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Measuring Volatility of BSE with ARCH Family Models: Context of Financial Crisis

Mr. Vivek Ayre[1] and Dr. Krunal Patel[2]

[1]Teaching Assistant, B.V Patel Institute of Management - Uka Tarsadia University
[2]Assistant Professor, MBA Programme, SRIMCA - Uka Tarsadia University

Abstract: *The present paper studies estimating the volatility of the BSE index with ARCH family models.Data used in the study BSE index return dated from 1st-Jan-2007 to 31st-Dec-2010. That time duration consist major impact of the financial crisis or high volatility in Indian stock exchanges. It confirmed that EGARCH (1, 1) is superior in modelling the volatility of returns on the equity market for the studied period.The model helps investor to identify the volatility patterns forecasting in indian stock market and it also suggest that the volatility appears to be more when price decline than when price increases.*

Keywords: Volatility, ARCH, GARCH, Financial Crisis

INTRODUCTION

Volatility assumes a vital part in finance since it is liable for alternative evaluating and hazards the board. Instability is straightforwardly connected with dangers and returns, higher the unpredictability the more monetary market is temperamental or varies. It might bring about both High benefits or loses in case instability is changing at higher rate. Unpredictability by one way or another controls resource returns series, value costs and unfamiliar trade rates. Numerous previous investigations in monetary financial aspects have managed the connection between the instability and securities exchange returns. Suddenly, when the normal market instability rises (decays), financial backers in the market request a higher (lower) anticipated pace of profits on stocks and consequently, stock costs go up (tumble down). This linkage proposes a straightforward system of a corresponding connection between changes in the instability file and varieties in the market list returns.

The high recurrence monetary time series information is expected to hold the bunching unpredictability which enormous developments followed by additional huge developments. On the off chance that the example of instability groups is read for longer term we see that, once assuming unpredictability arrives at its most elevated point, it will proceed for a more extended span. These are promptly perceived by Generalized Autoregressive Conditional Heteroscedasticity (GARCH) model presented by Bollerslev [1986]. The unpredictability models distinguish and track the instability groups that are arriving at either higher pinnacles or lower tops by demonstrating the instability bunches.

Curve and GARCH models are utilized to catch both unpredictability and leptokurtosis. The supposed "influence impact" is additionally regularly seen in the monetary time series. This typically happens when stock value changes are adversely corresponded with changes in unpredictability. Since ARCH and GARCH models are symmetric in nature, they neglect to catch the influence impact. To resolve this issue, numerous nonlinear augmentations of the GARCH models have been proposed. These incorporate uneven class of GARCH models, for example, dramatic GARCH (EGARCH) model by Nelson, the supposed GJR model by Glostenand the force GARCH (PGARCH) model by Ding. In the light of these perceptions in the monetary time series, a wide scope of changing difference models has been utilized to appraise and anticipate unpredictability.

The issue experienced by the GARCH model is that they don't completely accept this property of thick/substantial tails which are such a lot of apparent in the conduct of monetary time series. To resolve this issue, the Student's t-dispersion and non-typical appropriation are utilized. The instability examination of financial exchanges is significant for the financial backers in estimating and overseeing market chances all the more precisely which, thusly is valuable in evaluating capital resources, monetary protections, and choosing portfolios.

Literature Review:-

Omorogbe J.Asemota1 and UcheomaC.Ekejiuba (June,2017) inspected lopsided GARCH models on instability of banks value in Nigeria's financial exchange with week after week information of the six banks. In outcome ARCH impact was established in the investigation. On assessing the assessed models utilizing standard rules, EGARCH (1,1) and CGARCH (1,1) model in Student's t-circulation are declared the best instability. The investigation suggests that in demonstrating securities exchange unpredictability, variations of GARCH models and elective blunder dispersion ought to be considered for heartiness of results.

