Pacific Business Review International
Volume 6, Issue 9, March 2014

Modeling Asymmetric Volatility in Indian Stock Market

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Abstract

The main feature of any financial instruments is stochastic nature of its returns. The spread of outcome of return from the asset is called volatility which influences numerous financial decisions. The main goal of estimating the volatility is to assess the market risk. Volatility is one of the key parameters for pricing financial derivatives. Estimation of volatility helps in risk management and it also helps in efficient management of portfolios. In the present study, asymmetric nature of volatility is modeled by applying two popularly used asymmetric GARCH models i.e., GJR-GARH model and PGARCH model. BSE-Sensex is used as a proxy for Indian stock market and period of study is from 1st july, 1997 to 30th march,2013. Results of Augmented Dickey Fuller test reveals that the natural logarithmic values of Sensex returns and S&P 500 returns are stationary at their level form. Results of analysis with selected asymmetric GARCH models reveals the presence of leverage effect in Indian stock market and it also confirms the effect of periodic cycles on the conditional volatility in the market. In order to test whether the selected asymmetric GARCH models adequately captured the persistence in volatility and to test whether residuals from the selected models are free from ARCH effect, ARCH LM test is conducted. Results of ARCH-LM test concludes that there is no ARCH effect left in residuals obtained from both GJR-GARCH Model and PGARCH Model estimations.

Keywords:

Asymmetric volatility, Leverage effect, Indian stock market, GJR-GARCH Model , PGARCH Model, Conditional volatility.

JEL Classification: C13, C52, C53, C58, G10, G17

Introduction

In the recent past, there is a growing importance for estimating and analyzing volatility. Volatility has its impact on many issues in economics and finance. Volatility indicates the fluctuations detected in some phenomenon over a time. In terms of modeling and forecasting literature, it means "the conditional variance of the underlying asset return"(Tsay,2010). While estimating regression equation under tradition OLS model, one fundamental assumption is variance of all the squared residuals is homoscedastic, it means that all the squared residuals from regression estimation have the same level of variance. But, in the course of time, various empirical studies have showed that stock returns exhibit heteroskedasticity which means variance of squared error terms are not equal. For example, in the seminal work done by Mandelbrot(1963), he found that there will be a tendency of large changes in asset prices are succeeded by large changes and small changes are succeeded by small changes and it can be either positive or negative. After the seminal work of Mandelbrot(1963), there was growing importance for the new innovative regression models that can capture the heteroscedasticity effectively, so that valid estimation can be done with the regression models.

In 1982, Engle proposed Autoregressive Conditional Heteroscedasticity(ARCH) model to analyse volatility by relating conditional variance of error term to the linear combination of the squared error term with one period lagged values. The major limitation in the ARCH model was that the long lag lengths leads to large parameters and hence to overcome this limitation in 1986 Bellerslev introduced Generalized Autoregressive Conditional Heteroscedasticity(GARCH) model by modeling the conditional variance to depend on its lagged values as well as squared lagged values of the error term. Seminal works of Engle and Bellerslev led to increased interest in the study of volatility. Various people like academicians, investors, policy makers have started doing research on modeling conditional volatility. Though, ARCH and GARCH models are doing well in modeling volatility, major limitation in these models was they could not capture asymmetric effect. Asymmetric effect indicates that markets responds differently to negative and positive news. This type of asymmetric effect can be captured by applying various asymmetric GARCH models like Exponential GARCH (EGARCH) model proposed by Nelson in 1991 ; the GJR-GARCH model introduced by Glosten, Jagannathan and Runkle in 1993 and Power GARCH(PGARCH) model introduced by Higgins and Bera (1992) etc.,

Origin and growth of Indian stock market

The origin of Indian stock market can be traced back to the end of the eighteenth century in which long-tern negotiable instruments were issued for the first time. However, after the enactment of companies act in 1850 only the actual beginning of the of the stock market in India had been started. The main feature of companies act 1850 was the provisions relating to business organizations with limited liability which motivated many investors in India to invest in corporate securities. In 1875, 22 enterprising brokers under a Banyan tree established the Native share and stock brokers association at Bombay which was the predecessor of current Bombay Stock Exchange. It was followed by the formation of Associations/Exchanges in Ahmedabad(1894), Calcutta(1908) and Madras(1937).

