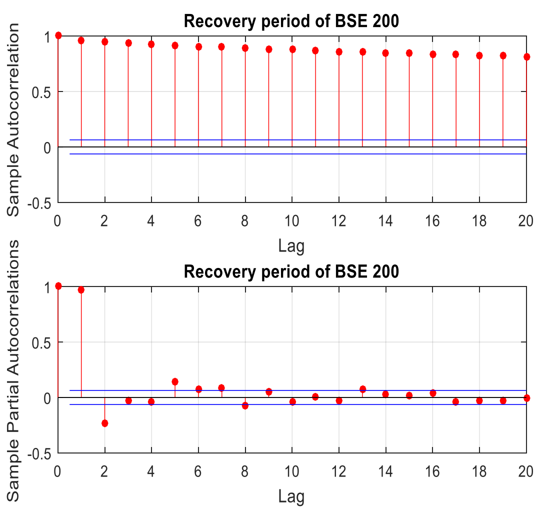
Appendix 6I. Autocorrelation Funciton (ACF) Graphs - BSE 200 and BSE 500



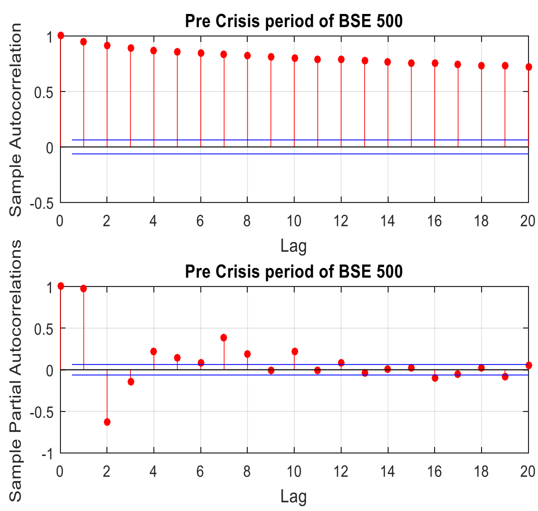
Autocorrelation, Pre Crisis: BSE



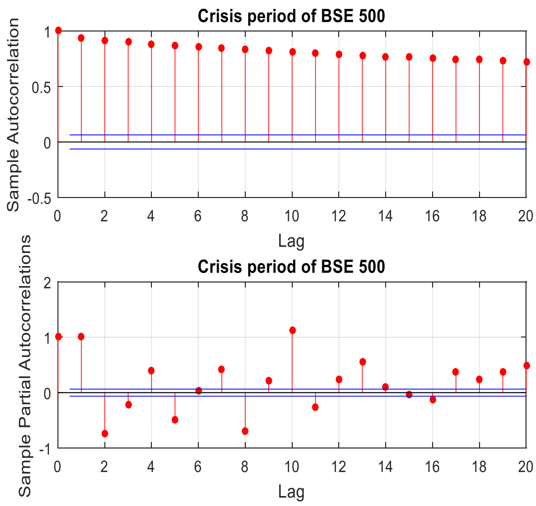
Autocorrelation, Crisis: BSE 200



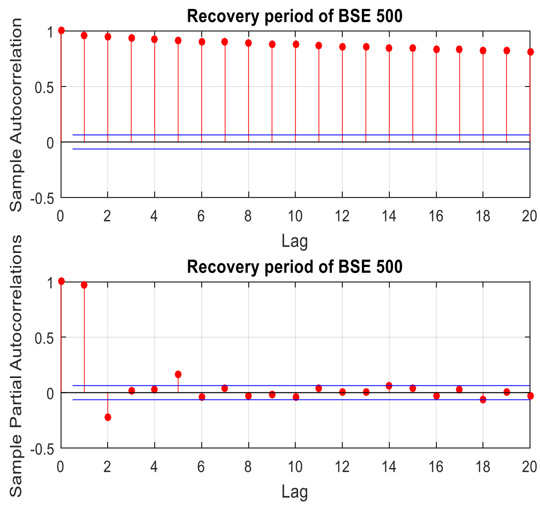