Gideon Boako, Albert and Joseph Magnus (September 2015) assessed multi GARCH approaches for instability elements in value returns. Unpredictability of stock returns in Ghana is displayed from July 4, 2011 to October 3, 2014 utilizing both symmetric and

topsy-turvy GARCH models like EGARCH, TARCH, PGARCH under the typical Gaussian dispersion suspicion. Results show that value returns display adapted attributes, for example, unpredictability bunching, peakedness, and influence impact found with most progressive financial exchanges

Hemanth Kumar and Basavaraj Patil (August 2016) measured the exhibition of GARCH methods for anticipating unpredictability by utilizing diverse circulation models. The distinctive GARCH dispersion models saw with chosen the SP 500 file as the information dataset. Instability is estimated for 10 days ahead of time and qualities are contrasted with the genuine qualities with discover the best dispersion model for unpredictability conjecture. The outcomes acquire it has been seen that GARCH with GED appropriation models has outflanked all models.

M.Tamilselvan and ShaikMastanVali (January 2016) evaluated market volatility forecasting of stock utilizing GARCH models in Muscat security market. Perceptions of records over the time of January 2001 to November 2015 utilizing GARCH(1,1), EGARCH(1,1) and TGARCH (1,1) models. The examination reveals that the unpredictability is exceptionally tireless and there is lopsided connection between return shocks and instability changes and the influence impact is found across all flour lists.

ArfaMaqsood and RafiaShafi (August 2017) investigated (GARCH) type models for the assessment of instability of the day by day returns of the Kenyan securities exchange: that is Nairobi Securities Exchange (NSE).The contingent difference is assessed utilizing the information from March 2013 to February 2016.fact uncovered by the outcomes is that the lopsided GARCH models give preferable fit to NSE over the symmetric models. This demonstrates the presence of influence impact in the NSE bring series back.

Prashant Joshi (July 2014) utilized three unique models: GARCH (1,1), EGARCH(1,1) and GJR-GARCH(1,1) to estimate day by day instability of Sensex of Bombay Stock Exchange of India from January 1, 2010 to July 4, 2014 and affirmed the perseverance of unpredictability, mean returning conduct and instability bunching and the presence of influence effect. The results uncover the presence of influence impact inferring effect of good and terrible news isn't same. After correlation of information the outcomes demonstrate that GARCH (1,1) is the best guaging model.

Methodology

The study applies Autoregressive conditional heteroscedasticity (ARCH) and its generalization (GARCH) models in estimating the volatility of the BSE.Data used in the study are adjusted closing prices of BSE index return dated from 1st-Jan-2007 to 31st-Dec-2010. That time duration consist major impact of the financial crisis or high volatility in indian stock exchanges. Augmented Dickey Fuller test (ADF) is used to test for stationarity of the return series. In this paper, both the symmetric and asymmetric approachesof GARCH are employed to model stock returns volatility in the BSE. [Like, ARCH(5,0), GARCH(1,1), TARCH or GJR-GARCH, EGARCH].A combination of information criteria such as Akaike Information Criteria (AIC) &Schwarz Criterion (SIC) values are considered to choose the volatility model that best models the conditional variance of the BSE. For the diagnostic purpose of validity of model different tests are applied in model like serial co-relation, ARCH-LM test and residual normality distribution test.

- **The Autoregressive Conditional Heteroscedastic (ARCH) Model**

The conditional mean equation and variance equation for an ARCH (q) model is given as:

$yt = \boldsymbol{\beta 1} + \boldsymbol{\beta 2 x 2 t} + \boldsymbol{\beta 3 x 3 t} + \boldsymbol{\beta 4 x 4 t} + \mu \boldsymbol{t}$ $\mu t \sim N(0,2)$ (1)

$\sigma t2 = \beta 0 + \sum \beta iqi=1\ \mu t-i\ 2$

(1b)where$\beta 0 > 0$; $\beta i > 0$; $\forall$ i = 1,…,q

Where μt is the error generated from the mean equation at time t. and $\sigma t2$ is the conditional variance equation.

