Modeling and Exploring Stock Market Volatility Using GARCH Models

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Abstract: The present study is being contemplated with the objective of modeling and exploring volatility in stock markets. This paper examines the relationships between Bovespa and Sensex. This study is aimed to understand the nature and different patterns of volatility in Brazilian and Indian stock markets. The daily observations comprising of closing data of Bovespa of Brazil stock market and Sensex of Bombay Stock Exchange for the period of 10 years i.e. from April 2007 to March 2017 is used for analysis. The data was collected from the websites www.bseindia.com and www.nseindia.com. The present study is attempted to examine the volatility of returns in Brazilian stock market and Indian stock market. GARCH (1, 1) models were used to see the volatility of selected stock markets. It was found that the highest volatility clustering is in case of Bovespa as compared by Sensex. It was concluded that negative shocks do have greater impact in Brazilian stock market as compared to positive shocks of the same magnitude in the Indian stock market.

Keywords: Asymmetric Volatility, Bovespa, Sensex, ARCH LM, GARCH (1, 1), TARCH (1, 1), EGARCH (1, 1) and MGARCH.

I. INTRODUCTION

Volatility measures the risk of a security. It is used in alternative pricing method to measure the fluctuations in the returns of the fundamental assets. Volatility indicates the pricing behavior of the security and helps estimation of the fluctuations that may occur in a short period of time. It is a rate at which the price of a security increases or decreases for a given set of returns. Volatility is measured by calculating the standard deviation of the annualized returns over a given period of time. It shows the range to which the price of a security may increase or decrease. If the prices of a security fluctuate rapidly in a short time span, it is termed to have high volatility. If the prices of a security fluctuate slowly in a longer time span, it is termed to have low volatility.

The high volatility is due to much foreign equity inflows. This results into dependence of Indian equity market on global capital market variations. It means any happening outside India will have its impact here as well. As when US economy was improving, resulted into falling rupee led negative sentiments to stock market crash. Domestic savings are lower which is increasing more foreign investments. In recent years, the interest in country fund especially in emerging economies has increased. Emerging markets are an attractive position for investment because of various reasons like open market system, moderate guidelines towards Foreign Direct Investment and Foreign Institutional Investment. Further, whereas constructing internationally diversified range of securities, the correlation in the returns of stocks from two different countries required to be calculated. Bovespa and Sensex indices are the oldest stock index of Brazil stock market and Indian stock market. The Bovespa Index is the main indicator of the Brazilian stock market’s average performance and Sensex Index represents the thirty stocks with largest free float market capitalization listed in Bombay stock exchange. This study analyzes the volatility of Brazil and India stock markets.

II. REVIEW OF LITERATURE

Karmakar (2005) conditional volatility models in an effort to capture the salient features of stock market volatility in India and evaluate the models in terms of out-of-sample forecast accuracy. The various GARCH models provided good forecasts of volatility and were useful for portfolio allocation, performance measurement, option valuation etc. This study will help diversify international portfolios and formulate hedging strategies.

Kumar (2006) evaluated the ability of ten different statistical and econometric volatility forecasting models to the context of Indian stock and forex markets. Based on the sample forecasts and measurements, the researcher used EWMA that will lead to improvements in volatility forecasts and GARCH (5,1) for forex market.

Dhankar & Chakraborty (2007) investigated the presence of non-linear dependence and GARCH effects in three major emerging markets of South Asia, India, Sri Lanka and Pakistan. The results were not necessarily inconsistent with efficient market hypothesis, simply because non-linearity did not essentially mean predictability.

Mishra et al. (2007) attempted useful insights into how information is transmitted from stock market to foreign exchange market and vice-versa. GARCH and EGARCH for modeling of spillover between stock returns and exchange rate returns have been applied in this paper.

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Alberg et al. (2008) analyzed the mean return and conditional variance of Tel Aviv Stock Exchange indices using different GARCH models. The researchers explained that the EGARCH model is the most successful for forecasting Tel Aviv Stock Exchange indices.

Joshi & Pandya (2008) examined the nature of the volatility of the Indian stock markets. The data set analyzed of two market indices (BSE and NSE). In order to study pattern of time varying volatility of daily returns, the researchers employed ARCH and GARCH models. The result found that analysis of stock market for the evaluation of risk has received lot of attention both from policy makers and researchers to study the behavior of volatility.

Leon (2008) studied the relationship between expected stock market returns and volatility in the regional stock market of the West African Economic and Monetary Union called the BRVM. The result also showed that volatility is persistent but contrary to the EGARCH model, there was no leverage effect.

Zhou & He (2009) studied the S&P 500 stock index for its time varying volatility and stylized facts. The ARMA mean equation with asymmetric power ARCH errors is used to model the series correlations and the conditional heteroscedasticity in the asset returns.