Autocorrelation, Recovery: BSE 200



Autocorrelation, Pre Crisis: BSE 500

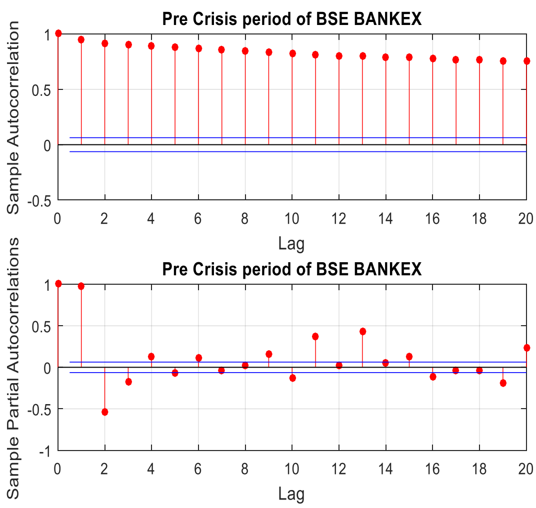


Autocorrelation, Crisis: BSE 500

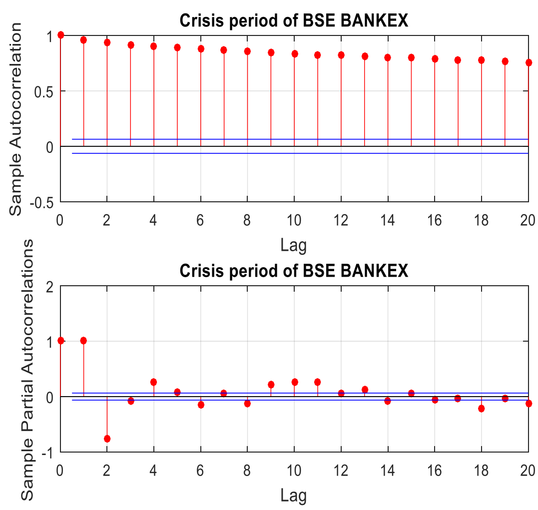


Autocorrelation, Recovery: BSE 500

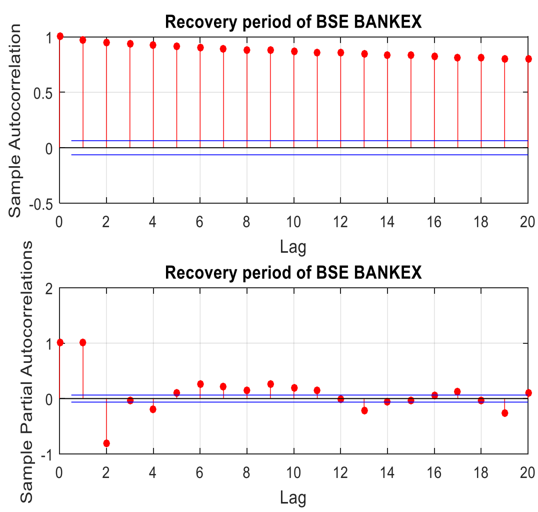
Appendix 6J. Autocorrelation Funciton (ACF) Graphs- BSE BAnkex