After the initiation of liberation measures in 1991, it was found necessary to make the Indian stock market trading system on par with international standards. On the basis of recommendations of Pherwani committee, the National Stock Exchange was incorporated in 1992. The key promoters of NSE are Industrial Development Bank of India, Industrial Credit and Investment Corporation of India, Industrial Finance Corporation of India, all Insurance Corporations, selected commercial banks and others.

Over the last 125 years, securities market in India is striving hard to make its trading system operationally and informationally efficient and to conform itself to international standards. Many reforms have been initiated in Indian securities market which helped to augment its growth in terms of trading volume and investor base. Important reforms introduced in recent past includes establishment of Securities Exchange Board of India(SEBI) in 1992 as governing body; introduction of screen based trading system, T+2 rolling settlement system, demutualization of stock exchanges, Demat form of trading, establishment of Clearing and Settlement houses, introduction of Straight through processing system, Value at Risk(VaR) based Margin system and many a more.

Literature review

Geert Bekaert et .,*al*(2000) investigated leverage effect and time-varying risk premium explanations of the asymmetric volatility. They conclude that mechanism behind the asymmetry for the high and the medium leverage portfolio is covariance asymmetry. They also conclude that negative shocks increase conditional covariance substantially, whereas positive shocks have a mixed impact on conditional covariance. **Christos Floros(2008)** examined the application of asymmetric GARHC models for modeling volatility and explaining financial market risk. They used two major indices i.e., CMA General index from Egypt and TASE-100 index from Israel. Results for the study provide strong evidence that asymmetric GARCH models can better explain volatility in two countries stock markets. Results of the study also concludes that increased risk will not necessarily lead to increased return in the market. **E. Abounoori** et **(2011)** studied the nature of stock market volatility in Tehran Stock exchange and in their study they estimated GJR-GARCH model with Gaussian innovations and fat-tailed distributions. Results of their study concludes that effect of bad news on the volatility is stronger than the effect of good news. **Suliman Zakaria (2012)** made an attempt to model volatility in Saudi stock market TASI index. He applied various asymmetric GARCH models like EGARCH, TGARCH and PGARCH. He observed persistence of conditional volatility and the results of his studies were in favour of 'positive correlation hypothesis' which established positive relationship between volatility and expected stock return. His studies also confirms the presence of leverage effect in market returns. **Emenike Kalu O** et **(2012)** analysed the response of volatility to negative and positive news in Nigerian stock exchange (NSE) by using daily closing prices from January 2nd 1996 to December 30th 2011. Results of their study supported the presence of asymmetric effect in the NSE stock returns but the study did not confirm the presence of leverage effect. The study provides evidence in support of positive news producing higher volatility in the immediate future than negative news with the same magnitude.

Data and methodology

The period of study is from 1st july, 1997 to 30th september,2012 and BSE-Sensex is used as surrogate index for Indian stock market and S&P 500 index is used as indicator of US stock market conditions. Natural logarithmic values are computed for daily-wise returns of Sensex and S&P500 and expressed in percentages. Descriptive statistics used in the study are mean, median, maximum, minimum, standard deviation, skewness and kurtosis.

Unit root test has been conducted to test the stationarity of daily-wise log returns and after analyzing the basic feature of time series data i.e., stationarity, the next step is to model the asymmetric volatility present in the market returns by employing two asymmetric GARCH models i.e., GJR-GARCH model and

PGARCH model.

GJR-GARCH

GJR-GARCH model is proposed by Glosten, Jagannathan and Runkle in 1993. It allows the conditional variance to respond differently to the negative and positive innovations. The model specification is as follows,

Mean Equation

$$R_t = \mu + \beta_1 \log(\sigma^2_t) + \beta_2 AR(1) \text{ ....(1)}$$

In equation(1), R_t is the Sensex return at time 't' and $\log(\sigma^2_t)$ is the natural logarithmic value of GARCH; $AR(1)$ is first order autoregression.