Goudarzi & Ramanarayanan (2010) examined the volatility of the Indian stock markets and examine the international financial markets turmoil. The study concluded that GARCH (1, 1) model explained volatility of the Indian stock markets. The results of this study was useful for implications for regulatory and policy markets in the Indian stock market.

Srinivasan & Ibrahim (2010) attempted to modeling and forecasting the volatility of the SENSEX Index returns of Indian stock market. The findings of this study were consistent that revealed parsimonious symmetric GARCH model was found superior in forecasting the conditional variance of SENSEX Index market returns rather than the asymmetric GARCH models.

Mehta & Sharma (2011) focused to examine the time varying volatility of Indian stock market specifically in equity market. The GARCH (1,1) model indicated the determination of time varying volatility during various time segments.

Ali & Afzal (2012) emphasised the impact of recent global financial crisis on stock markets of Pakistan and India. In this paper, the researchers applied EGARCH model to find volatility. This study shows that global financial crisis made mild negative impact on stock returns and enhanced volatility in Pakistan and Indian stock exchanges.

Gupta et al. (2013) aimed to understand the nature and different patterns of volatility in Indian equity market. This study examined the volatility of returns in Indian stock market. GARCH models were used to see the volatility of Indian equity market the results of this study found that there was spillover of information in the Indian stock market and with the significant coefficient of dummy in improved model.

Uyaebo et al. (2015) examined the daily all share index (ASI) of Nigeria, Kenya, South Africa, China, United State of America and Germany obtained from www.reuters.com. This study used daily data from February 14, 2000 to February 14, 2013. This study estimated TGARCH and EGARCH models assumptions with the view to obtaining the best fit volatility models (one for each market) for comparing volatilities in their stock returns. The best fitted models were compared in terms of conditional volatility reaction to market shocks. The results also suggested the absence of leverage effect in Nigeria and Kenya stock returns.

**Objectives of the Study**

- The present study is designed to explore the volatility of Brazil and India Stock Markets.

### III. RESEARCH METHODOLOGY

**Sample**

This study identifies to explore the volatility of Brazil and India Stock Markets. The daily closing prices of the eleven indices is taken from these stock markets from April 2007 to March 2017. The data is collected from the reliable sources such as Bloomberg, www.yahoo.finance.com and the websites of respective stock indices such as bseindia.com. The daily closing value is used for the analysis. Engle and Mezrich (1995) suggested that at least eight years of data should be used for correct GARCH estimation.

**Statistical Tools**

Statistical tools used to see the trends in stock market returns and volatility patterns in post liberalization period.

**Heteroscedasticity**

One of the most important issues before applying the Generalized Autoregressive Conditional Heteroscedasticity (GARCH) methodology is to first examine the residuals for evidence of heteroscedasticity. To test for the presence of heteroscedasticity in residuals, the Lagrange Multiplier (LM) test for ARCH effects proposed by Engle (1982) is applied.
ARCH LM Test

The study aims to study the volatility of the selected stock indices. For the purpose the residuals of the ARMA (1, 1) forecasting model on the different stock indices returns are examined. The ARCH LM test regresses the lagged residual terms with the residual term of the selected sample.

GARCH (1, 1) Model

GARCH (1, 1) model is also applied in the study on the selected index returns. In GARCH (1, 1) model, the dependent variable $\sigma_I^2$ represents the conditional volatility in the Index returns, the intercept ($\alpha_0$) represents the hypothetical long term average conditional volatility in index returns, and the first independent variable is ARCH term followed by second independent variable known as GARCH term.

GARCH (1, 1) model as proposed by Bollerslev in 1986 is the most popular model for analyzing the conditional volatility of a financial time series. GARCH (1, 1) model is represented as

$$\sigma_I^2 = \alpha_0 + \alpha_1 \mu_{t-1}^2 + \beta_1 \sigma_{I,t-1}^2$$

Where, the dependent variable $\sigma_I^2$ represents the conditional volatility, $\alpha_0$ represents the intercept coefficient

and represents the hypothetical long term average conditional volatility, the first independent variable $\mu_{t-1}^2$ is known as ARCH term and second independent variable $\sigma_{I,t-1}^2$ is known as GARCH term.