- **Generalized Autoregressive Conditional Heteroscedasticity (GARCH) Model**

The conditional variance for GARCH (p, q) model is expressed as:

$\sigma t2 = \beta 0 + \sum \beta iqi=1\ \mu t-i\ 2 + \sum \alpha j \sigma t-i\ 2pj=1$ (2)

Where i = 1… q; j = 1,…p. σt 2 is the conditional variance, q is the order of the ARCH terms μ2, p is the order of the GARCH terms σ2, and β0 is the constant term. The sum of the ARCH and GARCH term will inform us if volatility shocks are persistent.

- **The Threshold GARCH (TGARCH) Model**

The threshold GARCH model is also called the GJR-GARCH model. The TGARCH (p, q) is specified as:

$\sigma t2 = \beta 0 + \sum \beta i \mu t-i \; 2qi=1 + \sum \gamma i \; \mu t-i \; 2 \; dt-iqi=1 + \sum \alpha j \sigma t-j \; 2pj=1$ (5)

Where $dt-i$ = 1 if $\mu t < 0$ and 0 if $\mu t > 0$, and the condition for non-negativity is $\beta 0 > 0$, $\beta i > 0$, $\alpha j \geq 0$, and $\beta i + \gamma \geq 0$. In this model, good news implies that $\mu t-i \; 2 > 0$ and has an impact of βi and bad news implies that $\mu t-i \; 2 < 0$ with an impact of $\beta i + \gamma i$. These two shocks of equal size have different effects on the conditional variance.

- **The Exponential GARCH (EGARCH) Model**

The conditional variance of EGARCH (p, q) model is specified as:

$\log (\sigma t2) = \beta 0 + \sum \beta i \; |\mu t-i \sigma t-i \; |qi=1 + \sum \gamma i \; \mu t-i \sigma t-iqi=1 + \sum \alpha j \log (\sigma t-j \; 2 \;)pj=1$ (6)

In this model, good news implies that $\mu t-i$ is positive with total effects $(1+\gamma i)|\mu t-i \; |$ and bad news implies $\mu t-i$ is negative with total effect$(1-\gamma i)|\mu t-i \; |$. When $\gamma i < 0$, bad news would have higher impact on volatility than good news (leverage effect is present). The news impact is asymmetric if $\gamma i \neq 0$.

DATA ANALYSIS:-

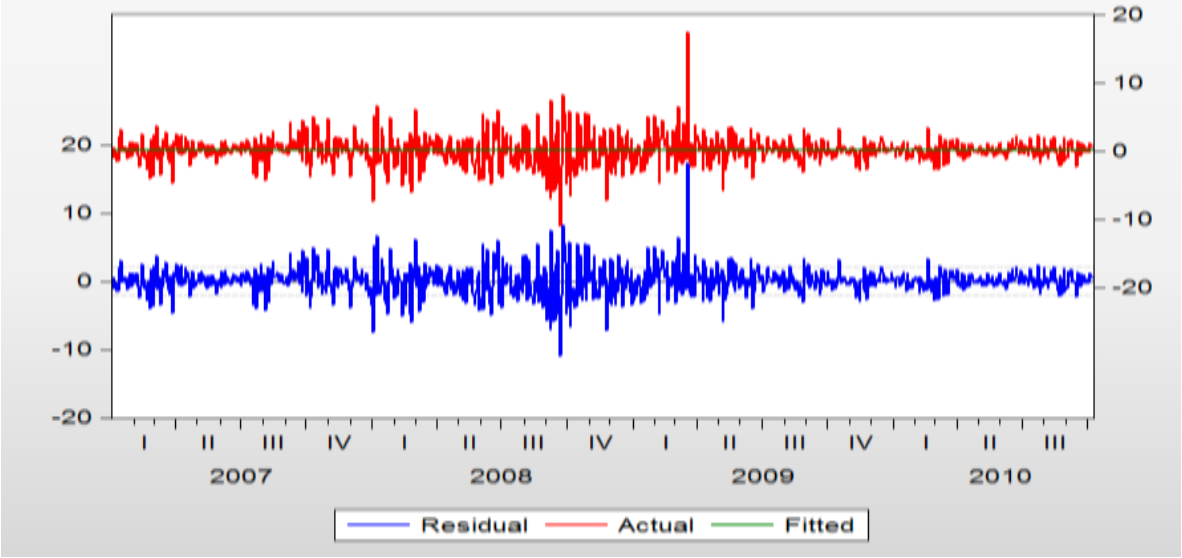
In order to analyse the return series, the first step is to check the stationaryscenario of return series. For this purpose, we employed the familiar Augmented Dickey Fuller (ADF) test. The results show that values of ADF test statistic,-22.2955 is less than the critical value, -2.8642 at 5% level. Hence the null hypotheses of ADF test is rejected and concluded that the return series data is stationary at level.

