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Volatility Clustering of Select Sectoral Indices in the BSE Stock Market

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***Abstract**: Volatility is a standard measure of financial vulnerability and it plays a vital role in analyzing the risk of the securities market. It is traditionally measured using the standard deviation, which indicates how the price of a stock is clustered around the mean or moving average. The intent of the study is to analyse the volatility clustering of six select sectoral indices such as S&P BSE AUTO (Automobile), S&P BSE BANKEX (Bank) , S&P BSE FMCG (Fast Moving Consumer Goods), S&P BSE IT (Information Technology), S&P BSE METAL (Metals), and S&P BSE OIL & GAS (Oil & Gas Industries). A sample of 2726 days of observations for 11 years period from 03.01.2011 to 31.12.2021 has been taken for the study. The econometric model namely ARCH and GARCH have been applied to analyse the data. The result of the study reveals the presence of volatility clustering in the select six sectoral indices. Metal Sector has shown the higher phase of volatility.*

***Keywords:** Volatility Clustering, Sectoral Indices, ARCH Model, GARCH Model*

I. INTRODUCTION

The stock market is considered to be volatile when there is sharp rise and sharp decline in the markets within a short span of time. Volatility has been a cause of concern for policy makers as well as for investors not only in India, but also throughout the world. It is the rate at which the price of a stock increases or decreases over a particular period. It increases the uncertainty and risk of the stock market and is detrimental to the normal operation of the stock market. To reduce this uncertainty, it is particularly important to measure accurately the volatility of stock index returns. The stock exchange market has the stock price values and the index values. Indexes are classified into two types namely, key indices and sectoral indices. Sectoral index values provide the index values of each industry or sector with companies incorporated with them. Standard & Poor's (S&P) is a leading index provider and data source of independent credit ratings.

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The popular S&P 500 Index is perhaps Standard & Poor's best-known product. S&P is considered as a benchmark of the stock index. Volatility is the measurement of frequency change that occurs in the sectoral indices from time to time. The clustering of information for a specific period of time is known as volatility clustering. The high volatility in the sectoral indices would tend to have high changes and low volatility leads to small change in the value of sectoral indices. Such extreme variations in sectoral indices have significant effect on the stock market and it can be examined with the sectoral indices returns over a time period. In this background, the study aim to analyse the volatility clustering of select sectoral Indices namely, S&P BSE AUTO (Automobile), S&P BSE BANKEX (Bank), S&P BSE FMCG (Fast Moving Consumer Goods), S&P BSE IT (Information Technology), S&P BSE METAL (Metals), and S&P BSE OIL & GAS (Oil & Gas Industries). The simple standard deviations (SD) or variances of time series data over a period of time is considered as a measure of volatility. For the present study, 11 years daily sectoral indices were considered for the analysis of volatility movements. The period from 03.01.2011 to 31.12.2021 consists of 2726 days of observations (i.e., during this period the days when trades were conducted were alone taken for the study). The usual variance formula can be applied to compute the variance of the sectoral index returns using the days on which the trades take place. However, since the variance is calculated for the entire period of 11 years, it will not show at which point of time the volatility is clustered (i.e., periods of high volatility followed by periods of low volatility is called volatility clustered). So, the overall variance does not take into account the volatility present in the sectoral indices over various time points. Therefore, the econometric tools, such as, ARCH (Autoregressive Conditional Heteroskedasticity) and GARCH (Generalised Autoregressive Conditional Heteroskedasticity have been applied to analyse the volatility clustering of the select six sectoral indices.

II. REVIEW OF LITERATURE

Pushpalatha, Srinivasan and Shanmuga Priya (2019) [1] have conducted a research on "Volatility in the Indian Stock Market with special reference to Nifty and selected companies of financial services sector of NSE in India". The main objective of the study is to evaluate the return and volatility relationship in NSE Nifty and Nifty 50 selected companies of financial services sector and to identify whether NSE 50 and Nifty 50 selected companies of financial service sector companies are efficient or not.