Autocorrelation, Pre Crisis: BSE Bankex

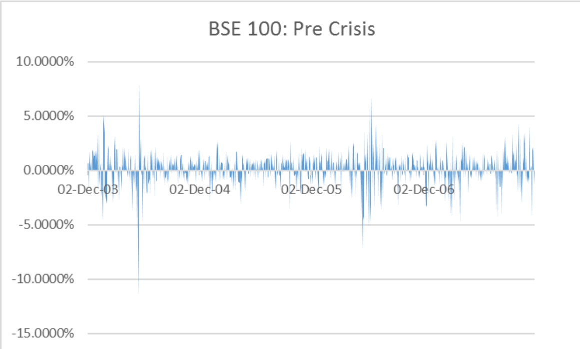


Autocorrelation, Crisis: BSE Bankex

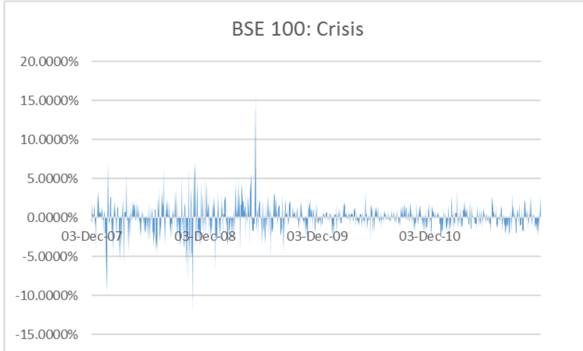


Autocorrelation, Recovery: BSE Bankex

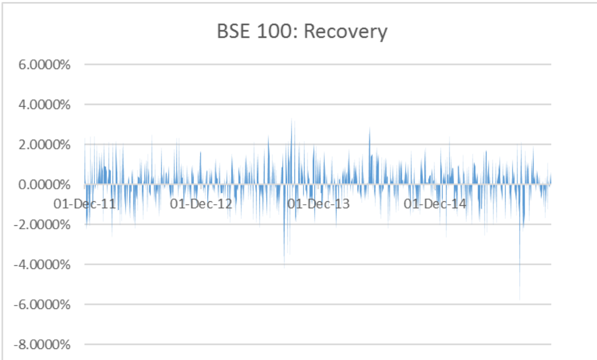
Appendix 6K. Returns Plot: Information on Structural Breaks - BSE 100



Returns Scatter Chart: Pre Crisis

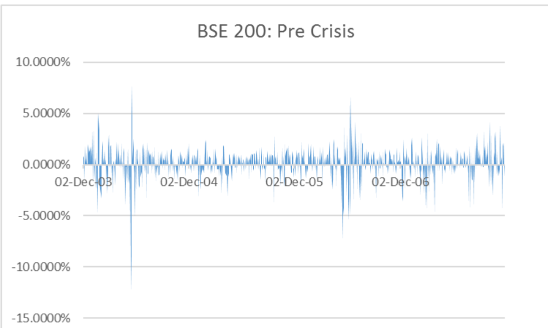


Returns Scatter Chart: Crisis

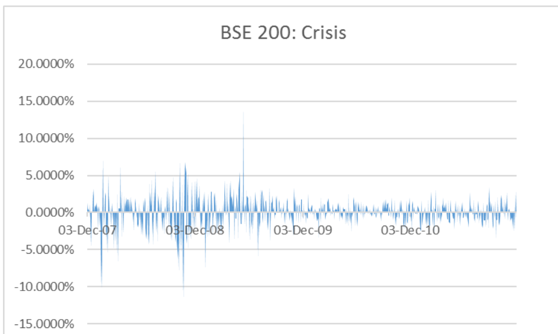


Returns Scatter Chart: Recovery

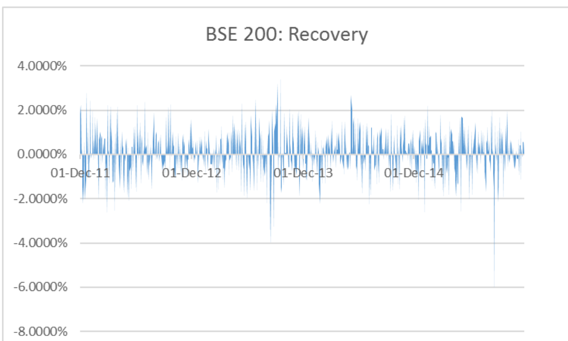
Appendix 6L. Returns Plot: Information on Structural Breaks - BSE 200



