# Chapter- IV

# ECONOMIC ANALYSIS AND SENSITIVITY OF STOCK MARKET

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## 4.1 INTRODUCTION

The relevance of the economic indicators is important to formulate a strategy for making an investment. It is an essential part of investment for investors to make their own economic forecasting prior to invest. An analysis of the economic forces would lead to make an idea about the future earnings of firm. Previous researches clearly indicate that most of the variability in the prices of stocks is determined by investigating the movements of the whole market. Hence, the success of economy will certainly include the growth of the overall market (Fisher and Gordan, 2008). Macroeconomic environment is an essential part to determine the behaviour of stock prices and there are various macroeconomic variables such as gross domestic product, inflation, interest rates, foreign direct investment, foreign institutional investors etc. Previous studies confirm that macroeconomic factors continue to impact the Indian stock market (Naik & Padhi, 2012 and Pal & Mittal, 2011). The importance of analysing the impact of macroeconomic variables on Indian stock market is continuously acknowledged by the investors and companies.

Another important factor for investment in stock market is volatility of assets. Volatility is an important aspect to consider while making an investment in the market. Variability in the stock prices is a serial dependence and it is referred to as a volatility clustering. Volatility symbolizes underlying variability of the financial assets returns and investors are usually interested to measure the investment risk because risk and returns are proved as crucial elements in the stock market. High volatile stock always possesses a high risk of losing capital and hence, investors try to avoid these kinds of stocks. As volatility is inherent part of stock market, investors need to be alert (Joshi, 2011).

The current chapter is divided in two sections. First section attempts to identify how the Indian stock market is affected by different macro economic variables. Basically, this part of the study is to investigate the relationship between Sensex & macroeconomic indicators and to analyse the impact of selected macro economic variables like inflation (WPI), Index of industrial production (IIP), gold price (GOLD), exchange rate (ER), money supply (MS) and foreign exchange reserve (FER) on the movement of BSE Sensex. Second section deals with the investigation of nature of volatility of Indian stock market (Sensex) and examines the relationship of the Sensex returns with volatility of Sensex returns to determine the risk and return.

## SECTION- I

### 4.2 PERFORMANCE OF INDIAN MACROECONOMIC INDICATORS

For examining the Indian macroeconomic environment and to identify the impact of macroeconomic indicators on Indian stock market, long run relationship between macroeconomic indicators and Sensex has been identified. Ahmed (2008) has accepted stock market as the leading indicator of economic activity. According to present value model and arbitrage pricing theory, macroeconomic fundamentals may influence the stock price / return (Rahman et al., 2009 and Chen et al., 1986). It is very difficult to study all the macroeconomic indicators; hence, the study is limited to selected macroeconomic indicators. On the basis of extensive literature review, the study proposed following variables and the description of these variables is comprised in table- 4.1. India is an emerging economy and widely recognised as fastest growing economy in the world.

**Table: 4.1**
**Description of Variables**

| Symbol | Variable | Description |
|---|---|---|
| **SX** | BSE SENSEX | Index with base year as1978-79 |
| **WPI** | Inflation Wholesale Price Index | Actual Value; Index with base year as 2004-05 |
| **ER** | Exchange Rate | Actual Value; Monthly Avg. Rs./$ |
| **IIP** | Index of Industrial Production | Actual Value; General Index with base year as 2004-05 |
| **MS** | Money Supply | Actual Value Rs. billion |
| **GOLD** | Gold Price | Actual Value; Monthly Avg. Price of Gold Rs./10 gms |
| **FER** | Foreign exchange reserve | Actual Value; in Rs. billion |

The glimpses of performance of selected macroeconomic indicators have been presented in table- 4.2 which depicts the growth of selected six macroeconomic indicators and Sensex from 2004-05 to 2013-14 under the study. It is clearly depicted from the table- 4.2 that all macroeconomic variables showed robust continuous growth over the period of the study. Highest growth in the whole study period is observed in case of gold rate, while 2006-07 and 2011-12 were the years when growth rate of gold rate is highest. On the close examination of the growth rate of variables, it is proved that there is a small decline in Sensex price (SX) in 2008-09; although, all indicators of Indian economy have not shown decline so far.

**Table: 4.2**
**Performance of Indian Macroeconomic Indicators**

| YEARS | SX | WPI | ER | IIP | MS | GOLD | FER |
|---|---|---|---|---|---|---|---|
| **2004-05** | 5751.2691 (----) | 100.025 (----) | 44.931533 (----) | 96.475 (----) | 21214.589 (----) | 6145.3842 (----) | 5619.425 (----) |
| **2005-06** | 8295.3541 (44%) | 104.46667 (4%) | 44.273483 (-1%) | 108.62373 (13%) | 24589.247 (16%) | 6900.56 (12%) | 6294.0992 (12%) |
| **2006-07** | 12319.944 (49%) | 111.35 (7%) | 45.2495 (2%) | 122.62145 (13%) | 29501.862 (20%) | 9240.3242 (34%) | 7815.4567 (24%) |
| **2007-08** | 16543.813 (34%) | 116.625 (5%) | 40.260667 (-11%) | 141.67757 (16%) | 36034.444 (22%) | 9995.6167 (8%) | 10173.093 (30%) |
| **2008-09** | 12305.511 (-26%) | 126.01667 (8%) | 45.993292 (14%) | 145.22659 (3%) | 43436.644 (21%) | 12889.743 (29%) | 12814.007 (26%) |
| **2009-10** | 15539.61 (26%) | 130.81667 (4%) | 47.443325 (3%) | 152.90762 (5%) | 51778.82 (19%) | 15756.093 (22%) | 13029.798 (2%) |
| **2010-11** | 18607.182 (20%) | 143.325 (10%) | 45.5626 (-4%) | 165.48703 (8%) | 60151.647 (16%) | 19227.084 (22%) | 13225.982 (2%) |
| **2011-12** | 17438.358 (-6%) | 156.34167 (9%) | 47.922925 (5%) | 170.26667 (3%) | 69671.392 (16%) | 25722.423 (34%) | 14801.077 (12%) |
| **2012-13** | 18214.959 (4%) | 168.26667 (8%) | 54.409108 (14%) | 172.2 (1%) | 79089.422 (14%) | 30163.933 (17%) | 15940.042 (8%) |
| **2013-14** | 20106.363 (10%) | 177.64167 (6%) | 60.501917 (11%) | 172.03333 (0%) | 89799.363 (14%) | 29190.393 (-3%) | 17510.564 (10%) |
| **CAGR** | 15% | 7% | 3% | 7% | 17% | 19% | 13% |

**Source:** RBI, Handbook of Statistics on Indian economy and Economic Survey, Various Issues, Department of Economic Affairs, Ministry of Finance, Government of India.

Only, ER showed downward trend in few years which express that ER remained most volatile and obtained only 3% CAGR during the study period. There is continuous growth in industrial production (IIP) which expresses the growth of industrial/manufacturing sectors of the economy. Money supply (MS) and foreign exchange reserve (FER) also showed positive trend that means, India has increased money in circulation as well as strong foreign exchange reserve. This indicates the improvement in the health of Indian economy in terms of monetary management and capital flows in the country. Therefore, there are opportunities for investment in Indian economy because of high export orientation, strong economy fundamentals and manufacturing/service sectors framework.

## 4.3 THEORETICAL UNDERPINNING OF MACROECONOMIC VARIABLES

Six macroeconomic variables are opted based on their importance towards the impact on the Indian stock market, performance and use in the previous literature. One of the important determinants of stock returns is GDP which is the real economic activity. However, due to unavailability of monthly data, many researchers have opted **Industrial production index** for real output. IIP is proved as an important macroeconomic variable which affects economic growth and an increase in IIP positively affects economic growth (Maysami et al., 2004). Relationship of stock prices and IIP is checked by numerous researchers such as Rahman et al. (2009) and Ratanapakorn & Sharma (2007) and studies revealed positive relationship between stock prices and IIP. **Inflation** is also found an extensively used variable in literature. The relationship of inflation and stock prices shows mixed results. Numerous researchers such as Pal & Mittal (2011); Bordo et al. (2008) and Chen et al. (1986) have observed negative correlation between inflation and prices of stocks. On the contrary, Ratanapakorn & Sharma (2007) found that there is a positive relationship between inflation & stock prices. Another important macroeconomic variable which is widely used in various researches to measure stock price movement is **money supply** but there are ambiguous studies of the association of money supply and stock prices. Various studies such as Ratanapakoram & Sharma (2007) and Maysami et al. (2004) found positive relationship between money supply and stock prices. On the other side, some researchers such as Rahman et al. (2009) found negative relationship.

Besides this, **exchange rate** also plays an important role to affect stock prices and the impact of this macroeconomic variable depends on country's policy of international trade. Pal & Mittal (1999) checked the impact of macroeconomic indicators on Indian market and they observed a significant but negative impact of exchange rate on BSE Sensex. Abdalla & Murinde (1997) also checked the relationship between exchange rate and stock price in the financial markets of India, Korea, Pakistan and the Philippines. They found the significant impact of exchange rate on stock prices in India, Korea, and Pakistan. It's a matter of fact that exchange rate and stock markets are closely related in most of the cases because stock markets of different economies collapsed due to the depreciation of exchange rate during the period of crisis. Various studies also prove the importance of **gold price** to study the impact of macroeconomic variable on stock prices and it is proved by the researchers that gold price is the significant macroeconomic variable that has a significant relationship with stock prices. Kalra (2012) found that gold prices are the most significant macroeconomic variable to affect stock prices. However, Büyüksalvarci (2010) has observed that gold price has no impact on the market. Therefore, gold price has been taken under consideration in the current study to find out whether gold price affects stock price in India or not and to observe the nature of relationship of gold price with the Sensex. **Foreign exchange reserve** is a significant component of international investment position of any country. Mookerjee & Yu (1997) found significant relationship between foreign exchange reserves and stock prices. Akbar et al. (2012) obtained that stock markets are negatively related with foreign exchange reserve while inverse relationship of foreign exchange reserves and stock prices is observed by Rehman et al. (2009). The study has made an attempt to discuss the relationship of above mentioned macroeconomic variables with Sensex return by considering the following model:

$$SX_t = (WPI_t, ER_t, IIP_t\ MS_t, GOLD_t, FER_t) \qquad \text{-----------------} \ (4.1)$$

Here, Sensex (SX) is dependent variable and other macroeconomic variables are independent variables. The time series analysis techniques have been employed to capture the relationship between macroeconomic variables and stock price. For time series analysis, the data series must obey the pre conditions of time series analysis to avoid spurious results. One of the properties of time series analysis is the stationary condition of the data. ADF and PP tests have been performed in this study to check out the stationary condition of the data series. Descriptive statistics are also computed to observe the nature of data series. Further, Johansen's Co-integration test has been applied to test the presence and the degree of co-integrating relationships among the underlying variables and Vector error correction model is also used for examining the interrelationship between variables in Vector Auto Regressive framework (VAR).