Table 1 ADF test statistic result

Result		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-22.29551	0.0000
Test critical values:	1% level	-3.436803	
	5% level	-2.864277	
	10%level	-2.568280	

After ensuring the non-existence of unit root in time series data, it should be further investigated whether the data is found with ARCH effect. The ARCH effect means Periods of low volatility tend to be followed by periods of low volatility for a prolonged period. Again, periods of high volatility is followed by periods of high volatility for a prolonged period. When ARCH effect is found in the time series data, then the forecasting can be estimated using ARCH family models. For that purpose we run regression line and identify the presence of volatility clustering or the ARCH effect in data series.

Table 2 ARCH effect



In all below output of different ARCH family models on BSE index return illustrated that the constant, C, is not statistically significant in both the mean and variance equations.

ARCH Model

Table 3 Output of ARCH Model

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.147754	0.040962	3.607071	0.0003
Variance Equation				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	3.748131	0.419510	8.934553	0.0000
RESID^2(-1)	0.097260	0.031809	3.057657	0.0023

The output of ARCH model on BSE index return illustrated that the variance equation describes that the RESID^2(-1) term is statistically significant for BSE index return which imply that volatility of risk is influenced by past square residual terms. So it can be mentioned that past volatility of BSE index significantly, influencing the current volatility.

ARCH (5,0) Model

Table 4 Output of ARCH (5,0)Model

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.147754	0.040962	3.607071	0.0003
Variance Equation				
C	0.667086	0.076479	8.722530	0.0000
RESID(-1)^2	0.110091	0.038131	2.887211	0.0039

RESID(-2)^2	0.131115	0.033853	3.873018	0.0001
RESID(-3)^2	0.193075	0.040245	4.797470	0.0000
RESID(-4)^2	0.371929	0.030336	12.26050	0.0000
RESID(-5)^2	0.163724	0.039865	4.106986	0.0000

The output of ARCH(5,0) model on BSE index return illustrated the variance equation describes the RESID^2(-1) to (-5) term is statistically significant for BSE index return which imply that volatility of risk is influenced by past square residual terms. So it can be mentioned that past volatility of BSE index significantly, influencing the current volatility.

GARCH (1,1) Model

Table 5 Output of GARCH(1,1) Model

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.125400	0.041905	2.992487	0.0028
Variance Equation				
C	0.035399	0.010630	3.330271	0.0009
RESID(-1)^2	0.126336	0.014872	8.494620	0.0000
GARCH(-1)	0.874698	0.013298	65.77530	0.0000

The output of GARCH model on BSE index return illustrated the variance equation describes the RESID^2(-1) term is statistically significant (0.00) for BSE index return which imply that volatility of risk is influenced by past square residual terms. The term GARCH(-1) is also significant for BSE index return. So it can be mentioned that past volatility of BSE index significantly, influencing the current volatility.

TARCH Model

Table 6 Output of TARCH Model

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.087875	0.043452	2.022329	0.0431
Variance Equation				
C	0.039496	0.009867	4.002735	0.0001
RESID(-1)^2	0.072780	0.011874	6.129494	0.0000
RESID(-1)^2*(RESID(-1)<0)	0.106746	0.024820	4.300740	0.0000
GARCH(-1)	0.873741	0.012915	67.65411	0.0000

The output of TARCH model on BSE index return illustrated that the variance equation describes the RESID^2(-1), RESID(-1)^2*(RESID(-1)<0)&GARCH(-1)term is statistically significant (0.00) for BSE index return which imply that volatility of risk is influenced by past square residual terms. So it can be mentioned that past volatility of BSE index significantly, influencing the current volatility.