Variance Equation

$$\sigma^2_t = \omega + \alpha_1 \varepsilon^2_{t-1} + \gamma d_{t-1} \varepsilon^2_{t-1} + \beta_1 \sigma^2_{t-1} + \phi S\&P500_{t-1} \text{ ....(2)}$$

In equation (2) σ^2_t is squared standard deviation at time t, ω is constant and it implies unconditional volatility(or long run average); ε^2_{t-1} is squared value of one day lagged error term and α_1 is its coefficient; d_{t-1} is a dummy variable which gives value '1' for bad news i.e., ε_{t-1} <0 and value '0' for good news i.e., $\varepsilon_{t-1} \geq 0$

γ is the coefficient for the product of d_{t-1} and ε^2_{t-1} and it tests the null hypothesis that $\gamma = 0$ which indicates that the news effect is symmetric. If $\gamma<0$ (or negative) it indicates that positive shocks tend to produce more volatility in the near future than negative shocks. If $\gamma>0$ (or positive), it points out that negative shocks tend to produce more volatility in near future than positive shocks. σ^2_{t-1} is one day lagged value of squared standard deviation and β_1 is its coefficient which indicates volatility clustering.

Sum of $\alpha 1 + \beta 1 + \gamma/2$ indicates persistence of shocks in the volatility. If its value is less than one, it signifies that shock is not expected to last for a long period and if its value is closer to one, then shock is expected for a long period. If it is equal to one, then shock is going to effect volatility for indefinite future.

PGARCH

Higgins and Bera proposed Power GARCH (PGARCH) model in 1992. Unlike other GARCH models, PGARCH model used standard deviation instead of the variance. In this model, power parameter is estimated unlike other models in which it is generally imposed on the model itself. The specification of the model is as follows,

Mean Equation

$$R_t = \mu + \beta_1 \log(\sigma^2_t) + \beta_2 AR(1) \text{ ....(3)}$$

In equation(3), Rt is the Sensex return at time 't' and $\log(\sigma^2_t)$ is the natural logarithmic value of GARCH; $AR(1)$ is first order autoregression.

Variance Equation

$$\sigma^\delta_t = \omega + \alpha_1 |\varepsilon_{t-1}| - \gamma_1 \varepsilon^\delta_{t-1} + \beta_1 \sigma^\delta_{t-1} + \phi S\&P500_{t-1} \text{ ....(4)}$$

In equation(4), σ^δ_t standard deviation raised to the power of δ; ω is constant and it implies unconditional volatility; $|\varepsilon_{t-1}|$ is modulus value of one day lagged error term and α_1 is its coefficient; ε^δ_{t-1} is one day lagged error term raised to the power of δ and γ_1 is its coefficient; σ^δ_{t-1} is one day lagged standard deviation raised to the power of δ and β_1 is its coefficient. ϕ is the coefficient of one day lagged log returns from S&P500.

Results and Discussion

Descriptive statistics of Sensex returns and S&P 500 returns from 1st July, 1997 to 30th September, 2012.

Table 1: Descriptive Statistics for log returns of Sensex and S&P500

Particulars	Sensex Returns	S&P 500 Returns
Mean	0.032984	0.006522
Median	0.092324	0.054721
Maximum	15.98998	10.95720
Minimum	-11.80918	-9.469514
Std. Dev.	1.666480	1.311478
Skewness	-0.057700	-0.203816
Kurtosis	8.572631	9.942141
Observations	3782	3782

Source: Author's Calculations

Table 1 presents descriptive statistics of Sensex returns and S&P 500 returns during the study period. As shown in the table, mean return of Sensex is 0.033% with a standard deviation of 1.666%, whereas the mean return of S&P 500 is 0.0065% with a standard deviation of 1.3115%. Skewness of the distributions of Sensex returns and S&P 500 returns are negative which indicates longer left tail of the distribution showing large number of high values in the distribution and comparatively higher value of negative skewness of S&P500 returns indicates that US stock market is more volatile than Indian stock market during the period. Kurtosis of the distributions of Sensex returns and S&P 500 returns are leptokurtic which implies that the values in the distribution are closer to their mean value and lesser erratic swings present in the distribution.