## 4.4 ANALYSIS OF THE RELATIONSHIPS BETWEEN INDIAN STOCK MARKET INDEX AND MACROECONOMIC VARIABLES

This part discusses the relationship between Indian stock market & macroeconomic indicators by using descriptive statistics, tests of stationarity, estimates of co-integration and vector error correction model.

### 4.4.1 Descriptive Statistics

Descriptive statistics is computed to study the nature of data series of variables for each underlying variable. Table- 4.3 reports the descriptive statistics of logarithmic value of Sensex and selected macroeconomic variables. It is clear from the value of standard deviation that Sensex, MS and GOLD series are comparatively more volatile and hence, risky during the period, whereas all other variables are found to be comparatively less volatile.

**Table: 4.3**
**Descriptive Statistics**

| Statistics | Mean | Std. Dev. | Skewness | Kurtosis | Jarque-Bera | Probability | Observations |
|---|---|---|---|---|---|---|---|
| LnSX | 9.5122 | 0.4061 | -1.0448 | 2.9087 | 21.8750 | 0.0000 | 120 |
| LnWPI | 4.8756 | 0.1914 | 0.1847 | 1.7333 | 8.7044 | 0.0128 | 120 |
| LnER | 3.8571 | 0.1155 | 0.8762 | 3.2532 | 15.6786 | 0.0003 | 120 |
| LnIIP | 4.9590 | 0.1967 | -0.5974 | 2.1251 | 10.9664 | 0.0041 | 120 |
| LnMS | 10.7221 | 0.4783 | -0.1602 | 1.7173 | 8.7396 | 0.0126 | 120 |
| LnGOLD | 9.5618 | 0.5633 | -0.0538 | 1.6513 | 9.1527 | 0.0102 | 120 |
| LnFER | 9.3030 | 0.3817 | -0.5876 | 1.9252 | 12.6814 | 0.0017 | 120 |

All variables have shown positive average which is obvious from the mean values. The skewness coefficient value of all variables is found to be different from zero and considered as fairly extreme. Results convey that all the variables are negatively skewed except WPI and ER. Very high or very low value of kurtosis specifies extreme lepokurtic or extreme platykurtic nature respectively. Kurtosis presents the platykurtic distribution of all series except ER. Finally, Jarque-Bera statistics is applied to check the normality of distribution and the significant value of this statistics reports the rejection of normal distribution of all data series.

### 4.4.2 Test of Stationarity (Unit Root test)

There is a requirement that variables of the study should be co-integrated for applying VECM, and all variables must be stationary at first difference for co-integration. Hence, presence of unit root in time series is detected to ensure the robustness of results. One of the simplest methods for determining the stationary condition of time series data is graphical representation which scrutinizes the fact of unit root in the series by observing the patterns of mean, variance, seasonality and autocorrelation. Figure- 4.1 to figure- 4.7 shows the graphical representation of all selected variables.