EGARCH Model

Table 7 Output of EGARCH Model

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.085759	0.040363	2.124678	0.0336
Variance Equation				
C(2)	-0.166370	0.017412	-9.554937	0.0000
C(3)	0.251919	0.024713	10.19387	0.0000
C(4)	-0.081341	0.016365	-4.970314	0.0000
C(5)	0.976216	0.004972	196.3325	0.0000

The output of TARCH model on BSE index return illustrated the variance equation describes the C(2), C(3), C(4), and C(5) term is statistically significant for BSE index return which imply that past volatility of BSE index significantly, influencing the current volatility. It also signifies that there existsthe asymmetric behavior in volatility which means that positive news are affecting differently than the negative news on volatility.

Compare best fitted model out of all selected models

Now compare the all models by threw of lower the value, better the model, researcher target the AIC (Akaike info criterion) and SIC (Schwarz criterion) value to compare.

Table 8 statistical performance result of all selected models

Index	Criteria	Models				
		ARCH	ARCH(5,0)	GARCH	TARCH	EGARCH
BSE	AIC	7.886783	3.930626	3.903141	3.892719	3.884734
	SIC	7.896749	3.965481	3.923057	3.917615	3.909630

Now we estimate which model is best fitted from ARCH family model. As per the guidelines lower the value of AIC and SIC, better the model fitted. EGARCH model is the best fitted model it have lowest value of AIC and SIC respectively 3.884734 and 3.909630 in BSE benchmark index.

Diagnostic process of best fitted model

Before considering the best fitted model out of all ARCH family models. We verified the diagnostic checking based on three points:

1. There is no serial correlation
2. There is no ARCH effect
3. Residuals should be normally distributed

Now we follow all above mention points for diagnostic checking in BSE index.

Table 9 serial correlation on EGARCH

Auto Correlation	Partial Correlation		AC	PAC	Q-Stat	Prob*
| |	| |	1	-0.037	-0.037	1.3368	0.248
| |	| |	2	-0.030	-0.032	2.2387	0.326
| |	| |	3	0.020	0.018	2.6412	0.450

		4	0.049	0.050	5.0282	0.284
		5	-0.028	-0.023	5.7769	0.329
		6	0.012	0.013	5.9142	0.433
		7	-0.003	-0.006	5.9263	0.548
		8	-0.020	-0.022	6.3354	0.610
		9	0.002	0.002	6.3391	0.706
		10	0.069	0.067	11.106	0.349
		11	-0.006	0.001	11.144	0.431
		12	-0.000	0.005	11.144	0.517
		13	0.028	0.025	11.942	0.532
		14	-0.012	-0.017	12.098	0.598
		15	0.013	0.016	12.257	0.659
		16	-0.008	-0.011	12.329	0.721
		17	-0.010	-0.011	12.438	0.773
		18	0.004	0.007	12.452	0.823
		19	-0.011	-0.014	12.576	0.860
		20	0.010	0.007	12.671	0.891
		21	0.007	0.009	12.727	0.918
		22	0.013	0.013	12.894	0.936
		23	-0.023	-0.023	13.421	0.942
		24	-0.003	-0.004	13.428	0.959
		25	-0.027	-0.032	14.160	0.959
		26	0.015	0.014	14.394	0.967
		27	-0.030	-0.026	15.305	0.965
		28	-0.036	-0.039	16.626	0.956
		29	0.051	0.053	19.212	0.916
		30	0.000	-0.001	19.212	0.935
		31	-0.007	-0.001	19.263	0.950
		32	-0.034	-0.036	20.447	0.943
		33	-0.036	-0.045	21.769	0.933
		34	0.070	0.071	26.777	0.806
		35	0.096	0.104	36.189	0.413
		36	-0.023	-0.009	36.729	0.435