Testing the Stationarity of Sensex Returns and S&P 500 Returns

Table 2: Augmented Dickey Fuller Test

[Lag length: 0 (Automatic based on SIC, maxlag=29)]

Index	t-statistic	Probability
Sensex Return	-57.70956	0.0001
S&P 500 Returns	-47.20204	0.0001

Source: Author's Calculations

Presence of non-stationarity is a common problem in time-series data. Hence, stationarity of the data series is tested by using augmented version of Dickey Fuller test. Results of the test concludes that Sensex returns and S&P 500 returns are stationary at their level form ($p<0.01$).

Estimation of Regression Equation under GJR-GARCH (1,1) Model

Table 3: Estimation results of GJR-GARCH (1,1) Model

Variable	Symbol of Coefficient	Coefficient	Std. Error	z-Statistic	Prob.
Mean Equation					
Constant	C	0.105356	0.024428	4.312917	0.0000
LOG(GARCH)	ı	-0.094669	0.036926	-2.563776	0.0104
AR(1)	β	0.081635	0.017587	4.641847	0.0000
Variance Equation					
Constant	ω	0.059834	0.007248	8.255460	0.0000
RESIDUAL(-1)^2	ı	0.058317	0.005963	9.780141	0.0000
[D_{t-1}* RESIDUAL(-1)^2] or Asymmetry parameter	γ	0.096634	0.012727	7.592675	0.0000
GARCH(-1)	ı	0.874029	0.007547	115.8050	0.0000
SP_500_RETURN (-1)	ϕ	-0.086039	0.011789	-7.298278	0.0000
Heteroskedasticity Test: ARCH LM Method					
F-statistic	0.356608	Prob. F(1,3765)			0.5504
Obs*R-squared	0.356764	Prob. Chi-Square(1)			0.5503

Source: Author's calculations

Table 3 presents results of analysis under GJR-GARCH model. In the mean equation, constant value is positive and significant ($p<0.05$). Coefficient of log value of GARCH is negative and significant which highlights that the exponential nature of conditional volatility has its impact on stock market returns($p<0.05$). Statistically significant positive value of AR(1) indicates the presence of first order positive autoregression effect on mean returns($p<0.05$). In the variance equation, constant which represents unconditional volatility is positive and significant ($p<0.01$) which points out the presence of seasonality effect on Indian stock market. Squared value of one day lagged residual, which surrogates the impact of recent news effect, is positive and significant indicating the quick reflection of recent news in the stock prices in the market($p<0.05$). Asymmetry parameter is the product of one day lagged squared value of error term and dummy variable which gives value '1' for bad news and value '0' for good news. When 'good news' is present, then γ will become zero and the model collapses to the standard GARCH form. In the present analysis, asymmetry parameter is positive and significant($p<0.05$). According Carter(2007), this type of situation indicates that negative shocks (i.e, bad news) have a large effect on conditional volatility than the positive shocks(i.e., good news) of same magnitude. One period lagged GARCH which proxies the impact of old news is positive and significant indicating the significant impact of old news on the market volatility and it also indicates the presence of stylized facts such as volatility clustering in conditional variance($p<0.05$). Sum of $/2+1+1\gamma\beta\alpha$indicates the persistence of shocks on the volatility. In the present case, its value is 0.9807 which is closer to one signifying that shock is expected to last for a long period. ARCH-LM test for Heteroskedasticity is conducted on residuals estimated from the GJR-GARCH model. Results of the test indicates that residuals derived from the regression estimation are free from heteroscedasticity ($p>0.05$) and variance equation is well specified for the GJR-GARCH model.