The Threshold GARCH (T-GARCH) Model

In the study TGARCH model is applied on the selected index returns in order to study the asymmetric effect of positive and negative shocks is that they impose response of volatility similar or symmetric to positive as well as negative shocks in the system. The conditional variance in TARCH model is given by

$$\sigma_I^2 = \alpha_o + \alpha_1 \mu_{t-1}^2 + \beta_1 \sigma_{I,t-1}^2 + \gamma \mu_{t-1}^2 I_{t-1}$$

Where, $I_{t-1} = 1$ if $\mu_{t-1} < 0$

$= 0$ otherwise

The results of TARCH model applied on the Index returns indicates that probability value of the dummy coefficient as represented by $RESID (-1) \cdot \mu_{t-1}^2(RESID (-1) < 0)$ is found to be less than five percent level of significance. This indicates the presence of significant asymmetric effect in the conditional volatility of selected Index returns.

The Exponential GARCH (E-GARCH) Model

Another modified model in GARCH family is exponential GARCH model. The EGARCH (exponential GARCH) model is a popular model among the different available asymmetric GARCH models. E-GARCH model was originally proposed by Nelson (1991) and it is based on log-transformation of conditional variance. In EGARCH model the conditional variance is always remains positive. In EGARCH model the ARCH term is divided into two different independent variables indicating the sign effect of shocks on Index volatility and the size (magnitude) effect of shocks on the volatility in the financial time series. In this study the following specification of the EGARCH model is used in order to study the conditional volatility in the selected Index returns

$$\ln(\sigma_I^2) = \omega + \beta \ln(\sigma_{I,t-1}^2) + \gamma \frac{\mu_{t-1}}{\sigma_{I,t-1}^2} + \alpha \left[ \frac{\mu_{t-1}}{\sigma_{I,t-1}^2} - \frac{2}{\pi} \right]$$

The EGARCH (exponential GARCH) model is a popular model among the different available asymmetric GARCH models. In EGARCH model the conditional variance is always remains positive. The EGARCH model is used to study the sign and size effects of the unexpected shocks which come in the system.

GARCH in Mean

GARCH-in-Mean or GARCH-M model which was originally proposed by Engle, Lilien and Robins (1987), assumes that the conditional mean is a linear function of conditional variance. Here the conditional variance may follow any of the GARCH specification. The GARCH M model can also be written as

$$Index\ return_{t} = \alpha + \beta_1 y_{t-1} + \beta_2 \sigma_{I,t-1} + \beta_3 \sigma_{t}^2$$

This GARCH in mean model assumes the assumption of non-negativity and stationary conditions as in case of GRACH (1, 1) model. The GARCH in mean model is applied in the study in order to examine that how the price discovery process in the selected index response to any change in conditional volatility.

IV. DATA ANALYSIS & INTERPRETATION

ARCH LM Results on Bovespa and Sensex Stock Indices Returns

Volatility clustering is well known phenomenon in the behaviour of financial time series returns. In the study the stock indices of the selected countries are analyzed with respect to the presence of volatility clustering.

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in the behavior of the series. The presence of volatility clustering is studied with the help of ARCH LM model where the conditional variance is regresses with its own previous lag squared residuals. The results of the ARCH LM test are shown below in Table 1.

### Table 1: ARCH LM Results on Different Stock Indices Returns

<table>
<thead>
<tr>
<th>Country</th>
<th>F Statistics</th>
<th>Obs*R-Squared</th>
<th>R Square</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bovespa</td>
<td>85.635</td>
<td>82.974</td>
<td>3.18%</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.000)</td>
<td></td>
</tr>
<tr>
<td>Sensex</td>
<td>69.958</td>
<td>68.182</td>
<td>2.6%</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.000)</td>
<td></td>
</tr>
</tbody>
</table>

The results indicate that the level of volatility clustering is different in different stock indices. Although the probability value if the F Statistics as well as Obs*R-Squared statistics is found to be less than five percent level of significance indicating the presence of significant volatility clustering in each stock indices selected in the study. The results indicate that the highest volatility clustering is found in case of Bovespa as represented by highest R square of 3.18 percent, followed by Sensex 2.6 percent.

### GARCH (1,1) Model Applied on Selected Indices

GARCH (1,1) model is also applied in the study on the selected index returns. The results of the GARCH (1,1) model indicates that the probability value of the slope coefficient of ARCH as well as GARCH term is found to be less than five percent level of significance indicating the significant impact of residuals at lag one and the GARCH term at lag one.

### Table 2: Results of GARCH (1,1) Model Applied on the Stock Indices

<table>
<thead>
<tr>
<th>Country</th>
<th>Intercept</th>
<th>GARCH(-1)</th>
<th>RESID(-1)^2</th>
<th>Decaying Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bovespa</td>
<td>7.58E-06</td>
<td>0.874</td>
<td>0.099</td>
<td>2.7%</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td></td>
</tr>
<tr>
<td>Sensex</td>
<td>1.84E-06</td>
<td>0.903</td>
<td>0.089</td>
<td>1.8%</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td></td>
</tr>
</tbody>
</table>

The higher decaying rate of volatility is found in case of Bovespa of 2.7 percent as compared to Sensex i.e. 1.8 percent. The GARCH model indicates the persistence in the volatility in the stock indices. This means once the market becomes volatile it remains volatile for many days.