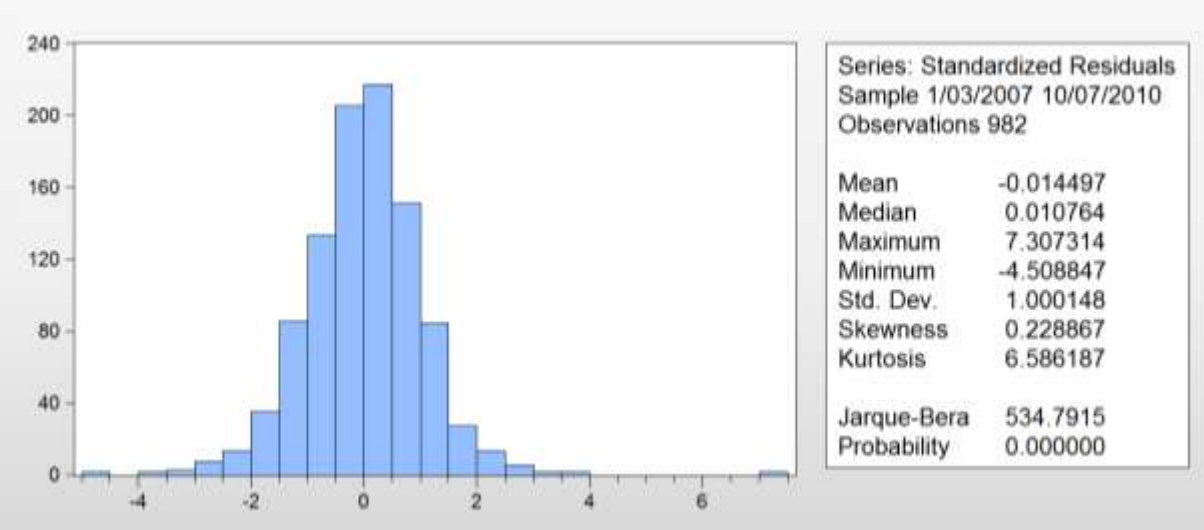
Correlogram of Q-statistic standardized residual square these is Null hypothesis- these is no serial correlation in the residuals of P-value is more than 5% we accept the null hypothesis, meaning that there is no serial correlation in residuals of EGARCH.

Table 10Heteroskedasticity ARCH LM test on EGARCH

F-statistic	1.330775	Prob. F(1,979)	0.2489
Obs*R-squared	1.331683	Prob. Chi-Square(1)	0.2485

The second diagnosis checking with ARCH LM model null hypothesis: there is no ARCH effect, which is desirable. Here the observed P-value is 0.2485 which is more than 5%. So we cannot reject the null hypothesis rather accept the null hypothesis, means there is no ARCH effects.

Table 11 Normal Distribution on EGARCH



This normality distribution is the last diagnostic checking for best fitted model EARCH in BSE index. Null hypothesis: residuals are normally distributed, which is desirable. Here P-value is 0.00 which is less than 5%, we can say that residual are not normally distributed.

Hence EGARCH model has no serial correlation also this model has no ARCH effect so we are happy about it but residuals are not normally distributed so we are unhappy with result. But many economists say so that all though the residual are not normally distributed we can accept the model. So based on that we can say that EGARCH model is best fitted for BSE index.

Conclusion

In the study, ARCH family model is used to measuring the volatility of BSE index. The daily data are used from 1st-Jan-2007 to 31st-Dec-2010 for study. According to many researchers that time duration considered as highly volatile time for the BSE index till now. ARCH family model examined all past, pre and during effects of financial crisis in model. After used of different ARCH family models like ARCH(1,0), ARCH(5,0), GARCH and TARCH resulted in different variance equation terms are statistically significant for BSE index return which imply that volatility of risk is influenced by past square residual terms. TARCH model on BSE index signifies that there exists the asymmetric behavior in volatility which means that positive news are affecting differently than the negative news on volatility. Estimation of best fitted model based on value of AIC and SIC. EGARCH model is the best fitted model it have lowest value of AIC and SIC respectively 3.884734 and 3.909630 in BSE benchmark index. The model helps investor to identify the volatility patterns forecasting in indian stock market and also suggest that the volatility appears to be more when price decline than when price increases.

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