Figure- 4.1(a)
**LnSensex**

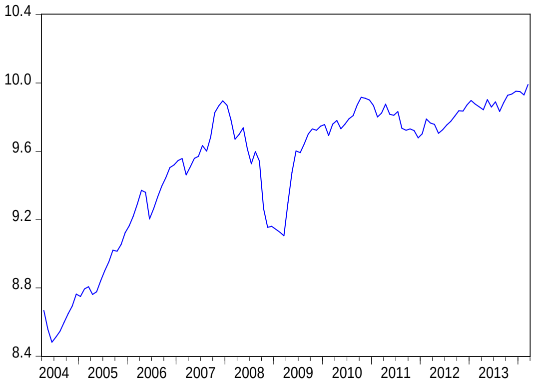



Figure- 4.1(b)
**Differenced LnSensex**

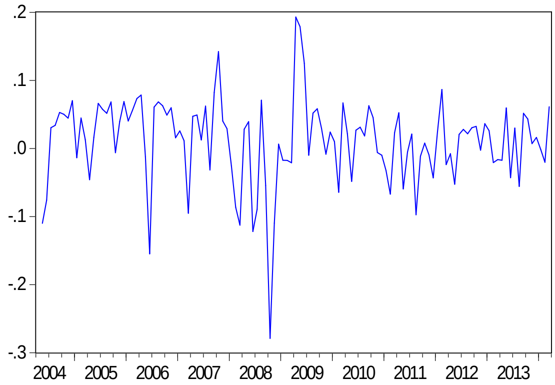



Figure- 4.2(a)
**LnWPI**

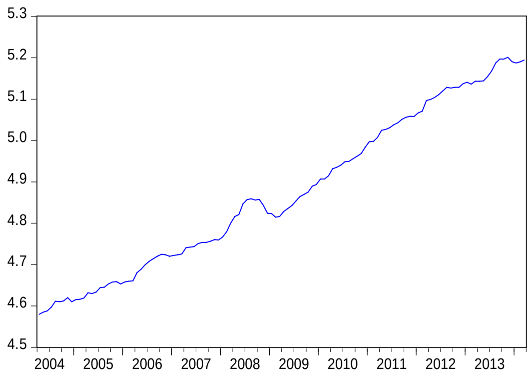



Figure- 4.2(b)
**Differenced LnWPI**

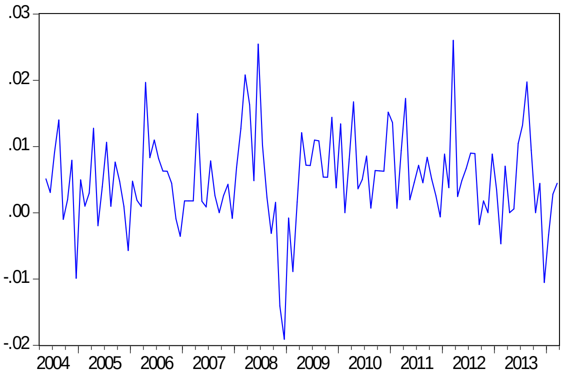



Figure- 4.3(a)
**LnER**

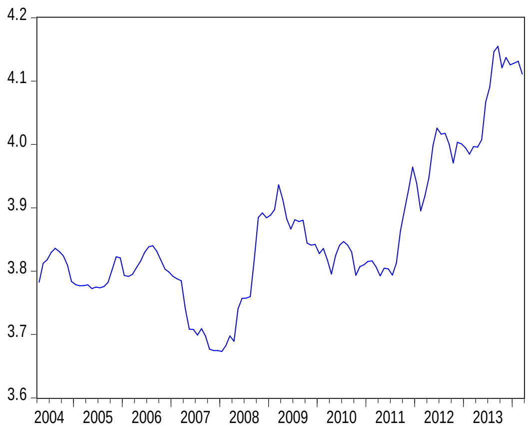



Figure- 4.3(b)
**Differenced LnER**

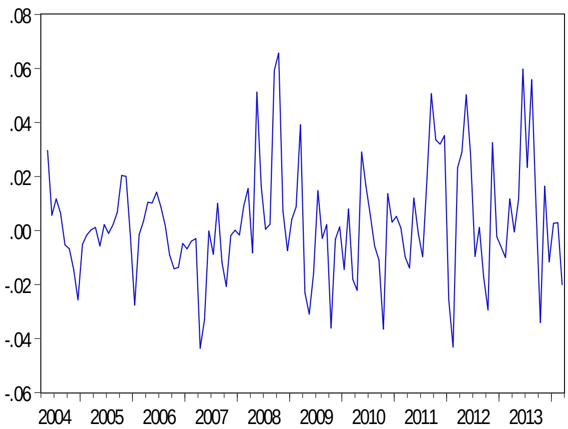


Figure- 4.4(a)
**LnIIP**

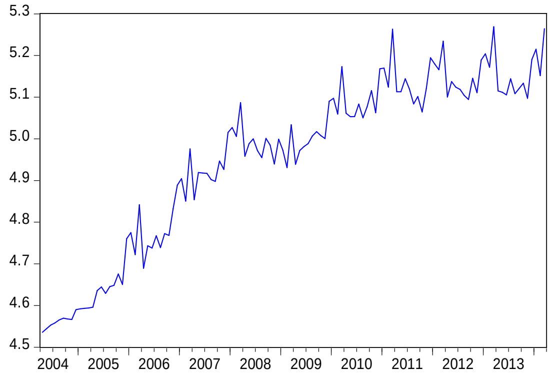



Figure- 4.4(b)
**Differenced LnIIP**

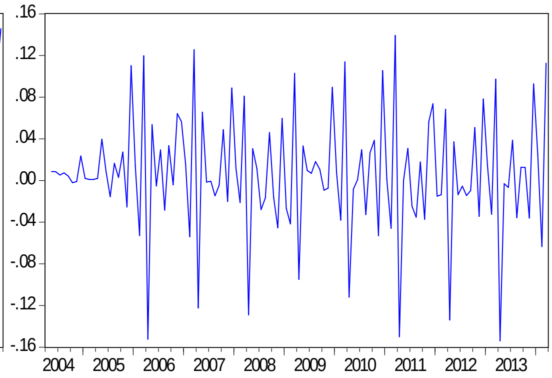



Figure- 4.5(a)
**LnMS**

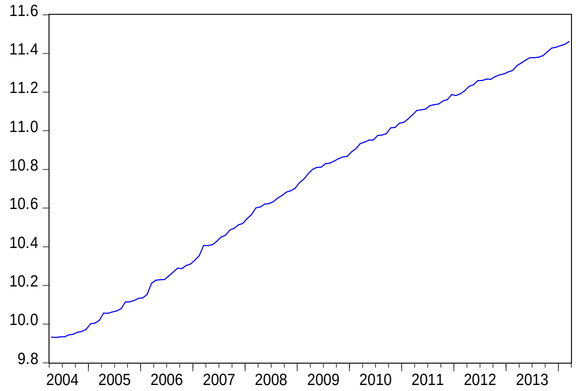



Figure- 4.5(b)
**Differenced LnMS**

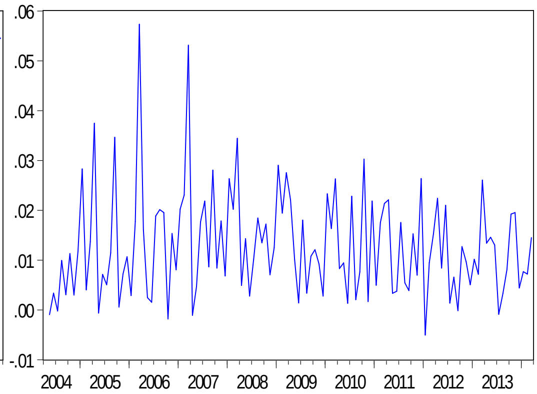



Figure- 4.6(a)
**LnGOLD**

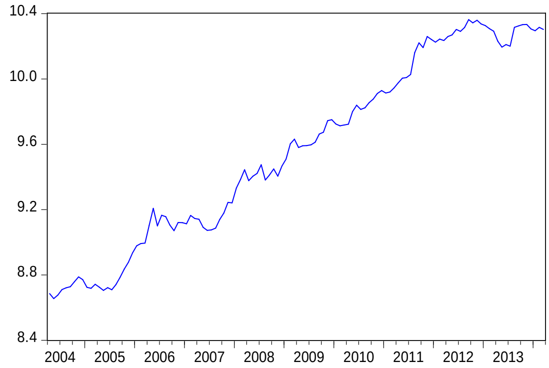



Figure- 4.6(b)
**Differenced LnGOLD**

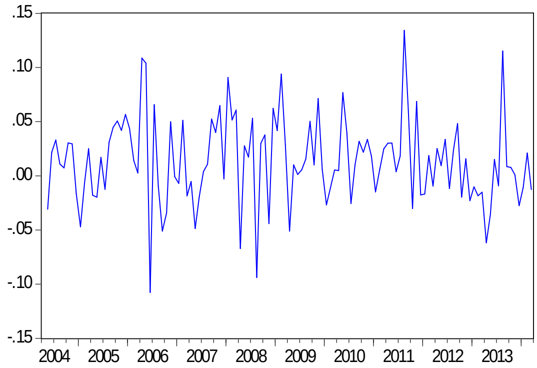



Figure- 4.7(a)
**LnFER**

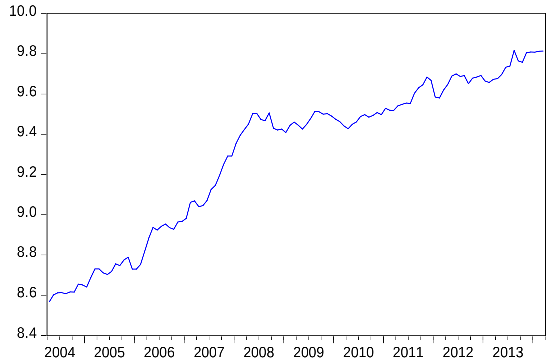
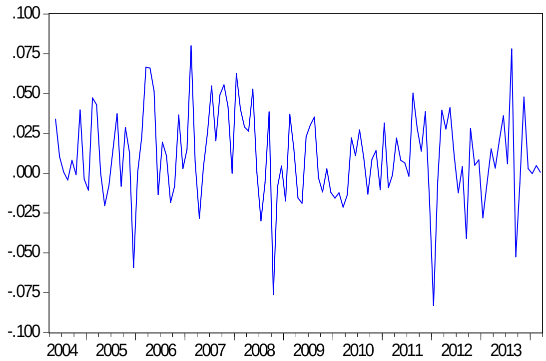



Figure- 4.7(b)
**Differenced LnFER**



It is clear that all patterns of raw data have irregular vertical fluctuations at level. This indicates non-constant mean, variance and presence of trends in the series which make the series non-stationary. The patterns of differenced series of variables presents the glimpses of stationary condition at first difference [See figure- 4.1 (a) to figure- 4.7 (b)].

Further, ADF and PP tests are also performed to confirm this evidence. These tests of unit root are most appropriate for researches to determine the stationary nature of series. The order of integration of the time series variables is also obtained from unit root tests. Table- 4.4 displays the results of stationary condition of Sensex and selected macroeconomic variables which is tested by employing ADF and PP under the null hypothesis i.e. $H_0$: Series has a unit root (non-stationary). The ADF test is criticised because of its low power; therefore, PP test is also used in compliment with ADF test. The optimum lag lengths for these tests are based on Akaike Info Criteria and Newwy-West for Bartlett kernel respectively.

**Table: 4.4**
**Results of Unit Root Test**

| Variables | ADF Test (t-Statistic) | | PP Test (t-Statistic) | | | Order of Integration |
|---|---|---|---|---|---|---|
| | Intercept | Trend & Intercept | Intercept | Trend & Intercept | Comments | |
| LnSX | -2.509989 | -2.974372 | -1.774094 | -2.115800 | Failed to reject H0 | |
| ΔLnSX | -4.886629* | - 4.99350* | -7.9305* | -7.952407* | Rejected H0 | I(1) |
| LnWPI | 0.672189 | -3.232508*** | 0.106343 | -2.586464 | Failed to reject H0 | |
| ΔLnWPI | -5.764226* | -5.824397* | -8.235818* | -8.173291* | Rejected H0 | I(1) |
| LnER | -0.658411 | -2.144212 | -0.199494 | -1.509639 | Failed to reject H0 | |
| ΔLnER | -7.640215* | -7.608966* | -7.603244* | -7.508540* | Rejected H0 | I(1) |
| LnIIP | -3.094546 ** | -1.358415 | -1.506107 | -4.202272* | Rejected H0 | I(0) |
| ΔLnIIP | -2.007502 | -3.003014 | -27.02762* | -30.91207* | | |
| LnMS | -2.600196 | -0.386017 | -0.985708 | -0.739290 | Failed to reject H0 | |
| ΔLnMS | -11.29346* | -2.803639 | -11.57048* | -11.66821* | Rejected H0 | I(1) |
| LnGOLD | -0.836651 | -2.004484 | -0.83646 | -2.325181 | Failed to reject H0 | |
| ΔLnGOLD | -10.64098* | -10.63836* | -10.64042* | -10.63762* | Rejected H0 | I(1) |
| LnFER | -1.386746 | -1.493734 | -1.583568 | | Failed to reject H0 | |
| ΔLnFER | -9.273858* | -9.322971* | -9.217001* | -9.225917* | Rejected H0 | I(1) |
| Test critical values | | | | | | |
| | Intercept | Trend & Intercept | | | | |
| 1% level | -3.486064 | -4.037668 | | | | |
| 5% level | -2.885863 | -3.448348 | | | | |
| 10% level | -2.579818 | -3.149326 | | | | |

**Notes:** *, **, and *** indicate rejection of null hypothesis at 1, 5 and 10% level of significance respectively.

Both these test statistics do not reject the null hypothesis of unit root at levels that shows all the series are non-stationary at level with intercept and trend & intercept except LnIIP which is found to be stationary with 5% level of significance. But after taking the first difference, all series are examined to be stationary. Hence, all the series are converted at their first difference to make them stationary except LnIIP. Nevertheless, the tests show that all variables are individually integrated of order I (1) except LnIIP which is integrated of order I (0). This provides the justification of the fulfillment of requirement to apply Johansen's approach of error correction model to examine the presence of long run relationship among variables.

Johansen's co-integration and VECM test need the optimum number of lags. So, various 'information criteria' like AIC, SIC, HQC, LR and FPE are applied to derive optimum order of lag in a VAR framework. It is important that none of the criteria is superior to other (Gujrati et al., 2012). Some researches recommend SIC and many others favour AIC (Stock, 1994 and Caporale et al., 2004). The results of information criteria are presented in table- 4.5 and it is depicted from results that all criteria show different lag selection for the VAR framework. Hence, AIC is considered for the present study by following the study of Stock (1994) in case of such dispute.

**Table 4.5**
**VAR Lag Order Selection Criteria**

| Lag | LogL | LR | FPE | AIC | SC | HQ |
|---|---|---|---|---|---|---|
| 0 | 793.1927 | NA | 1.89E-15 | -14.0392 | -13.8693 | -13.9702 |
| 1 | 1907.163 | 2068.802 | 1.04E-23 | -33.0565 | -31.69723* | -32.50499* |
| 2 | 1967.087 | 103.7967 | 8.64e-24* | -33.2516 | -30.703 | -32.2175 |
| 3 | 2007.068 | 64.25456 | 1.04E-23 | -33.0905 | -29.3526 | -31.5739 |
| 4 | 2057.512 | 74.76531 | 1.06E-23 | -33.1163 | -28.189 | -31.1171 |
| 5 | 2109.199 | 70.14679 | 1.10E-23 | -33.1643 | -27.0476 | -30.6826 |
| 6 | 2172.871 | 78.45317* | 9.59E-24 | -33.4263 | -26.1203 | -30.462 |
| 7 | 2222.086 | 54.48865 | 1.15E-23 | -33.43011* | -24.9348 | -29.9833 |
| 8 | 2266.291 | 43.41545 | 1.62E-23 | -33.3445 | -23.6598 | -29.4151 |

**Notes:** * indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

### 4.4.3 Estimates of Co-integration test

At the second stage, the presence of significant number of co-integrating relationships among the underlying variables is estimated through Johansen's procedure for co-integration test suggested by the i.e., Johansen (1991) and Johansen & Juselius (1990). 7 lag order has been specified for multivariate VAR estimation using AIC criteria for testing the co-integration among the variables in the period of the study. Exclusively, maximum likelihood eigen values based on trace statistic ($\lambda_{trace}$) and max statistic ($\lambda_{max}$) are used to measure the number of co-integrating vectors between the macroeconomic variables and Sensex. The results of $\lambda_{trace}$ statistics and $\lambda_{max}$ statistics with critical values are presented in table- 4.6.