### TGARCH (1,1) Model on Indian & Brazilian Stock Market Indices Returns

TGARCH model is modified version of GARCH model as it imposes symmetric response to positive as well as negative shocks in the system.

### Table 3: Analysis of Asymmetric Volatility using TGARCH (1,1) Model on Indian & Brazilian Stock Market Indices Returns

<table>
<thead>
<tr>
<th>Country</th>
<th>Intercept</th>
<th>RESID(-1)^2</th>
<th>GARCH(-1)</th>
<th>RESID(-1)^2*(RESID(-1)&lt;0)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bovespa</td>
<td>6.96E-06</td>
<td>0.029</td>
<td>0.888</td>
<td>0.115</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
</tr>
<tr>
<td>Sensex</td>
<td>2.03E-06</td>
<td>0.044</td>
<td>0.897</td>
<td>0.102</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
</tr>
</tbody>
</table>

In case of stock returns, such asymmetries occur due to the overreaction and under reaction of the investors to the negative and positive information’s. Also the TARCH model has one additional dummy variable added in the model which examines the presence of possible asymmetries in the conditional volatility.

### E-GARCH Model on Indian & Brazilian Stock Market Indices Returns

E-GARCH model is used to study the sign and size effects of the unexpected shocks which come in the system on the selected International indices. The second term in the EGARCH model indicates the impact of GARCH term (volatility persistence) on the future conditional volatility in stock indices returns.

### Table 4: Analysis of E-GARCH Model on Indian & Brazilian Stock Market Indices Returns

<table>
<thead>
<tr>
<th>Country</th>
<th>Intercept</th>
<th>GARCH term</th>
<th>Sign effect of lagged ARCH term</th>
<th>Size effect of ARCH term</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bovespa</td>
<td>-0.334</td>
<td>0.164</td>
<td>-0.082</td>
<td>0.975</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
</tr>
<tr>
<td>Sensex</td>
<td>-0.282</td>
<td>0.188</td>
<td>-0.080</td>
<td>0.984</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
</tr>
</tbody>
</table>

The results indicate that the conditional volatility in selected returns have inverse relationship with the sign of the shock. Also the slope coefficient of the sign effect indicates that conditional volatility is having the inverse relationship with the nature of the sign of the shock. The positive news decreases the volatility and the negative news increases the volatility in the stock indices.
M-GARCH Model on Indian & Brazilian Stock Market Indices Returns

GARCH-in-mean model assumes the assumption of non-negativity and stationary conditions as in case of GRACH (1, 1) model. If conditional volatility is related to the returns in the index then in such case the impact of the conditional volatility on the conditional return must be positive and significant.

Table 5: Analysis of M-GARCH Model on Indian & Brazilian Stock Market Indices Returns

<table>
<thead>
<tr>
<th>Country</th>
<th>Intercept</th>
<th>GARCH term</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bovespa</td>
<td>-0.001(0.8142)</td>
<td>3.421(0.0373)</td>
</tr>
<tr>
<td>Sensex</td>
<td>0.001(0.019)</td>
<td>0.872(0.660)</td>
</tr>
</tbody>
</table>

In the study the GARCH in mean model is applied on the selected stock indices. The aim of applying the M GARCH model is to examine the impact of conditional volatility on the index return. If conditional volatility is related to the returns in the index then in such case the impact of the conditional volatility on the conditional return must be positive and significant.

The results of the GARCH in mean model applied on the Bovespa returns indicates that the slope coefficient of the GARCH model in the mean equation is found to be 3.421 with the probability value of 0.0373. The results of the GARCH in mean model applied on the Sensex returns indicates that the slope coefficient of the GARCH model in the mean equation is found to be 0.872 with the probability value of 0.660. Since the probability value of the slope coefficient of the GARCH model is found to be more than five percent level of significance.

V. CONCLUSION

The present study is attempted with the objective of studying volatility of Brazilian and Indian stock markets. The study is aimed to understand the nature and different patterns of volatility in Brazilian and Indian stock markets. The four volatility models GARCH (1, 1), TARCH (1, 1), EGARCH (1, 1) and M-GARCH have been used. In the present study, ARCH models were used to detect the volatility in the returns of Brazilian and Indian stock markets. It was found that the highest volatility clustering is in case of Bovespa as compared by Sensex. It was concluded that negative shocks do have greater impact in Brazilian stock market as compared to positive shocks of the same magnitude in the Indian stock market.

VI. REFERENCES