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They have taken 10 companies of financial sector which are listed in Nifty 50 for the period from January 2009 to December 2018. They have used various tools like descriptive statistics, Kolmogorov-Smirnov test and Runs test. The result of the study shows that all the selected ten financial service companies are not homogeneous during the study period.
They have also examined that the run test in the Indian stock market is Weak form efficient and the non-random behavior of the market has only short-term implications. They suggested that the companies should take necessary step to maintain its financial health and to increase the market share in India.

Shashidhara and Shiva Shankar (2018) [2] have conducted a study on **"Stock Market Volatility -A study of Indian Stock Market"**. The main objective of the study is to analyse the causes of volatility in Indian Stock Market, various aspects of Indian Stock Market and the measures have been adopted to control volatility. They have taken the daily closing index value. The result of the study has shown that the Stock Market cycles have dampened in the recent past. Volatility has declined in the post liberalization phase in both the bull and bear phase of the stock market cycle.

Kavita (2017) [3] has conducted a study on **"Volatility of Indian Stock Market - A Study of BSE Sensex"**. The main objective of the study is to examine whether the past (previous day) Sensex returns has an explanatory power for today Sensex return. She has used daily closing prices of BSE Sensex from April 2000 to March 2015. She has used Descriptive Statistics, Unit root test, ARCH model and GARCH model to analyse the data. The results revealed that past Sensex returns have affected the today's Sensex returns.

Nisha (2014) [4] has conducted a study on **"Stock Returns and Volatility: A study of Indian Stock Market''**. The main objective of the study is to assess whether there is any rate of return and volatility relationship exist in Indian Stock Market. The purpose of the study is to examine the shifts in stock price volatility and nature of events that causes the shifts in volatility. She has used daily index closing values from January 2003 to December 2012. She has used statistical tools, such as, unit root test, GARCH, E-GARCH, T-GARCH, runs test, etc., for the analysis by using e-views software. The study evidences from all the indices of time varying which exhibit the sign of clustering, high persistent and predictability in Indian stock market. The result of the study reveals that returns responded differently to the arrival of the negative and positive stocks.

Belgaumi (1995) [5] has conducted a study on **"Efficiency of the stock market: An Empirical study".** The main objective of the study is to examine the share price in the Indian stock market and its movement over a short period. The study has analysed 70 companies listed in the 'A 'listed category on the BSE using Random walk model, serial correlation and run analysis. The results of the study have shown that the share price behavior in the Indian stock market follows random walk model and they are weakly efficient.

III. OBJECTIVES OF THE STUDY

The study focuses on the following objectives:

1. To study the Sensex returns of the select Sectoral Indices.
2. To analyse the volatility clustering of select Sectoral Indices.

IV. RESEARCH METHODOLOGY

A. Period of Study and Sample Design

The study covers a period of 11 years from 1st January 2011 to 31st December 2021. The data have been collected from the Bombay Stock Exchange website namely www.bseindia.com. The BSE has 19 sectoral indices, out of which, the select six sectoral indices namely S&P BSE AUTO, S&P BSE BANKEX, S&P BSE FMCG, S&P BSE IT, S&P BSE METAL, S&P BSE OIL & GAS have been taken for the study by adopting convenient sampling technique. The study has taken daily closing sectoral indices values of the select sectors.

B. Statistical Tools Used

The following statistical and econometric tools have been applied to analyse the data

- Descriptive Statistics
  - Mean
  - Median
  - Standard Deviation
  - Skewness
  - Kurtosis
  - Jarque-Bera test
- ARCH Model
- GARCH Model

C. Hypothesis

The following null hypothesis has been framed for the study:
H_0: There is an absence of volatility clustering in the select sector indices of BSE stock market.

V. ANALYSIS AND INTERPRETATION

Generally, for any time series, the returns are calculated as LOG (X_t) - LOG (X_{t-1}) i.e., X_t is the index value at current day and X_{t-1} is the index value at previous day. The descriptive statistics of select sectoral Indices for the period 2011 to 2021 are given below in Table 1.