Estimation of Regression Equation under PGARCH (1,1) Model

Table 4: Estimation results of PGARCH (1,1) Model

Variable	Symbol of Coefficient	Coefficient	Std. Error	z-Statistic	Prob.
Mean Equation					
Constant	C	0.101701	0.024721	4.114003	0.0000
LOG(GARCH)	ı	-0.091429	0.036344	-2.515626	0.0119
AR(1)	β	0.081609	0.017410	4.687396	0.0000
Variance Equation					
Constant	ω	0.054672	0.006902	7.920919	0.0000
Modulus RESIDUAL(-1)	ı	0.109959	0.007334	14.99232	0.0000
RESIDUAL(-1) ^Power term	ı	0.276503	0.036065	7.666762	0.0000
STD.DEV(-1))^Power term	ı	0.876600	0.007698	113.8808	0.0000
Power term	δ	1.609397	0.151111	10.65042	0.0000
SP_500_RETURN(-1)	ϕ	-0.064992	0.012862	-5.052920	0.0000
Heteroskedasticity Test: ARCH LM Method					
F-statistic	0.145951	Prob. F(1,3765)			0.7025
Obs*R-squared	0.146023	Prob. Chi-Square(1)			0.7024

Source: Author's calculations

Table 4 shows the analysis results of PGARCH model. In the mean equation, constant is positive and significant. Effect of log value of GARCH and first order autoregression are same as in the case of GJR-GARCH model($p<0.05$). In the variance equation, unconditional volatility represented by constant is positive and significant($p<0.05$). Modulus value of one period lagged residual is positive and significant indicating significant impact of absolute value of error term on the volatility ignoring positive and negative signs of the error term($p<0.05$). The estimated value of power term coefficient is 1.6094 which is positive and significant ($p<0.05$). When one period lagged residual and one period lagged standard deviation are raised to the power of δ, both are positive and significant($p<0.05$) which indicates the influence of power term in ARCH and GARCH. The results of residual diagnostic tests confirms that the residuals obtained from the PGARCH model are not heteroskedastic ($p>0.05$).

Forecast Performance Evaluation

Table 5: Evaluation of Forecasts of the selected GARCH Models

	RMSE		MAE		MAPE		TI	
	Statistic	Rank	Statistic	Rank	Statistic	Rank	Statistic	Rank
GJR-GARCH(1,1)	1.665741	2	1.190608	2	102.2284	1	0.989353	2
PGARCH(1,1)	1.665481	1	1.190314	1	102.7390	2	0.988695	1

Source: Author's calculations

In financial markets research, forecasting of volatility is crucial task and it is essential to evaluate the performance of the selected forecasting models. In the present study, Root Mean Squared Error(RMSE), Mean Absolute Error(MAE), Mean Absolute Percentage Error(MAPE) and Theil Inequality Coefficient(TI) are used to evaluate the forecasting performance of the selected asymmetric GARCH models and they are presented in table 5. Based on RMSE, MAE and TI, PGARCH model outperforms GJR-GARCH models. However, the values of forecast evaluation measures for the two models have very low difference, so it can be concluded that both the models are well suited for Indian stock market.

Final findings

In the present study, modest attempt has been made to model the asymmetric volatility in the Indian stock market. BSE-Sensex is used a proxy for Indian stock market. Findings of the analysis brings out the fact that the returns from Indian stock market have the impact of asymmetric volatility. A common phenomenon in stock markets is that the market is more volatile to price declines than to price rises and this type of stylized behaviour of stock returns indicates 'leverage' effect. Leverage effect in Indian stock market analyzed by applying two popularly used asymmetric models i.e., GJR-GARCH and PGARCH. GJR-GARCH model results concludes that shocks due to bad news have strong effect on conditional volatility compared to shocks due to good news and findings under GJR-GARCH model are consistence with the studies by made **E. Abounoori at el (2011).** PGARCH model results highlights significant influence of power term on the conditional volatility. In the present era of global integration of emerging stock markets like India with other world major stock markets, presence of leverage effect in the Indian stock market indicates that any negative shocks in the international markets can easily spillover to Indian markets and which adversely affect the Indian market and it was clearly evident from global financial crisis in 2008. Hence, there is an urgent need for strengthening control mechanism like setting circuit breakers in the market more effectively, proper control on FII transaction and establishing good surveillance system in the stock markets. The Government of India should frame its monetary policy, fiscal policy and foreign trade policy in such a way that it should give due care for promoting the development of financial markets in the country and at the same time the market should be well-regulated.

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