Modeling Symmetric and Asymmetric Volatility in the Indian Stock Market

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Abstract

The term leverage effect refers to the observed relationship between an asset's volatility to be negatively correlated with the asset's returns. The study intended to find whether the volatility tendency increased when the stock markets experienced a fall and attempted to explore the heteroskedastic behavior of Indian equity market stocks by using the GARCH family models to examine the leverage effect that explained the asymmetric volatility of the automobile stocks listed on the NSE (National Stock Exchange). It attempted to find the effects of good and bad news on volatility in the Indian stock market during the extensive and crucial periods from April 24, 2003 to September 7, 2015, when the equity markets experienced three bull and three bear phases. The study used three different volatility estimators from the return series data of the selected stocks of NSE to account for the robustness in the analysis. The standard GARCH models were applied to study whether there was volatility during the study period ; hence, asymmetric volatility models, that is, EGARCH and TGARCH were employed to find out the leverage effect. The study reported an evidence of volatility, which exhibited the clustering and persistence of stocks. The return series of the stocks selected for the study were found to react on the good and bad news asymmetrically. The negative shocks to these stocks exhibited more volatility than the positive shocks of the same magnitude.

Keywords : **volatility, leverage effect, GARCH models, Indian stock market, NSE**

JEL Classification : G10, G11, G14, G19

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The important attribute of any financial instrument is the stochastic nature of its returns and its associated risk. This spread of outcome of the stock behavior in the equity market refers to volatility. It may be described as a phenomenon which characterizes changeableness of a variable under consideration. Volatility is associated with unpredictability and uncertainty. It is one of the key parameters which influences numerous financial decisions. Financial markets play a key role in redesigning the economic position of any nation. Due to its crucial role, it has been studied by both academicians and practitioners from different point of views. In the recent past, tremendous importance has been given for estimating and analyzing volatility, and extensive works have been done on the modeling of financial time series. Estimation of volatility addresses the issues in risk management and helps to manage the investor's portfolio efficiently. Reliable volatility estimation is crucial for hedging against risk and portfolio management. Several studies have been undertaken in modeling the stock market volatility with respect to various global stock exchanges, and many researchers have made an attempt to investigate the volatility pattern in their respective stock markets.

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Review of Literature

An attempt was made by Poterba and Summers (1986) to examine the influence of changing volatility in the American stock market on the level of stock prices. Their study demonstrated that volatility was weakly serially correlated, implying that shocks to volatility did not persist. These shocks only had a small impact on stock market prices, since changes in the volatility affect had expected required rates of return for relatively short intervals. They also confirmed that volatility was not highly persistent and suggested that the autonomous changes in volatility should only have a relatively small effect on share prices. Nicholls and Tonuri (1995) focused on the asymmetric generalized auto regressive conditional heteroskedasticity (GARCH) models and evaluated the applicability of the same to stock market data in Australia. They found that the stock returns data were typically characterized by volatility clustering, where large returns tended to be followed by large returns and small returns tended to be followed by small returns, leading to contagious periods of volatility and stability. From their observations, they asserted that the basic GARCH model has inspired a number of other related formulations describing the evaluation of the variance of time series. Henry (1998), in his study on modeling the asymmetry of stock market volatility, suggested that a negative shock to stock price would generate more volatility than a positive shock of equal magnitude. The study used the daily data from Hong Kong Stock Exchange to illustrate the nature of stock market volatility.

The time series of stock returns and volatility of China's stock exchanges were examined by Lee, Chen, and Rui (2001). They applied GARCH and EGARCH models to obtain the appropriate series of conditional variances, which could be used as expected volatility estimates. The authors found that there was strong evidence of time varying volatility and showed that volatility was highly persistent and predictable. Karmakar (2005) conducted a study to estimate the conditional volatility of the Indian stock market. The investigation was made for a period of 14.5 years from July 1990 to December 2004. His study found that there was a strong evidence of time varying volatility - a tendency of periods of high and low volatility to cluster, and a high persistence and predictability of volatility in the Indian stock market. The study also concluded that various GARCH models provided good forecasts of volatility and were useful for portfolio allocation, performance measurement, and options valuation. Pandey (2005) evaluated the extreme value volatility estimators and their empirical performance in the Indian capital market. He used the S&P CNX Nifty data from January 1999 to December 2002 and used two traditional estimators (open to open and close to close volatility), four extreme value estimators (Parkinson ; Garman & Klass ; Rogers - Satchell ; and Yang-Zhang methods), and two conditional volatility models (GARCH and E-GARCH models). According to him, for estimating volatility, the extreme value estimators performed better on efficiency and bias criteria than the traditional models. He also found that the conditional volatility models performed better than the extreme value estimators in respect of bias.