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Table 1- Descriptive Statistics of Select Sectoral Indices

	S&P BSE AUTO	S&P BSE BANKEX	S &P BSE FMCG	S &P BSE IT	S &P BSE METAL	S &P BSE OIL & GAS
Mean	0.000326	0.000404	0.000483	0.000629	2.54E-05	0.000184
Median	0.000752	0.000541	0.000691	0.000632	0.000381	0.000463
Maximum	0.097632	0.101692	0.079156	0.089285	0.084232	0.086650
Minimum	-0.143339	-0.184006	-0.110071	-0.117586	-0.127129	-0.13561
Std. Dev.	0.013806	0.015730	0.010631	0.013449	0.017901	0.013947
Skewness	-0.363992	-0.564074	-0.354356	-0.603236	-0.266201	-0.826909
Kurtosis	11.48652	13.80958	12.50618	11.46797	5.957581	12.71145
Jarque-Bera	8237.553	13411.51	10317.50	8306.954	1025.365	11018.92
Probability	0	0.000000	0.000000	0.000000	0.000000	0.000000
Sum	0.887378	1.099743	1.317103	1.714069	0.069171	0.501917
Sum Sq. Dev.	0.519235	0.674037	0.307871	0.492691	0.872866	0.529863
Observations	2725	2725	2725	2725	2725	2725

There are totally 2725 observations of the data from 03/01/2011 to 31/12/2021. The average daily return is high in IT sector at the value of 0.000629 and low in Metal sector at the value of 0.0000254. The remaining sector values are close to the IT sector values. The standard deviation is high in Metal at the value of 0.017901 and low in FMCG sectors at the value of 0.010631.Metal sector has high volatility and high risk as it has high value of standard deviations and vice-versa for FMCG sector. The coefficients of the skewness are found to be significant and negative for all the returns. The negative Skewness implies many small wins and a few large losses on the investment. Similarly, the coefficients of the kurtosis are to be positive and are significantly higher than 0 which indicates the heavier tails for all the sectoral indices. The Jarque-Bera test is a goodness-of-fit to test the normality of the series indicating the p-values of Jarque-Bera test is between 0 and 1. It has shown normal distribution for all the sector indices.

A. Unit Root Test

The volatility of selected sectoral indices has been analyzed for the daily data. Further, Unit root test, ARCH LM and GARCH model have been done. Before estimating volatility of the series, it is necessary to prove that the time series is stationary. In the sense that the serious has constant mean and variance and auto-correlation structures are time invariant. The statistical test called unit root test to verify whether the series is stationary or not. Augmented Dickey-Fuller (ADF) and 't' statistic value produced by the test is compared with the appropriate critical value at certain probability levels.

To test the stationary of the time series data as well as return series, the following null hypothesis is framed.

H₀: "The returns series of S&P BSE Select Sectoral Indices (X1R) have unit root" (Non-stationary)

H1: "The returns series of S&P BSE Select Sectoral Indices (X1R) do not have unit root" (Stationary)

The results of unit root test (Augmented Dickey-Fuller test) of select sectoral Indices for the period 2011 to 2021 are given below in Table 2.

Table 2- Augmented Dickey-Fuller test for Select Sectoral Indices

Sectoral Indices	't' – statistic	Probability value
S&P BSE AUTO	-49.77461	0.0001
S&P BSE BANKEX	-48.84741	0.0001
S&P BSE FMCG	-51.85166	0.0001
S&P BSE IT	-52.23296	0.0001
S&P BSE METAL	-51.84425	0.0001
S&P BSE OIL & GAS	-51.67443	0.0001

Source: Computed using E views 10 - Significant at 1 per cent level

The table 2 depicts the t statistics of S&P BSE AUTO (-49.77461), S&P BSE BANKEX (-48.84741), S&P BSE FMCG (-51.85166), S&P BSE IT (-52.23296), S&P BSE METAL (-51.84425), S&P BSE OIL & GAS (-51.67443) and its corresponding P values (0.0001) are significant at 1 per cent level, which confirms the presence of stationarity of select sectoral Indices. Hence, the null hypothesis is rejected and accepts the alternative hypothesis.