**Table: 4.6**
**Multivariate (Johansen) Co-integration Test**

| **Panel A: Trace Statistics $\lambda_{trace}$** | | | | |
|---|---|---|---|---|
| | | **Trace** | **0.05** | |
| **Hypothesized No. of CE(s)** | **Eigenvalue** | **Statistic** | **Critical Value** | **Prob.**** |
| | | | | |
| None * (r = 0) | 0.475515 | 207.0373 | 125.6154 | 0.000 |
| At most 1 * (r ≤ 1) | 0.361175 | 134.7593 | 95.75366 | 0.000 |
| At most 2 * (r ≤ 2) | 0.230652 | 84.56931 | 69.81889 | 0.002 |
| At most 3 * (r ≤ 3) | 0.220667 | 55.20163 | 47.85613 | 0.0088 |
| At most 4 (r ≤ 4) | 0.132656 | 27.27815 | 29.79707 | 0.0951 |
| At most 5 (r ≤ 5) | 0.08117 | 11.33839 | 15.49471 | 0.1915 |
| At most 6 (r ≤ 6) | 0.016444 | 1.857077 | 3.841466 | 0.173 |
| | | | | |
| **Panel B: Max Statistics $\lambda_{max}$** | | | | |
| | | **Max-Eigen** | **0.05** | |
| **Hypothesized No. of CE(s)** | **Eigenvalue** | **Statistic** | **Critical Value** | **Prob.**** |
| | | | | |
| None * (r = 0) | 0.475515 | 72.27792 | 46.23142 | 0.000 |
| At most 1 * (r ≤ 1) | 0.361175 | 50.19003 | 40.07757 | 0.0026 |
| At most 2 (r ≤ 2) | 0.230652 | 29.36768 | 33.87687 | 0.1573 |
| At most 3 * (r ≤ 3) | 0.220667 | 27.92348 | 27.58434 | 0.0453 |
| At most 4 (r ≤ 4) | 0.132656 | 15.93976 | 21.13162 | 0.2284 |
| At most 5 (r ≤ 5) | 0.08117 | 9.48131 | 14.2646 | 0.2483 |
| At most 6 ((r ≤ 6) | 0.016444 | 1.857077 | 3.841466 | 0.173 |
| | | | | |

**Notes:** Trace test indicates 4 cointegrating eqn(s) at the 0.05 level.
Max-eigenvalue test indicates 2 cointegrating eqn(s) at the 0.05 level.
* denotes rejection of the hypothesis at the 0.05 level.
r is the co-integration rank or the number of co-integration vectors.
**MacKinnon-Haug-Michelis (1999) p-values.

The results of $\lambda_{trace}$ statistics report that null hypotheses of r = 0 to r ≤ 3 are rejected as $\lambda_{trace}$ statistics is greater than its critical value at 5% level of significance. However, the test is failed to reject the null hypothesis of r ≤ 4 against the alternative hypothesis of $r \geq 4$ as the $\lambda_{trace}$ statistic value (27.27) is less than its critical value (29.79) at 5% level of significance. Therefore, according to $\lambda_{trace}$ statistics, 4 co-integrating vectors are significantly present among the variables under the study. The results of Johansen's Max ($\lambda_{max}$) statistics which are presented in table- 4.6 explores that the null hypotheses of $r = 0$ and $r \leq 1$ can be rejected as $\lambda_{max}$ statistics is higher than its critical value at 5% level of significance. However, it fails to reject the null hypothesis of $r \leq 2$ against the alternative $r = 3$ as the $\lambda_{max}$ statistics value (29.36) is less than its critical value (33.87) at 5% level of significance. Therefore, according to $\lambda_{max}$ statistics, 2 co-integrating vectors are significantly present among the variables under the study. Hence, it is identified from the results of $\lambda_{trace}$ statistics and $\lambda_{max}$ statistics that co-integration is present between the selected macroeconomic variables and Sensex. Engel & Granger (1987) has established that variables would not drift apart over the time period if the variables are co-integrated and as a consequence of co-integration, the relationships among the non-stationary variables can be observed. Therefore, there is a justification to run VECM instead of unrestricted VAR to establish short-run and long-run relationships between the dependent (Sensex return) and independent variables (macroeconomic indicators).

### 4.4.4 Estimates of Vector Error Correction Model

The study finds the impact of macroeconomic variables on Sensex. The existence of stationary and co-integrating vectors in the equation for the time horizon from April 2004 to March 2014 implies the application of VECM for long-run and short-run relationships. Johansen's procedure provides the VECM (Vector Error Correction Model) model to estimate the long and short-run interactions of the variables. Under this model, the error correction term (ECT) estimates the speed of adjustment that is the measure of the speed with which the long-term equilibrium is re-established (Ghosh, 2010). The necessary justification regarding multicollinearity is also tested and no evidence has been found in support of this. The results obtained from VECM specification after assuming co-integrating vectors are represented in table- 4.6 to table- 4.9. The long-term elasticity measures of variables are taken with their log transformation. Therefore, co-integrating relationship based on estimated normalised co-integrating coefficients is represented as follows:

LnSX = 2.01016 - 0.20759 LnWPI + 0.26558 LnER + 0.35177 LnIIP + 0.29215 LnMS - 0.045191 LnGOLD + 0.04341 LnFER ---------------------------- (4.2)

The estimates of normalised co-integrating coefficient, its associated t statistics and standard error are showed in table- 4.7. The results demonstrate the relationship between Sensex & macroeconomic variables and explore that coefficients of four variables out of six variables are significant and the sign of the variables are in accordance to the theoretical literature (Akbar et al., 2012; Naik & Padhi, 2012; Pal & Mittal, 2011; Rahman et al., 2009; Ratanapakorn & Sharma, 2007 and Maysami et al., 2004). The results of table- 4.7 show that the intercept term is positive. It is also clear that the coefficient of LnWPI is negative and significant, while the coefficients of LnER, LnIIP and LnMS are positive and significant. On the contrary, the coefficients of LnGOLD and LnFER are negative and positive respectively but found to be statistically insignificant.

On the basis of this, it infers that the negative relation between Sensex returns and inflation assists the alternate effect of Fama (1981) for the negative relationship of stock price with inflation which explains that higher inflation adversely affects the profitability and the level of real economic activity as it raise the production cost which lead to reduce the stock price. Akbar et al. (2012) and Pal & Mittal (2011) also found negative relationship between stock price and inflation in Pakistan and India. On the other hand, Ratanapakorn & Sharma (2007) found positive association between inflation and stock prices. According to the results of VECM, the stock returns are positively and significantly related to the index of industrial production (the real output) and this relationship specifies that increase in industrial production index leads the growth in the stock price because increase in index of industrial production enhance the present value of the firm and ultimately increase the corporate earning with an increase in the national disposable income. The result is consistent with the results of Maysami et al. (2004), Rahman et al. (2009), Naik & Padhi (2012). It is further noticed that money supply is positively related with Sensex returns under the study which indicates that the stock prices increased because of the economic motivation and rise in money supply. The study of Ratanapakorn & Sharma, (2007) and Maysami et al. (2004) support the results of the positive relationship between the stock price and money supply which proves the significance of this variable for understanding stock price behaviour. Previous studies like Pal & Mittal (2011) found a significant and negative impact of exchange rate on Sensex. However, the results of VECM under the current study reveal that exchange rate is also responsible for determining the stock price as the relationship is significant; although, the sign of the coefficient is observed positive.

**Table: 4.7**
**Estimates of Normalised Co-integrating coefficients**

| | **Coefficient** | **Standard error** | **t-statistics** | **p-value** |
|---|---|---|---|---|
| LnSX(-1) | 1 | | | |
| LnWPI(-1) | 0.20759 | -0.10349 | -2.00586 | 0.0495** |
| LnER(-1) | -0.26558 | -0.05744 | -4.62361 | 0.000* |
| LnIIP(-1) | -0.35177 | -0.13162 | -2.67258 | 0.0098* |
| LnMS(-1) | -0.29215 | -0.14934 | -1.95629 | 0.0553** |
| LnGOLD(-1) | 0.045191 | -0.03232 | 1.39822 | 0.1674 |
| LnFER(-1) | -0.04341 | -0.02349 | -1.84783 | 0.0697 |
| Constant | -2.01016 | | | |

**Note:** *Significant at 1% level of significance.
**Significant at 5% level of significance.

On the other hand, table- 4.7 shows that the relationship of stock price with foreign exchange reserve & gold price is statistically insignificant. Although, the coefficient of foreign exchange reserve is found to be significant at 10% level of significance, it means to some extent stock prices are also fluctuated due to foreign exchange reserve. The table- 4.8 displays the estimates of coefficients of error correction and -0.14549, -0.20946, -0.34756 and 0.046835 values of the estimated coefficients of the error correction terms (ECTs) in ECM are obtained. Out of these coefficients, the results have suggested one ECT during the period of study because coefficient of this ECT (2) is significant at 1% level of significance. In other words, negative value indicates long run equilibrium relationship between Sensex and macroeconomic variables. This implies that there is a presence of long run equilibrium in the model. 21% magnitude of ECT is observed which reveals that the speed of adjustment of the stock price in the absence of any shocks is approximately 21% per month. It means stocks respond for equilibrium relationship once the deviation occurs.

**Table: 4.8**
**Estimates of coefficients of error correction Term (ECT)**

| **Error Correction term:** | **Coefficient** | **Standard Error** | **t-statistics** | **p- value** |
|---|---|---|---|---|
| ECT (1) | -0.14549 | -0.09464 | -1.53728 | 0.1297 |
| ECT (2) | -0.20946 | -0.21744 | 2.76378 | 0.0076* |
| ECT (3) | -0.34756 | -0.15728 | -2.20977 | 0.0911 |
| ECT (4) | 0.046835 | -0.09913 | 0.47246 | 0.6384 |

**Note:** *Significant at 1% level of significance.

The results obtained from VECM specification for short run causality on Sensex returns are represented in table- 4.9 (a) and table- 4.9 (b). It is clear from the results of table- 4.9 (b) that only ER and FER significantly affect Sensex in the short run as p value of their coefficient is less than 0.05; while IIP, WPI, MS and GOLD are insignificant to explain Sensex. The comprehensive picture of the short term estimates can be observed from table- 4.9 (a) which express the impact of all variables on Sensex with seven lag.