Returns Scatter Chart: Pre Crisis

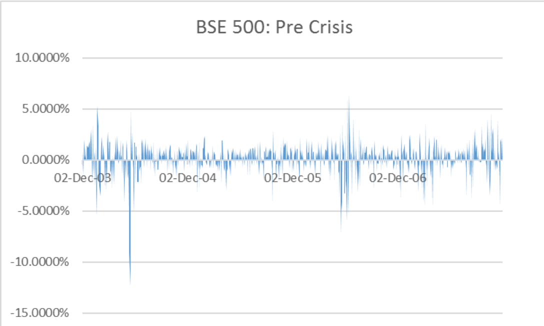


Returns Scatter Chart: Crisis

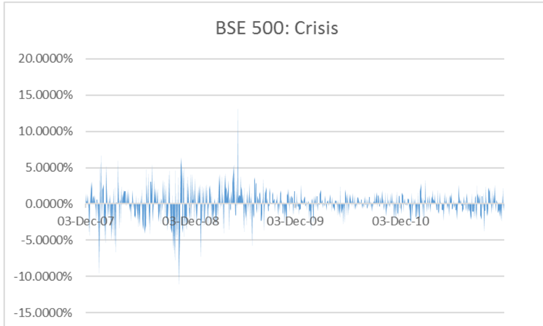


Returns Scatter Chart: Recovery

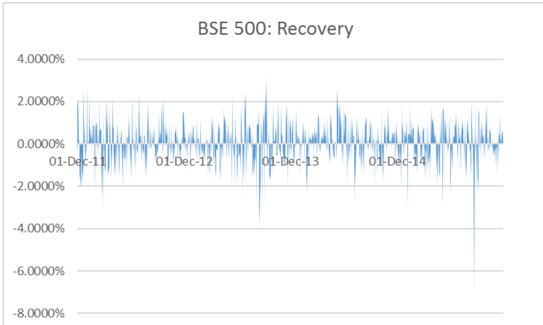
Appendix 6M. Returns Plot: Information on Structural Breaks - BSE 500



Returns Scatter Chart: Pre Crisis

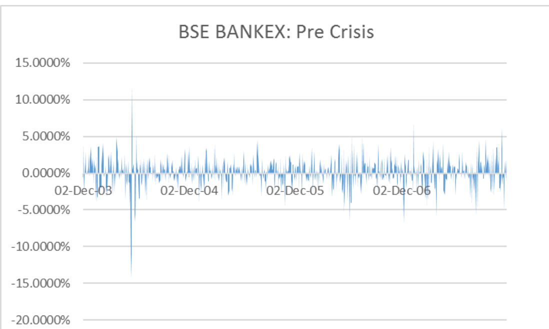


Returns Scatter Chart: Crisis

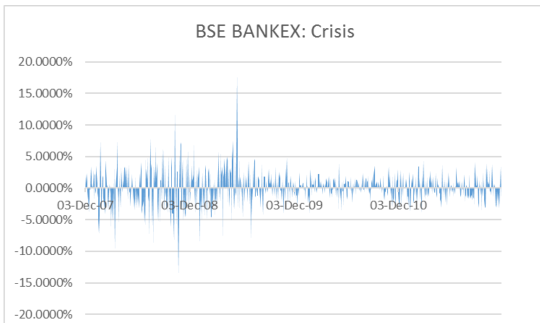


Returns Scatter Chart: Recovery

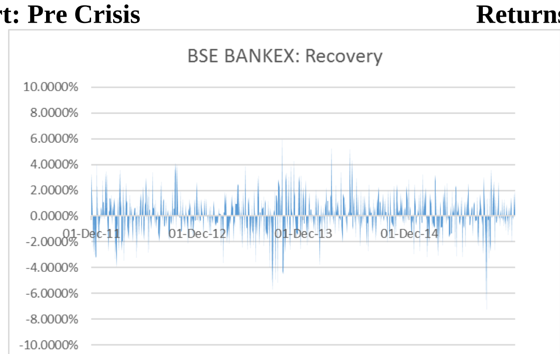
Appendix 6N. Returns Plot: Information on Structural Breaks – BSE Bankex



Returns Scatter Chart: Pre Crisis



Returns Scatter Chart: Crisis



Returns Scatter Chart: Recovery