However, the sector indices may exhibit volatility clustering and infer that it can be estimated by model specification. The ARCH Model is used to analyze volatility in time series in order to forecast future volatility. In the financial world, ARCH modeling is used to estimate risk by providing a model of volatility using the existing time series data. ARCH modeling shows that periods of high volatility are followed by more high volatility and periods of low volatility are followed by more low volatility.

The basic ARCH model can be specified as an auto regressive term of the form

$$X_t = \alpha + \beta X_{t-1} + \varepsilon_t \text{ --------------------- (1)}$$

Where X_t is the time series data

ε_t is the residual term

α and β are the coefficient terms to be estimated

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The volatility (σ^2) is estimated from the variance of the series and the residuals obtained from the regression equation given above which can be given as

$$\sigma^2_t = \omega + \alpha\varepsilon^2_{t-1} \text{ ------------------- } (2)$$

This is basic ARCH (1) process which is used to estimate the volatility.

B. ARCH LM Model

The model is used to test whether the past volatility of select sectoral indices returns can affect the present volatility of the same series. The null hypothesis for the returns series has been framed as:

H_0. There is no significant ARCH effect in the select sectoral indices returns.

The results of ARCH LM Model of select sectoral Indices for the period 2011 to 2021 are given below in Table 3.

Table 3- ARCH LM Model of Select Six Sectoral Indices

Dependent Variable: X1R - BSE AUTO INDEX RETURNS				
Method: ML ARCH – Normal distribution (BFGS / Marquardt steps)				
GARCH = C(3) + C(4)*RESID(-1)^2				
Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.000399	0.00023	1.735463	0.0827
X1R(-1)	0.083566	0.011078	7.54307	0
Variance Equation				
C	0.000139	3.22E-06	43.11671	0
RESID(-1)^2	0.287993	0.016891	17.04985	0
Dependent Variable: X2R – BSE BANK INDEX RETURNS				
Method: ML ARCH – Normal distribution (BFGS / Marquardt steps)				
GARCH = C(3) + C(4)*RESID(-1)^2				
Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.000113	0.000255	0.441256	0.659
X2R(-1)	0.153431	0.014224	10.78644	0
Variance Equation				
C	0.000186	4.40E-06	42.3475	0
RESID(-1)^2	0.273972	0.01832	14.95502	0
Dependent Variable: X3R - BSE FMCG INDEX RETURNS				
Method: ML ARCH – Normal distribution (BFGS / Marquardt steps)				
GARCH = C(3) + C(4)*RESID(-1)^2				
Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.00045	0.000194	2.313989	0.0207
X3R(-1)	0.060504	0.015707	3.85207	0.0001
Variance Equation				
C	9.44E-05	1.66E-06	56.8398	0
RESID(-1)^2	0.146738	0.014817	9.90365	0
Dependent Variable: X4R - BSE IT INDEX RETURNS				
Method: ML ARCH – Normal distribution (BFGS / Marquardt steps)				
GARCH = C(3) + C(4)*RESID(-1)^2				
Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.000825	0.000205	4.03261	0.0001
X4R(-1)	0.006295	0.010149	0.620237	0.5351
Variance Equation				
C	0.000129	2.78E-06	46.5494	0
RESID(-1)^2	0.341561	0.020264	16.85541	0
Dependent Variable: X5R - BSE METAL INDEX RETURNS				
Method: ML ARCH – Normal distribution (BFGS / Marquardt steps)				
GARCH = C(3) + C(4)*RESID(-1)^2				
Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.00014	0.000332	0.421316	0.6735
X5R(-1)	0.048278	0.021104	2.287615	0.0222
Variance Equation				
C	0.000272	6.76E-06	40.27032	0
RESID(-1)^2	0.140777	0.014994	9.389142	0
Dependent Variable: X6R - BSE OIL &GAS INDEX RETURNS				

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Method: ML ARCH – Normal distribution (BFGS / Marquardt steps)				
GARCH = C(3) + C(4)*RESID(-1)^2				
Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.000385	0.000246	1.56392	0.1178
X6R(-1)	0.043443	0.016516	2.630431	0.0085
Variance Equation				
C	0.000143	3.49E-06	41.0841	0
RESID(-1)^2	0.232432	0.0192	12.10581	0

Source: computed – significant at 1 percent level.