**Table: 4.9 (a)**
**Estimates of VAR (Vector Autoregressive Framework)**

| | **Coefficient** | **Std. Error** | **t-Statistic** | **Prob.** |
|---|---|---|---|---|
| $\Delta LnSX_{t-1}$ | 0.426196 | 0.168141 | 2.534751 | 0.014** |
| $\Delta LnSX_{t-2}$ | -0.27556 | 0.175177 | -1.57302 | 0.1212 |
| $\Delta LnSX_{t-3}$ | 0.260691 | 0.179009 | 1.456301 | 0.1507 |
| $\Delta LnSX_{t-4}$ | 0.091196 | 0.158766 | 0.574402 | 0.5679 |
| $\Delta LnSX_{t-5}$ | -0.29107 | 0.161149 | -1.80619 | 0.0761*** |

| | | | | |
|---|---|---|---|---|
| $\Delta LnSX_{t-6}$ | -0.20825 | 0.160301 | -1.2991 | 0.199 |
| $\Delta LnSX_{t-7}$ | -0.08071 | 0.154946 | -0.5209 | 0.6044 |
| $\Delta LnWPI_{t-1}$ | 1.828447 | 1.183716 | 1.544668 | 0.1279 |
| $\Delta LnWPI_{t-2}$ | -0.7539 | 1.197712 | -0.62945 | 0.5315 |
| $\Delta LnWPI_{t-3}$ | 0.14359 | 1.208261 | 0.11884 | 0.9058 |
| $\Delta LnWPI_{t-4}$ | 0.080492 | 1.155458 | 0.069663 | 0.9447 |
| $\Delta LnWPI_{t-5}$ | 1.569892 | 1.25923 | 1.246708 | 0.2175 |
| $\Delta LnWPI_{t-6}$ | -0.89344 | 1.278929 | -0.69859 | 0.4876 |
| $\Delta LnWPI_{t-7}$ | 0.702657 | 1.254217 | 0.560236 | 0.5775 |
| $\Delta LnER_{t-1}$ | -0.04618 | 0.52978 | -0.08716 | 0.9308 |
| $\Delta LnER_{t-2}$ | -1.27022 | 0.555862 | -2.28513 | 0.026** |
| $\Delta LnER_{t-3}$ | 0.441443 | 0.562239 | 0.785153 | 0.4356 |
| $\Delta LnER_{t-4}$ | -0.06619 | 0.542897 | -0.12192 | 0.9034 |
| $\Delta LnER_{t-5}$ | -1.01843 | 0.573247 | -1.7766 | 0.0809*** |
| $\Delta LnER_{t-6}$ | -0.30078 | 0.575772 | -0.5224 | 0.6034 |
| $\Delta LnER_{t-7}$ | -0.35249 | 0.508019 | -0.69385 | 0.4905 |
| $\Delta LnIIP_{t-1}$ | -0.65416 | 0.480282 | -1.36204 | 0.1785 |
| $\Delta LnIIP_{t-2}$ | -0.33949 | 0.414276 | -0.81947 | 0.4159 |
| $\Delta LnIIP_{t-3}$ | -0.13333 | 0.389198 | -0.34258 | 0.7332 |
| $\Delta LnIIP_{t-4}$ | -0.02352 | 0.386857 | -0.06079 | 0.9517 |
| $\Delta LnIIP_{t-5}$ | -0.29833 | 0.351517 | -0.84869 | 0.3995 |
| $\Delta LnIIP_{t-6}$ | 0.071308 | 0.293827 | 0.242688 | 0.8091 |
| $\Delta LnIIP_{t-7}$ | 0.194005 | 0.200163 | 0.969236 | 0.3365 |
| $\Delta LnMS_{t-1}$ | -0.34496 | 0.952729 | -0.36208 | 0.7186 |
| $\Delta LnMS_{t-2}$ | -0.52789 | 0.963818 | -0.54771 | 0.586 |
| $\Delta LnMS_{t-3}$ | -1.34618 | 0.999714 | -1.34656 | 0.1834 |
| $\Delta LnMS_{t-4}$ | -0.45473 | 1.039851 | -0.4373 | 0.6635 |
| $\Delta LnMS_{t-5}$ | -0.23296 | 0.962456 | -0.24205 | 0.8096 |
| $\Delta LnMS_{t-6}$ | -0.70292 | 0.870878 | -0.80714 | 0.4229 |
| $\Delta LnMS_{t-7}$ | 0.456585 | 0.76387 | 0.597726 | 0.5523 |
| $\Delta LnGOLD_{t-1}$ | -0.15358 | 0.198095 | -0.77529 | 0.4413 |
| $\Delta LnGOLD_{t-2}$ | 0.103222 | 0.18672 | 0.552815 | 0.5825 |
| $\Delta LnGOLD_{t-3}$ | 0.093729 | 0.184959 | 0.506756 | 0.6142 |
| $\Delta LnGOLD_{t-4}$ | 0.009948 | 0.181954 | 0.054671 | 0.9566 |
| $\Delta LnGOLD_{t-5}$ | -0.22958 | 0.184156 | -1.24663 | 0.2175 |
| $\Delta LnGOLD_{t-6}$ | -0.09999 | 0.175271 | -0.5705 | 0.5705 |
| $\Delta LnGOLD_{t-7}$ | -0.12285 | 0.188741 | -0.65091 | 0.5177 |
| $\Delta LnFER_{t-1}$ | -0.06204 | 0.3479 | -0.17833 | 0.8591 |
| $\Delta LnFER_{t-2}$ | 0.629591 | 0.346995 | 1.814411 | 0.0748*** |
| $\Delta LnFER_{t-3}$ | 0.655467 | 0.398084 | 1.646555 | 0.1051 |
| $\Delta LnFER_{t-4}$ | 0.13372 | 0.409549 | 0.326505 | 0.7452 |
| $\Delta LnFER_{t-5}$ | 0.89826 | 0.376101 | 2.388345 | 0.0202** |
| $\Delta LnFER_{t-6}$ | 0.296165 | 0.405647 | 0.730104 | 0.4683 |
| $\Delta LnFER_{t-7}$ | 0.505541 | 0.385306 | 1.312051 | 0.1947 |
| C | 0.027623 | 0.060666 | 0.455336 | 0.6506 |

**Note:** * Significant at 1% level of significance, ** Significant at 5% level of significance, ***Significant at 10% level of significance.

**Table: 4.9 (b)**

**Short Term Estimates of Vector Error Correction Model**

| **Dependent variable: D(LNSENSEX)** | | | |
|---|---|---|---|
| | **Chi-sq** | **df** | **Prob.** |
| ΔLWPI | 4.441223 | 7 | 0.7278 |
| ΔLnER | 14.10565 | 7 | 0.0493** |
| ΔLnIIP | 9.001035 | 7 | 0.2526 |
| ΔLnMS | 2.903816 | 7 | 0.8938 |
| ΔLnGOLD | 3.333751 | 7 | 0.8525 |
| ΔLnFER | 13.64081 | 7 | 0.058** |
| All | 44.74843 | 42 | 0.3572 |

**Note:** ** Significant at 5% level of significance.

**Table: 4.10**
**Model Specifications for Fitness of Model**

| | | | |
|---|---|---|---|
| R-squared | 0.598844 | Mean dependent var | 0.011584 |
| Adjusted R-squared | 0.23227 | S.D. dependent var | 0.063101 |
| S.E. of regression | 0.055289 | Akaike info criterion | -2.64624 |
| Sum squared resid | 0.177302 | Schwarz criterion | -1.33553 |
| Log likelihood | 202.1894 | Hannan-Quinn criter. | -2.11444 |
| F-statistic | 1.633623 | Durbin-Watson stat | 2.04101 |
| Prob(F-statistic) | 0.034394 | | |
| | | | |
| Jarque-Bera | 3.059351 | | |
| Prob. | 0.216606 | | |
| | | | |
| **Breusch-Godfrey Serial Correlation LM Test:** | | | |
| F-statistic | 0.404503 | Prob. F(7,51) | 0.8951 |
| Obs*R-squared | 5.891168 | Prob. Chi-Square (7) | 0.5525 |
| **Heteroskedasticity Test: ARCH LM test:** | | | |
| F-statistic | 1.080627 | Prob. F(7,97) | 0.3817 |
| Obs*R-squared | 7.595902 | Prob. Chi-Square (7) | 0.3696 |

Overall, adjusted $R^2$ value shows that 23.22% variation in Sensex is explained by the macroeconomic variables under the current study. Durbin Watson statistics confirms the absence of autocorrelation in the residuals of equation and this feature of model is also established by Breusch-Godfrey Serial Correlation LM test as $p > 0.05$. The Jarque-Bera statistics fails to reject the null hypothesis of normality of residuals which confirms the normality of residuals. According to ARCH-LM test, it is proved that there is no ARCH effect or heterosecdasticity remained in the model. These results provide evidence for the fitness of the model for analysing the relationship between Sensex and macroeconomic indicators.

# SECTION- II

## 4.5 VOLATILITY OF INDIAN STOCK MARKET

While selecting a portfolio, investor needs to go through the volatility of stocks. Volatility can be expressed as the magnitude of uncertainty and risk associated with extent of changes of an asset's value. A higher volatility can be the reason of substantial change in either direction in the price of an asset over a short period of time and a lower volatility defines that the value of asset does not fluctuate substantially over a period of time. There is an increased interest of econometricians to study the volatility for establishing an accurate model for the prediction of volatility nowadays which was previously assumed as constant. It is discovered by various researchers for Indian markets or the markets of other nations that the volatility is a time varying factor which needs to be studied consistently to determine the accurate situation of the market (Li & Hong, 2011). Nature of volatility is checked with the number of ways such as model of time series i.e. GARCH and stochastic volatility. Volatility is also checked through option price implied volatilities and direct measures like the realized volatility. But, GARCH model is proved to be the best and as a result, widely accepted model for modeling the time-varying conditional volatility. The strong point of the GARCH model is its flexible adaptation of the dynamics of volatilities and ease of calculation when it is compared to the other models for checking the volatility.