The first part of the table explains the regression term and the second part of the table explains the ARCH term (variance equation). The corresponding regression and ARCH terms for the select six sectoral indices are as follows:

A. S&P BSE Auto Indices

Regression equation: X1R = C(1) + C(2)*X1R(-1)
Variance equation: GARCH = C(3) + C(4)*RESID(-1)^2

The equations with the substituted coefficients can be written as

X1R = 0.000399 + 0.083566*X1R (-1)

$\sigma^2{}_t = 0.000139 + 0.28799 * \varepsilon^2{}_{t\text{-}1}$

In ARCH term, the coefficient of the squared residuals (0.28799) shows the presence of ARCH effect in the variance series.

B. S&P BSE Bankex Indices

Regression equation: X2R = C(1) + C(2)*X2R(-1)
Variance equation: GARCH = C(3) + C(4)*RESID(-1)^2

The equations with the substituted coefficients can be written as

X2R = 0.000113 + 0.153431*X2 R (-1)

$\sigma^2{}_t = 0.000186 + 0.273972 * \varepsilon^2{}_{t\text{-}1}$

In ARCH term, the coefficient of the squared residuals (0.273972) shows presence of the ARCH effect in the variance series.

C. S&P BSE FMCG Indices

From the above table the estimated regression and variation equation can be expressed as:

Regression equation: X3R = C(1) + C(2)*X3R(-1)
Variance equation: GARCH = C(3) + C(4)*RESID(-1)^2

The equation with the substituted coefficients can be written as

X3R = 0.000450 + 0.060504 * X3R (-1)

$\sigma^2{}_t = 9.44\text{e-}05 + 0.146738 * \varepsilon^2{}_{t\text{-}1}$ (-1)^2

In the second equation (ARCH term) the coefficient of the squared residuals (0.146738) shows the presence of ARCH effect in the variance series.

D. S&P BSE IT Indices

From the above table the estimated regression and variation equation can be expressed as:

Regression equation: X4R = C(1) + C(2)*X4R(-1)
Variance equation: GARCH = C(3) + C(4)*RESID(-1)^2

From the values shown in the table given above, the equation with the substituted coefficients can be written as:

X4R = 0.000825 + 0.006295 * X4R(-1)

$\sigma^2{}_t = 0.000129 + 0.341561 * \varepsilon^2{}_{t\text{-}1}$

In the second equation (ARCH term) the coefficient of the squared residuals (0.341561) shows the presence of ARCH effect in the variance series.

E. S&P BSE Metal Indices

From the above table the estimated regression and variation equation can be expressed as:

X5R = C(1) + C(2) * X5R (-1)
GARCH = C(3) + C(4)*RESID(-1)^2

From the values shown in the table given above, the equation with the substituted coefficients can be written as:

X5R = 0.000140 + 0.048278 * X5R (-1)

$\sigma^2{}_t = 0.000272 + 0.140777 * \varepsilon^2{}_{t\text{-}1}$

In the second equation (ARCH term) the coefficient of the squared residuals (0.140777) shows the presence of ARCH effect in the variance series.

F. S&P BSE Oil & Gas Indices

From the above table the estimated regression and variation equation can be expressed as:

X6R = C(1) + C(2) * X6R (-1)

GARCH = C(3) + C(4)*RESID(-1)^2

From the values shown in the table given above, the equation with the substituted coefficients can be written as:

X6R = 0.000385 + 0.043443 * X6R (-1)

$\sigma^2{}_t = 0.0001434 + 0.232432 * \varepsilon^2{}_{t\text{-}1}$

In the second equation (ARCH term) the coefficient of the squared residuals (0.232432) shows the presence of ARCH effect in the variance series. The z-statistic computed for the ARCH coefficient of $\varepsilon^2{}_{t\text{-}1}$ for S&P BSE AUTO (17.04985), S&P BSE BANKEX (14.95502), S&P BSE FMCG (9.903650), S&P BSE IT (16.85541), S&P BSE METAL (9.389142), S&P BSE OIL & GAS (12.10581) and their corresponding probability value (Prob.=0.0000) shows that the ARCH effect is significant at 1 percent level (P<0.01). Hence, the null hypothesis is rejected, which shows the presence of ARCH effect in the select sectoral Indices returns.

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G. Residual Diagnostic test for ARCH effect

The ARCH LM test has been applied to test the heteroskedasticity effect in the residual series of the ARCH term. The null hypothesis is as follows:

H_0: There is no heteroskedasticity in the residual series

The results of Diagnostic test of ARCH LM Model of select sectoral Indices for the period 2011 to 2021 are given below in Table 4

Table 4 – Residual Diagnostic test for ARCH Effect

Sectoral Indices	F – statistic	Probability value
S&P BSE AUTO	1.881792	0.170244
S&P BSE BANKEX	1.400973	0.236664
S&P BSE FMCG	0.645752	0.421706
S&P BSE IT	2.266533	0.132311
S&P BSE METAL	0.391142	0.531752
S&P BSE OIL & GAS	0.219470	0.639482

Sources: computed using E-views 10 - significant at 5 percent level

The F-statistic of S&P BSE AUTO (1.881792), S&P BSE BANKEX (1.400973), S&P BSE FMCG (0.645752), S&P BSE IT (2.266533), S&P BSE METAL (0.391142), S&P BSE OIL & GAS (0.219470) and their corresponding p-values for S&P BSE AUTO (0.170244), S&P BSE BANKEX (0.236664), S&P BSE FMCG (0.421706), S&P BSE IT (0.132311), S&P BSE METAL (0.531752), S&P BSE OIL & GAS (0.639482) are found to be not significant. Hence, the null hypothesis is accepted. The result shows the absence of heteroskedasticity in the residual series. Thus, the S&P BSE select sector indices have the presence of ARCH effect in the return series and the absence of heteroskedasticity in the residual terms.

H. Estimation of GARCH model

One form of ARCH model is Generalised ARCH, GARCH in short. The GARCH model is an extension of ARCH model where the lagged dependent variable is added is an additional GARCH term. The GARCH model at lag 1 can be written as

$$\sigma^2_t = \alpha_2 + \alpha_3 \varepsilon^2_{t-1} + \alpha_4 \sigma^2_{t-1} \ldots\ldots\ldots\ldots (2.2)$$

That is the error variance, σ^2_t at time t, estimated from the regression equation (equation 1) is dependent on the residual term at time t-1 as well as error variance at time t-1.

This is GARCH (1,1) model where (1,1) refers to the Autoregressive order 1 and Moving Average order 1.

The general hypothesis for the returns series has been framed as:

H_0: There is no significant GARCH effect in the BSE auto indices returns.

The GARCH (1 1) model estimation results for the returns series are given below in the table 5

Table 5 - GARCH Model of Select Six Sectoral indices

Dependent Variable: X1R - BSE AUTO INDEX RETURNS				
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)				
GARCH = C(3) + C(4)*RESID(-1)^2 + C(5)*GARCH(-1)				
Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.000548	0.000227	2.41345	0.0158
X1R(-1)	0.092923	0.02042	4.550617	0
	Variance Equation			
C	5.23E-06	9.81E-07	5.329211	0
RESID(-1)^2	0.085521	0.007594	11.26239	0
GARCH(-1)	0.886258	0.010948	80.9541	0
Dependent Variable: X2R - BSE BANK INDEX RETURNS				
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)				
GARCH = C(3) + C(4)*RESID(-1)^2 + C(5)*GARCH(-1)				
Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.000734	0.00024	3.054478	0.0023
X2R(-1)	0.075626	0.021732	3.47998	0.0005
Variance Equation				
C	3.73E-06	7.30E-07	5.117508	0
RESID(-1)^2	0.07822	0.005855	13.35895	0
GARCH(-1)	0.906471	0.007663	118.2961	0
Dependent Variable: X3R - BSE FMCG INDEX RETURNS				
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)				
GARCH = C(3) + C(4)*RESID(-1)^2 + C(5)*GARCH(-1)				
Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.000529	0.000178	2.971086	0.003
X3R(-1)	0.04073	0.020247	2.011707	0.0443
Variance Equation				