It is an assumption under GARCH model that good and bad news are symmetrical impacting factor for volatility. But in most of the markets, there is presence of a leverage effect and volatility proved to be more affected by bad news in comparison to good news that violated this assumption of GARCH model. Leverage effect has been checked firstly by Black (1976) and this fact is also checked under this current study for Indian stock market. The relationship between the returns and volatility of an asset has also been extensively studied in various markets. Various asset pricing models associate return of an asset with its own return variance. But, it has been a matter of debate that whether this relationship is positive or negative in nature. Most of the asset-price models hypothesize a positive relationship between return and volatility of a portfolio. However, there are other evidences of the models available which found negative correlation between volatility of stock market and stock return (Black, 1976 and Whitelaw, 2000).

This section deals with the modeling of volatility of Sensex and estimates the best fit model for Sensex volatility. It presents the results of unit root tests, diagnostic tests with descriptive statistics of Sensex. Daily Sensex price has been used to examine the extent of volatility in Indian stock market. GARCH familiy models have been developed to examine the volatility of Sensex to study the behaviour of volatility of Sensex. Various popular GARCH family models such as GARCH, EGARCH, TGARCH and GARCH-M models are developed and the results have been compared to decide best fitted model.

### 4.5.1 Descriptive Statistics of Sensex and Diagnostic Tests

GARCH class models are return based models and returns of closing price are constructed for this purpose in the study. Daily Sensex prices from the period April 1, 2004 to March 31, 2014 have been converted to daily returns to analyze the extent of volatility in Indian stock market. Logarithmic difference of prices of two successive periods has been used for the calculation of returns.

The rate of return is calculated on the basis of following equation:

$$R_t = Ln(P_t / P_{t-1}) * 100 \qquad \text{--------- (4.3)}$$

Here, Ln is natural logarithm; $R_t$ is return in the period t; $P_t$ is the daily closing Sensex price at a particular time t; $P_{t-1}$ is the closing Sensex price for the preceding period.

Figure- 4.8 displays the plot of daily return data series of Sensex to show the fluctuations in returns for diagnostic testing. Descriptive statistics is calculated to better examine the nature of data series and table- 4.11 presents the descriptive statistics. Table- 4.10 also displays ARCH-LM statistics for ARCH effect to test the null hypothesis based on no hetroscedascity. Ljung Box statistic, Q(k) and $Q^2(k)$ are used to examine the existence of the order of autocorrelation under the null hypothesis based on no autocorrelation in residuals of return and squared residuals of return series respectively. The results for independence and identically normal distribution of return series are also exhibited in the table- 4.11.

**Figure- 4.8: Daily Return of SENSEX**

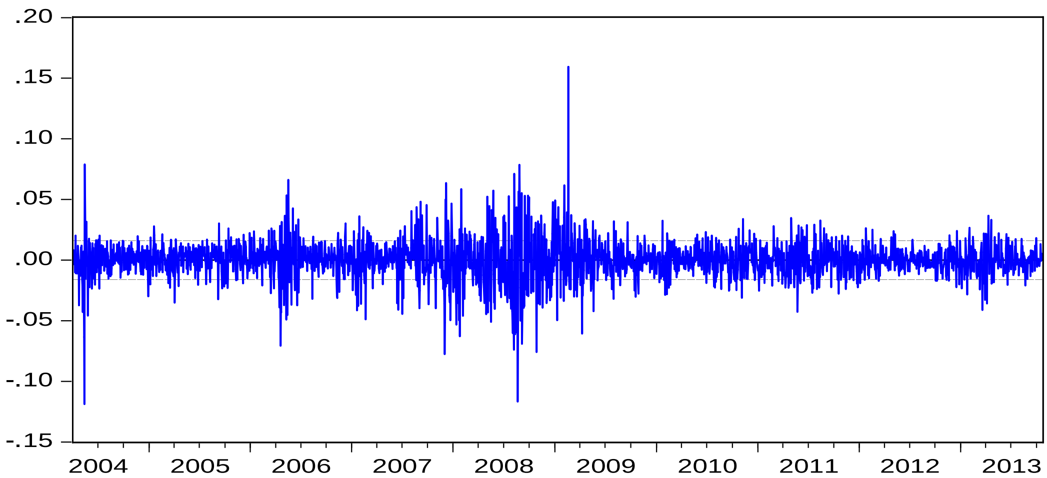



Figure- 4.8 clearly proposes that returns are moving around an approximately zero-mean with time-varying clustering volatility where large returns tend to be followed by large returns and small returns tend to be followed by small returns leading to contiguous periods of volatility. It can be observed that volatility was high and low in different periods with the positive and negative directions in clusters. There is all justification to run GARCH family models in this condition.

The results of descriptive statistics in table- 4.11 exhibit that standard deviation explains a significant variation in daily returns of Sensex and minimum & maximum values display a large distance in returns. The mean of returns (0.0005) is very close to zero and demonstrates that the series is mean reverting which is usually expected for a time series return. The coefficient of skewness is negative that represents the presence of non symmetric and left tail distribution with large negative returns. The return distribution has large value of kurtosis that suggests leptokurtic distribution. The Jarque-Bera statistics displayed in table- 4.11 to check the normality of data series and the probability value of Jarque-Bera statistics ($p < 0.05$) confirms the rejection of null hypothesis of normal distribution.

**Table: 4.11**
**Descriptive and Diagnostic Statistics of Sensex Returns**

| Statistic | DLSensex |
|---|---|
| Observation period | April 1, 2004 to March 31, 2014 |
| Number of observations | 2493 |
| Mean | 0.000546 |
| Std. Dev. | 0.016092 |
| Skewness | -0.0696 |
| Kurtosis | 11.49951 |
| Jarque-Bera | 7506.118 (0.0000) |
| ARCH-LM statistics (at lag =1) | 100.4072 (0.000) |
| Q(1) (correlogram of residuals) | 11.404 (2-tailed p=0.001) |
| $Q^2(1)$ correlogram of residuals squared | 96.742 (2-tailed p=0.000) |
| Q(20) | 57.79 (2-tailed p=0.000) |
| $Q^2(20)$ | 936.68 (2-tailed p=0.000) |

Table- 4.11 also shows the result of ARCH- LM statistics applied with lag 1 to check the presence of ARCH effect and heterosecdasticity which assumes that there is no ARCH affect. The observed $R^2$ value and its corresponding p value (p = 0.000) provides the evidence of ARCH effect in the residuals of the model. Hence, null hypothesis is rejected and proves that there is a presence of heteroscedasticity in the return series. Further, p-values (< 0.05) of Ljung Box statistic, Q(k) and $Q^2(k)$ indicate strong autocorrelation in the return and squared returns series upto $20^{th}$ order of autocorrelation. This suggests that residual are conditionally heteroscedastice. Therefore, GARCH class models are found to be suitable to run.

On the basis of above findings, it is clearly revealed that daily return series of Sensex has thick tailed, clustering volatility, and ARCH effect. Hence, series is proved to be having hetroscedasticity. Now, four volatility models i.e. GARCH (1,1), EGARCH (1,1), TGARCH (1,1) and GARCH-M have been estimated and compared to find the best fit volatility model for Indian stock market.

### 4.5.2 Test of Stationarity (Unit Root Test)

Unit root tests (ADF and PP tests) have been applied in order to check the presence of unit root in the time series of daily Sensex price. ADF and PP tests check the null hypothesis that series has a unit root. The selection of optimum lag is based on Akaike Info Criteria (AIC) and Newey-West Bandwidth criteria. The results on unit root tests are reported in the table- 4.12.

**Table: 4.12**
**Results of Unit Root Tests**

| **Variables** | **ADF Test** | | **PP Test** | |
|---|---|---|---|---|
| | (t-Statistic) | | (t-Statistic) | |
| | Level | First difference | level | First difference |
| **Constant** | 1.486153 | -10.43637* | 1.618683 | -46.60082* |
| p-value | 0.9665 | 0.000 | 0.9747 | 0.0001 |
| **Intercept** | -1.86778 | -10.5562* | -1.72411 | -46.569* |
| p-value | 0.3479 | 0.000 | 0.4189 | 0.0001 |
| **trend & intercept** | -2.20833 | -10.5842* | -2.01983 | -46.5689* |
| p-value | 0.4842 | 0.000 | 0.5896 | 0.000 |
| Test critical values | | | | |
| | Constant | intercept | trend & intercept | |
| 1% level | -2.565890 | -3.48606 | -3.96176 | |
| 5% level | -1.940951 | -2.88586 | -3.41163 | |
| 10% level | -1.616614 | -2.57982 | -3.12768 | |

**Notes:** * represent rejection of null hypothesis at 1 percent significance level.

It is clear from the table- 4.12 that ADF and PP tests do not reject null hypothesis of a unit root at levels and hence, show the evidence that Sensex data series is non stationary at levels but after taking the first difference of the series, the results of both ADF and PP tests show that Sensex series is stationary at first difference and confirms the fact that return series of Sensex is stationary at 1% level of significance.

### 4.5.3 Modeling of Volatility of Sensex

Mean equation and variance equation are two equations in ARCH models. The residuals derived from mean equation of the model are applied to calculate the variance equation. Box- Jenkins Methodology is applied first to estimate mean equation and then variance equation is calculated in the later phase by applying GARCH family models.

#### 4.5.3.1 Application of Box- Jenkins Methodology

Box-Jenkins methodology is applied to estimate an appropriate mean equation. Table- 4.12 displays that p-values of Ljung–Box Q statistics for the return series and squared returns are less than 0.05 and hence, indicate the presence of autocorrelation in the return series and squared return upto 20th order. It is interesting to observe the patterns of autocorrelation function (ACF) and partial autocorrelation function (PACF) statistics. Diagnostics for ARIMA identifies only moving average (MA) term with order 1 in the Sensex return series. This fact provides the sign to employ the models of volatility forecasting with MA (1) process.

**4.5.3.2 Measuring Volatility: GARCH- family Models**

Presence of significant ARCH effect and volatility clustering give the indication to move for the next step of modeling the conditional variance equation of residuals by employing MA (1) process. Various GARCH class models are used to measure the volatility of daily return distribution. Akaike Information Criterion and Schwarz's Bayesian Information Criterion with log likelihood are used for selecting the most appropriate model to capture the volatility in Indian stock market. After diagnostic check on appropriateness of model order, it is found that (1,1) process is the best fitted model for conditional variance. The results of all volatility models, AIC, SIC and log likelihood are reported in table- 4.13 to 4.15. Relationship between stock returns (Sensex) and volatility has also been examined and results are displayed in table- 4.16.

**4.5.3.2.1 Symmetric Volatility Model: GARCH**

GARCH model is given by Bollerslev (1986). GARCH (p,q) model allows that the conditional variance depends on its conditional variance in the previous time period and squared error term in the previous time period. The specification of conditional variance under GARCH model is as follows:

$$\sigma_t^2 = \alpha_0 + \alpha_1 a_{t-1}^2 + \beta_1 \sigma_{t-1}^2 \qquad \text{---- (4.4)}$$

Here, $\alpha_{0,}$ $\alpha_1$, $\beta_1$= parameters to be estimated, $\sigma_t$ = conditional variance at period t, q= number of return innovation lags included in the model, p= number of past volatility lags included in the model, a = innovation in return at time t. The results parameters of GARCH (1, 1) model are presented in table- 4.13. The estimates from table- 4.13 states that the coefficient of MA (1) is significant at 5% level of significance. Hence, the diagnosis of MA (1) process under the Box- Jenkins methodology holds good that indicates the impact of news on Sensex volatility.

**Table: 4.13**
**Coefficient of GARCH (1, 1) Model**

| Variable | Coefficient | Std. Error | z-Statistic | Prob. |
|---|---|---|---|---|
| **Mean Equation** | | | | |
| C | 0.001036 | 0.000237 | 4.36317 | 0.000 |
| MA(1) | 0.068885 | 0.021607 | 3.188114 | 0.0014 |
| **Variance Equation** | | | | |
| C | 3.76E-06 | 6.31E-07 | 5.964598 | 0.000 |
| RESID(-1)^2 α | 0.114096 | 0.008509 | 13.40857 | 0.000 |
| GARCH(-1) β | 0.87312 | 0.009009 | 96.91453 | 0.000 |
| α + β | 0.987 | | | |
| | | | | |
| R-squared | 0.004209 | Mean dependent var | | 0.000546 |
| Adjusted R-squared | 0.003809 | S.D. dependent var | | 0.016092 |
| S.E. of regression | 0.016061 | Akaike info criterion | | -5.81177 |
| Sum squared resid | 0.642562 | Schwarz criterion | | -5.80009 |
| Log likelihood | 7249.365 | Hannan-Quinn criterion | | -5.80753 |
| Durbin-Watson stat | 1.993958 | | | |
| **ARCH-LM test** | | | | |
| F-statistic | 0.00471 | 0.9453 | | |
| Obs*R-squared | 0.004714 | 0.9453 | | |
| Inverted MA Roots | -0.07 | | | |

Findings of GARCH (1,1) model indicate that estimates of all the parameters are significant which supports the strong validity of GARCH (1,1) model. Now, it is important to note that coefficients of lagged squared residuals and lagged conditional variance of residuals terms are statistically significant in the variance equation which reinforce on earlier findings about the presence of significant clustering effect. It is worth to notice that the estimate of coefficient of GARCH (β) is greater than the coefficient of ARCH (α) and explores the fact that higher volatility is due to persistence of volatility in Sensex and supports the research literature on Indian stock market volatility (Karmakar, 2007; Kaur, 2004; Joshi, 2011 and Padhi, 2006). However, it is obvious from significant value of α that there has been significant impact of bad news and good news on volatility of Sensex. Also, the sum of coefficients of α and β is less than unity (0.987) which indicate that the condition of stationarity is not violated and hence, proves that model is perfectly structured. The sum of coefficients is very close to unity. On the basis of this observation from GARCH (1,1) model, it can be concluded that there is presence of long persistence of conditional shocks in volatility which means volatility in Sensex dies out slowly and affects the volatility for a long time.

After applying ARCH-LM test, it is clear from probability of F-statistics ($p > 0.05$) that there is no ARCH effect left in the estimates of the model. Hence, GARCH (1, 1) model captures time varying volatility and it is fit.

#### 4.5.3.2.2 Asymmetric Volatility Models: Testing of Leverage Effect

GARCH process generates symmetric response function for the stock returns. French, Schwert & Stambaugh (1987) and Christie (1982) have shown differential response in terms of leverage effect and captured the magnitude as well as sign effect. This implies that returns are likely to be more volatile in response to negative shocks to returns and less volatile in response to positive shocks. Popular asymmetric models (EGARCH and TGARCH) have been employed for examining the leverage effect.

#### 4.5.3.2.2 (a) EGARCH (1,1) Model

The results of table- 4.14 show that EGARCH (1,1) model confirms the findings of GARCH (1,1) model. Under normal distribution, the analysis of EGARCH model suggests the significant effect of news, persistence of volatility and leverage on Sensex volatility. It is found that ARCH term ($\alpha$) is significant which means previous day's Sensex return information influences today's return volatility. GARCH term ($\beta$) is also found to be significant which indicates previous day's return volatility influences today's return volatility. It also observed that coefficients of ARCH ($\alpha$= 0.217), coefficients of GARCH ($\beta$= 0.972) are positive and hence, display more effect of persistence of volatility which is similar to the results of GARCH (1,1) model.

**Table: 4.14**
**Coefficients of EGARCH (1, 1) Model**

| Variable | Coefficient | Std. Error | z-Statistic | Prob. |
|---|---|---|---|---|
| **Mean Equation** | | | | |
| C | 0.000515 | 0.000232 | 2.216406 | 0.0267 |
| MA(1) | 0.078857 | 0.021255 | 3.710045 | 0.0002 |
| **Variance Equation** | | | | |
| | | | | |
| C(3) | -0.40263 | 0.035212 | -11.4344 | 0.000 |
| C(4) α | 0.216998 | 0.014128 | 15.35991 | 0.000 |
| C(5) γ | -0.08973 | 0.009331 | -9.61703 | 0.000 |
| C(6) β | 0.972573 | 0.003261 | 298.2241 | 0.000 |
| | | | | |
| R-squared | 0.005029 | Mean dependent var | | 0.000546 |
| Adjusted R-squared | 0.004629 | S.D. dependent var | | 0.016092 |
| S.E. of regression | 0.016054 | Akaike info criterion | | -5.82388 |
| Sum squared resid | 0.642033 | Schwarz criterion | | -5.80987 |
| Log likelihood | 7265.466 | Hannan-Quinn criterion | | -5.81879 |
| Durbin-Watson stat | 2.014637 | | | |
| **ARCH-LM test** | | | | |
| F-statistic | 0.414195 | 0.5199 | | |
| Obs*R-squared | 0.414458 | 0.5197 | | |
| Inverted MA Roots | -0.08 | | | |

However, the coefficient of leverage (γ = -0.089) is different from zero and statistically significant at 1% level of significance. This presents the evidence of asymmetric effect of good news & bad news on Sensex volatility and hence, indicates an existence of leverage effect on the returns of Sensex. The leverage effect implies that decrease in stock prices leads to an increase in risk of holding stocks. The coefficient of γ confirms negative relationship of returns with volatility and suggests that returns reduce with more volatility in returns. The results are in the line of studies of Kumar & Sumanjeet (2006) and Padhi & Pandya (2008). On comparing the values of information criteria, it is found that EGARCH model outperforms the GARCH model for Sensex as the AIC & SIC are lower and log-likelihood is higher as compared with GARCH (1,1).

### 4.5.3.2.2 (b) TGARCH (1,1) Model

The outcomes of the TGARCH (1,1) model are presented in table- 4.15 to capture leverage and sign effect. It is important to note that all parameters are significant. The result estimation of TGARCH model represents the similar results of

EGARCH model as coefficient of leverage term is significant and greater than zero (γ = 0.127) which implies leverage effect and sign effect. This reinforces the assumption that bad and good news have different impact on volatility of returns. Negative surprises are the reasons of more volatility in returns in comparison with positive surprises and hence, market response more to bad news and less to good news which supports the studies of Schwert (1989) and French et al. (1987).

**Table: 4.15**
**Coefficients of TGARCH (1,1) Model**

| Variable | Coefficient | Std. Error | z-Statistic | Prob. |
|---|---|---|---|---|
| **Mean Equation** | | | | |
| C | 0.000643 | 0.000242 | 2.654568 | 0.0079 |
| MA(1) | 0.077248 | 0.022169 | 3.484447 | 0.0005 |
| **Variance Equation** | | | | |
| | | | | |
| C | 4.46E-06 | 5.75E-07 | 7.75742 | 0.000 |
| RESID(-1)^2 (α) | 0.043928 | 0.007391 | 5.943564 | 0.000 |
| RESID(-1)^2*(RESID(-1)<0) γ | 0.127417 | 0.014747 | 8.640361 | 0.000 |
| GARCH(-1) (β) | 0.874368 | 0.009054 | 96.57007 | 0.000 |
| | | | | |
| R-squared | 0.005011 | Mean dependent var | | 0.000546 |
| Adjusted R-squared | 0.004611 | S.D. dependent var | | 0.016092 |
| S.E. of regression | 0.016054 | Akaike info criterion | | -5.82879 |
| Sum squared resid | 0.642044 | Schwarz criterion | | -5.81478 |
| Log likelihood | 7271.582 | Hannan-Quinn criterion | | -5.8237 |
| Durbin-Watson stat | 2.011504 | | | |
| **ARCH-LM test** | | | | |
| F-statistic | 1.336107 | 0.2478 | | |
| Obs*R-squared | 1.336463 | 0.2477 | | |
| Inverted MA Roots | -0.08 | | | |

The values of AIC and SIC of this model are lower with higher log-likelihood value as compared with GARCH and EGARCH models which confirms that this model is best fitted for Sensex volatility estimation.

### 4.5.3.2.3 Relationship between Return & Volatility: GARCH-M Model

An investor should always be rewarded with higher return for taking higher risk while preparing portfolio. Engle, Lilien and Robins (1987) proposed an ARCH-M specification to measure the effect of risk on return. Since, GARCH models are comparatively more famous than ARCH model in finance; So, GARCH-in-mean model is applied to check the relationship between return and risk in Sensex. Results are reported in table- 4.16.