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C	5.36E-06	9.76E-07	5.495677	0
RESID(-1)^2	0.073733	0.006599	11.17252	0
GARCH(-1)	0.874604	0.013935	62.76495	0
Dependent Variable: X4R - BSE IT INDEX RETURNS				
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)				
GARCH = C(3) + C(4)*RESID(-1)^2 + C(5)*GARCH(-1)				
Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.000781	0.000236	3.308315	0.0009
X4R(-1)	0.017609	0.020798	0.846653	0.3972
Variance Equation				
C	1.98E-05	2.43E-06	8.154786	0
RESID(-1)^2	0.098808	0.00844	11.70755	0
GARCH(-1)	0.788524	0.021139	37.3018	0
Dependent Variable: X5R - S&P BSE METAL INDEX RETURNS				
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)				
GARCH = C(3) + C(4)*RESID(-1)^2 + C(5)*GARCH(-1)				
Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	9.17E-06	0.000316	0.029041	0.9768
X5R(-1)	0.043733	0.021119	2.070808	0.0384
Variance Equation				
C	8.02E-06	1.97E-06	4.066105	0
RESID(-1)^2	0.058279	0.007282	8.003457	0
GARCH(-1)	0.915575	0.011431	80.09718	0
Dependent Variable: X6R - S&P BSE OIL &GAS INDEX RETURNS				
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)				
GARCH = C(3) + C(4)*RESID(-1)^2 + C(5)*GARCH(-1)				
Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.000282	0.000239	1.179628	0.2381
X6R(-1)	0.077688	0.020654	3.761457	0.0002
Variance Equation				
C	1.16E-05	1.92E-06	6.066869	0
RESID(-1)^2	0.097805	0.006949	14.07526	0
GARCH(-1)	0.838736	0.015453	54.27513	0

Sources: computed - significant at 1 per cent for ARCH Model

The first part of the table explains the regression term and the second part of the table explains the ARCH term (variance equation). The corresponding regression and ARCH terms for the select six sectoral indices are as follows:

A.S&P BSE Auto Indices

Regression equation: X1R = C(1) + C(2)*X1R(-1)
Variance equation: GARCH = C(3) + C(4)*RESID(-1)^2 + C(5)*GARCH(-1)

The equations with the substituted coefficients can be written as

X1R = 0.000548 + 0.092923*X1R (-1)

$\sigma^2_t = 5.2276e\text{-}06 + 0.085521*\varepsilon^2_{t-1} + 0.886258*\sigma^2_{t-1}$

B. S&P BSE BANKEX Indices

The estimated regression and variance equations are given below

Regression equation: X2R = C(1) + C(2)*X2R(-1)
Variance equation: GARCH = C(3) + C(4)*RESID(-1)^2 + C(5)*GARCH(-1)

From the values shown in the table given above, the equations with the substituted coefficients can be written as

X2R = 0.000734 + 0.075626*X2R (-1)

$\sigma^2_t = 3.7348e\text{-}06 + 0.078220*\varepsilon^2_{t-1} + 0.906471*\sigma^2_{t-1}$

C. S&P BSE FMCG Indices

The estimated regression and variance equations are given below

Regression equation: X3R = C(1) + C(2)*X3R(-1)
Variance equation: GARCH = C(3) + C(4)*RESID(-1)^2 + C(5)*GARCH(-1)

From the values shown in the table given above, the equations with the substituted coefficients can be written as

X3R = 0.000529 + 0.040730 * X3R (-1)

$\sigma^2_t = 5.36433e\text{-}06 + 0.073733 * \varepsilon^2_{t-1} + 0.874604*\sigma^2_{t-1}$

D. S&P BSE IT Indices

The estimated regression and variance equations are given below

Regression equation: X4R = C(1) + C(2)*X4R(-1)
Variance equation: GARCH = C(3) + C(4)*RESID(-1)^2 + C(5)*GARCH(-1)