**Table: 4.16**
**Coefficients of GARCH-M Model**

| Variable | Coefficient | Std. Error | z-Statistic | Prob. |
|---|---|---|---|---|
| **Mean Equation** | | | | |
| SQRT(GARCH) | 0.03709 | 0.060652 | 0.611528 | 0.5408 |
| C | 0.000635 | 0.000679 | 0.935303 | 0.3496 |
| MA(1) | 0.069306 | 0.021658 | 3.199957 | 0.0014 |
| | | **Variance Equation** | | |
| | | | | |
| C | 3.76E-06 | 6.36E-07 | 5.919542 | 0.000 |
| RESID(-1)^2 (α) | 0.114236 | 0.008518 | 13.41062 | 0.000 |
| GARCH(-1) (β) | 0.873013 | 0.009024 | 96.74465 | 0.000 |
| | | | | |
| R-squared | 0.003353 | Mean dependent var | | 0.000546 |
| Adjusted R-squared | 0.002552 | S.D. dependent var | | 0.016092 |
| S.E. of regression | 0.016071 | Akaike info criterion | | -5.81111 |
| Sum squared resid | 0.643114 | Schwarz criterion | | -5.7971 |
| Log likelihood | 7249.549 | Hannan-Quinn criterion | | -5.80602 |
| Durbin-Watson stat | 1.992315 | | | |
| | | | | |
| **ARCH-LM test** | | | | |
| F-statistic | 0.005096 | 0.9431 | | |
| Obs*R-squared | 0.0051 | 0.9431 | | |
| Inverted MA Roots | -0.07 | | | |

It is clear that estimated parameters of conditional mean equation which is SQR GARCH has a positive sign but statistically not significant as its p-value is in excess of 0.05. This implies no feedback from conditional variance to conditional mean and hence, no evidence of higher Sensex returns in case of higher volatility. This is also found by various researchers (Karmakar, 2007; Joshi, 2011 and Shah & Iqbal, 2005).

### 4.5.4 Diagnostic Tests for Model Adequacy

There are several diagnostic tests for volatility models and the most important tests are autocorrelation of standardised squared residuals, ARCH effect and normality. Now, the diagnostic tests for all the volatility models are also performed to check whether these models are adequate or not for estimation of Sensex volatility. Results of these tests are presented in table- 4.17 to 4.19. Presence of serial correlation to capture volatility clustering phenomenon has been checked by Ljung-Box, Q statistics under the null hypothesis of no serial correlation in the residuals.

**Table: 4.17**
**Autocorrelation of Standardised Residuals**

| Autocorrelation | Partial Correlation | | AC | PAC | Q-Stat | Prob |
|---|---|---|---|---|---|---|
| GARCH | | | | | | |
| | | 1 | 0.016 | 0.016 | 0.6579 | |
| | | 20 | -0.038 | -0.037 | 22.492 | 0.26 |
| | | 30 | -0.007 | -0.004 | 27.814 | 0.528 |
| | | | | | | |
| | | 1 | 0.001 | 0.001 | 0.0047 | |
| | | 20 | 0.004 | 0.004 | 16.664 | 0.613 |
| | | 30 | 0 | 0.003 | 24.067 | 0.726 |
| EGARCH | | | | | | |
| | | 1 | 0.005 | 0.005 | 0.0712 | |
| | | 20 | -0.036 | -0.037 | 24.927 | 0.163 |
| | | 30 | -0.01 | -0.008 | 29.983 | 0.415 |
| | | | | | | |
| | | 1 | -0.013 | -0.013 | 0.4151 | |
| | | 20 | 0.015 | 0.014 | 19.164 | 0.446 |
| | | 30 | 0.006 | 0.005 | 24.385 | 0.71 |
| | | | | | | |
| TGARCH | | | | | | |
| | | 1 | 0.008 | 0.008 | 0.1762 | |
| | | 20 | -0.036 | -0.036 | 23.069 | 0.234 |
| | | 30 | -0.007 | -0.004 | 28.157 | 0.51 |
| | | | | | | |
| | | 1 | -0.023 | -0.023 | 1.3385 | |
| | | 20 | 0.015 | 0.014 | 15.017 | 0.722 |
| | | 30 | 0.005 | 0.005 | 20.346 | 0.882 |
| GARCH-M | | | | | | |
| | | 1 | 0.016 | 0.016 | 0.6698 | |
| | | 20 | -0.037 | -0.037 | 22.835 | 0.245 |
| | | 30 | -0.007 | -0.004 | 28.022 | 0.517 |
| | | 1 | 0.001 | 0.001 | 0.0051 | |
| | | 20 | 0.004 | 0.004 | 16.558 | 0.62 |
| | | 30 | 0.001 | 0.003 | 24.034 | 0.727 |

Table- 4.17 contains the results of correlogram of standardised residuals and standardised squared residuals for all volatility models under the study. It is clear that the null hypothesis of no autocorrelation within standardised residuals and standardised squared residuals can not be rejected as corresponding p-value is greater than 0.05. Also, the correlogram of ACF (autocorrelations) and PACF (partial autocorrelations) produce an evidence that the residuals calculated under the models are purely white noise. Hence, it can be concluded that models are strong in capturing volatility clustering. Normality of standardised returns is checked with Jarque-Bera test to prove the goodness of the model under the null hypothesis that residuals are normally distributed. Table- 4.18 contains the results of normality test in case of all estimated models.

**Table: 4.18**
**Normality of Standardized Returns**

| | GARCH (1,1) | EGARCH (1,1) | TARCH (1,1) | GARCH-M |
|---|---|---|---|---|
| Jarque-Bera | 333.76 | 521.72 | 631.14 | 334.00 |
| p-value | 0.000 | 0.000 | 0.000 | 0.000 |

It is evident from the p-value (< 0.05) of Jarque-Bera statistics that the null hypothesis (residuals are normally distributed) would not be accepted in case of all estimated models. This presents that distributions of standardised returns are far from Gaussian normal distribution which supports the study of Joshi (2011). ARCH- LM test is applied to check the presence of heteroscedasticity in returns under the null hypothesis of no ARCH affect in the models of volatility of Sensex. The results are displayed in table- 4.19.

**Table: 4.19**
**Model Adequacy: ARCH-LM test**

| **Heteroscedasticity Test: ARCH** | | | |
|---|---|---|---|
| **Models** | | coefficient | p-value |
| GARCH (1,1) | F-statistic | 0.00471 | 0.9453 |
| | Obs*R-squared | 0.004714 | 0.9453 |
| EGARCH (1,1) | F-statistic | 0.414195 | 0.5199 |
| | Obs*R-squared | 0.414458 | 0.5197 |
| TARCH (1,1) | F-statistic | 1.336107 | 0.2478 |
| | Obs*R-squared | 1.336463 | 0.2477 |
| GARCH-M | F-statistic | 0.005096 | 0.9431 |
| | Obs*R-squared | 0.0051 | 0.9431 |

After applying ARCH-LM test, it is clear from probability of F-statistics (p > 0.05) that the hypothesis of no ARCH effect can not be rejected in case of all volatility models under the study that represents the fitness of volatility models. This produces an evidence of violation of hetroscedasticity and no significant ARCH effect. Hence, models are observed to be fit for capturing time varying volatility of Sensex for measuring the behaviour of Sensex. Diagnostic tests justified that residuals of models have no ARCH effect and no serial correlation that represents the fitness of volatility models.

### 4.5.5 Comparison of GARCH- family Models

Information criteria are useful as model selection tools and hence, Akaike Information Criterion (AIC) and Schwarz's Bayesian Information Criterion (SIC) are employed. Log-likelihood is also used to determine the best fitted model. These are reported for each model in table- 4.20.

**Table: 4.20**
**Values of Information Criteria**

| | GARCH (1,1) | EGARCH | TGARCH | GARCH-M |
|---|---|---|---|---|
| AIC | -5.81177 | -5.82388 | -5.82879 | -5.81111 |
| SIC | -5.80009 | -5.80987 | -5.81478 | -5.7971 |
| Log likelihood | 7249.365 | 7265.466 | 7271.582 | 7249.549 |

It is obvious that all asymmetric models outperform the symmetric model on the basis of AIC, SIC and log-likelihood because asymmetric models show low AIC & SIC values with high log-likelihood value. This signifies that unlike GARCH model, the returns respond differently to positive and negative news in accordance to asymmetric models. Overall, TGARCH model is found to be the best fitted model to capture time varying volatility of Sensex return on the basis of the guideline of AIC & SIC and log-likelihood value.

## 4.6 SUMMARY

Results of the study revealed that money supply, exchange rate and index of industrial production have positive impact on Sensex, whereas inflation showed negative impact and 23.22% of variation in Sensex was explained by these variables. It was also concluded that stock prices respond significantly for equilibrium if deviation occurs and speed of adjustment for equilibrium was calculated approximately 21% per month. Therefore, it is quite obvious that macroeconomic variables have a clear relation with the fluctuation in Sensex. This chapter of the study also made an attempt to test the stock price behaviour in Indian stock market with special reference to Sensex daily return by applying GARCH class models. According to Box-Jenkins methodology, Sensex market identifes moving avearge structure with lag 1. The volatility in Sensex return exhibits, the presence of volatility clustering, mean reverting behaviour and persistence of conditional volatility. It is found that asymmetrical GARCH models performed better than symmetric GARCH models for Sensex volatility. Out of asymmetrical models, TGARCH model has performed best on the basis of AIC and SIC. Therefore, TGARCH model is found to be the best model to capture time varying volatility of Sensex return followed by EGARCH model.

It is appealing to note that Sensex returns are found to be more affected by persistence of volatility as the coefficient of conditional squared residuals is proved to be significant in all selected models. The study explores previous' days information about return volatility has significant effect on Sensex volatility. It is also observed that present day news has an impact on volatility of Sensex return which shows Sensex return volatility is influenced by its own internal shocks. Leverage effect is also observed in Sensex volatility which is one of the recommendations of this study. Therefore, it is obvious that conditional volatility depends on magnitude of error and its sign. It is also found that there is asymmetric news effect on volatility which means negative shocks create more volatility in daily Sensex return in comparison with positive shocks. However, there is no strong evidence that high volatility always caused high returns.