From the values shown in the table given above, the equations with the substituted coefficients can be written as

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X4R = 0.000780782674504 + 0.0176085899734 * X4R(-1)
σ^2_t = 1.98437e-05 + 0.098808 * ε^2_{t-1} + 0.788524 * σ^2_{t-1}

E. S&P BSE Metal Indices

The estimated regression and variance equations are given below:
Regression equation: X5R = C(1) + C(2)*X5R(-1)
Variance equation: GARCH = C(3) + C(4)*RESID(-1)^2 + C(5)*GARCH(-1)
From the values shown in the table given above, the equations with the substituted coefficients can be written as
X5R = 9.175894e-06 + 0.043733 * X5R (-1)
σ^2_t = 8.0156e-06 + 0.058279 * ε^2_{t-1} + 0.915575 * σ^2_{t-1}

F. S&P BSE Oil &Gas Indices

The estimated regression and variance equations are given below
Regression equation: X6R = C(1) + C(2) * X6R (-1)
Variance equation: GARCH = C(3) + C(4)*RESID(-1)^2 + C(5)*GARCH(-1)
From the values shown in the table given above, the equations with the substituted coefficients can be written as
X6R = 0.000281759838176 + 0.0776879616023*X6R(-1)
σ^2_t = 1.164457e-05 + 0.097805 * ε^2_{t-1} + 0.838736 * σ^2_{t-1}

The z-statistic computed for GARCH Term for S&P BSE AUTO (80.95410), S&P BSE BANKEX (118.2961), S&P BSE FMCG (62.76495), S&P BSE IT (37.30180), S&P BSE METAL (80.09718), S&P BSE OIL & GAS (54.27513) and their corresponding probability value (Prob.=0.0000) shows that the GARCH effect is significant at 1 percent level ($P<0.01$). Hence, the null hypothesis is rejected, which shows the presence of GARCH effect in the select sectoral Indices returns.

E. Residual Diagnostic test for GARCH effect

The ARCH LM test provides a means of testing for serial dependence (auto-correlation) due to a conditional variance process by testing for auto-correlation within the squared residuals. The null hypothesis is that the auto-correlation between the residuals for a set of lags. (lags = 1)

H_0: There is no heteroskedasticity in the residual series

Table 6 – Residual Diagnostic test for GARCH Effect

Sectoral Indices	F – statistic	Probability value
S&P BSE AUTO	0.281730	0.595613
S&P BSE BANKEX	1.305964	0.253227
S&P BSE FMCG	1.219765	0.269505
S&P BSE IT	0.031726	0.858643
S&P BSE METAL	2.698877	0.100535
S&P BSE OIL & GAS	23.40643	0.000001

Sources: computed using E-views 10 - significant at 5 percent level

The F-statistic of S&P BSE AUTO (0.281730), S&P BSE BANKEX (1.305964), S&P BSE FMCG (1.219765), S&P BSE IT (0.031726), S&P BSE METAL (2.698877), S&P BSE OIL & GAS (23.40643) and their corresponding p-values of S&P BSE AUTO (0.595613), S&P BSE BANKEX (0.253227), S&P BSE FMCG (0.269505), S&P BSE IT (0.858643), S&P BSE METAL (0.100535), and S&P BSE OIL & GAS (0.000001) are found to be not significant. Hence, the null hypothesis is accepted. The result shows the absence of heteroskedasticity in the residual series. Thus, the S&P BSE select sector indices have the presence of GARCH effect in the return series and the absence of heteroskedasticity in the residual terms.

VI. CONCLUSION

The presence of ARCH effect and GARCH effect shows the existence of volatility clustering in the select six sectoral indices. The sectoral indices have shown higher phase of volatility in Metal sector. It is followed by Bankex, Oil & Gas, Auto and IT sectors. The low phase of volatility is in FMCG sector. Therefore, the general hypothesis namely there is an absence of volatility clustering in the select sector indices of BSE stock market has been disproved. Thus, the study would helpful to the individual and the institutional investors, financial consultants and portfolio managers to avoid the high volatility in future to take investment decisions and to balance the risk and return of the investments.

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