Padhi (2006) studied the volatility of individual stocks and of the aggregate indices using ARCH model, GARCH model, and ARCH in mean model for daily data for the time period from January 1990 to November 2004. The analysis revealed the same trend of volatility in the case of aggregate indices and five different sectors such as electrical, machinery, mining, non-metallic, and power plant sector. The GARCH (1,1) model performed well for all the five aggregate indices and individual stocks. Saleem (2007) conducted a study to find the varying volatility and asymmetry of the Karachi Stock Exchange. In his study, he examined the time varying volatility by employing GARCH (1,1) and EGARCH models and found that in KSE-100 Index stocks, positive returns were associated with higher volatility than negative returns of equal magnitude. The study also found that past residuals highly influenced the current volatility. Kumar and Dhankar (2010) conducted a study to estimate the conditional heteroskedasticity and asymmetric effect on volatility and also tested the relationship between stock returns with expected volatility and unexpected volatility. The data relating to the daily opening and closing prices of S&P 500 and NASDAQ 100 for the period from January 1990 to December 2007 were used, and they applied GARCH

(1,1), and T-GARCH (1,1) to examine the heteroskedasticity and the asymmetric nature of stock returns, respectively. The results of their study suggested the presence of the heteroskedasticity effect and the asymmetric nature of the stock returns.

Majumder and Nag (2013) made an attempt to explore the linkages between the flow of foreign institutional investments (FII), stock market returns, and volatility after the outburst of the global financial crisis in the context of India. The analysis was done based on the auto regressive conditional heteroscedasticity (ARCH) family models. By analyzing the daily data from January 2008 to February 2012, they found that higher stock market returns amplified the volume and volatility of the FII flows without any evidence on the other direction. Moreover, the intraday and overnight stock market returns had different implications for FII flow and its volatility. An attempt was made by Dadhich, Chotia, and Chaudhry (2015) to study the volatility patterns in Indian equity markets through properties such as volatility clustering and leverage effect. They attempted to examine the FII flows in Indian securities market and assessed the impact of foreign institutional investments on the volatility of the Indian stock market. Effect of news in the first moment was modeled with the help of ARCH-GARCH process and the change over 24 hours (from a closing rate to a closing rate) was measured for a period from 2004 - 2014. Their analysis revealed the persistence of volatility and confirmed the presence of leverage effect in the Indian securities market. A study was conducted by Banumathy and Azhagaiah (2015) to empirically investigate the volatility pattern of the Indian stock market based on time-series data, which consisted of daily closing prices of S&P CNX Nifty index for 10 years from January 2003 to December 2012 by using both symmetric and asymmetric models of GARCH. Their study proved that models GARCH (1,1) and TGARCH (1,1) estimations were found to be most appropriate models to capture the symmetric and asymmetric volatility, respectively. The study also rendered evidence that the asymmetric effect captured by the parameters of EGARCH (1,1) and TGARCH (1,1) models showed that negative shocks had a significant effect on the volatility.

Mattack and Saha (2016) conducted a study aimed to find out whether introduction of options and futures contracts had an effect on the volatility of the underlying equities listed in the Indian stock market. They applied GARCH models in their study and proved that volatility of most of the underlying stocks selected for the study decreased with the listing of equity options and futures. Varughese and Mathew (2017) attempted to analyze the stock return volatility, especially the asymmetric effect of the Indian stock market, and contribution of foreign portfolio investment to that volatility. The study was conducted by taking daily data for a period of 12 years from April 1, 2003 to March 31, 2015 consisting of 2898 trading observations. To study the leverage effect and impact of foreign portfolio investment on stock market volatility, they used ARCH family models - GARCH, E-GARCH, and TARCH. The results of their study confirmed the existence of volatility clustering and leverage effect in the Indian stock market. They concluded that the investment activities of foreign portfolio investments had a significant impact on the volatility of the Indian stock market.

Studies conducted so far to estimate the volatility pattern in India and abroad considered the data relating to the price behavior of the common stocks or market index for a span of time which was convenient for the researchers (to collect the data), without giving importance to the nature of market situations, that is, whether bull or bear trend existed in the market. So, these studies were not able to reveal the volatility pattern exactly, more specifically, the asymmetric volatility. Hence, this study, in contrast to other earlier studies, selected a study period representing an equal number of bull and bear phases, which can exhibit both symmetric and asymmetric volatility, with more precision and accurate results.

Data Collection and Methodology

The primary objective of this research study is to investigate the volatility pattern of the Indian stock market using GARCH family models and to identify the presence of leverage effect in the daily return series of stocks using asymmetric models. To achieve this objective, data relating to the daily closing price of the stocks selected for the study were collected from the official website www.nseindia.com of National Stock Exchange. For the analytical purpose of the study, auto sector index stocks of NSE were taken into consideration.

The reason for the selection of the auto sector was that among the 11 sectoral indices available in NSE, auto sector stocks delivered the highest returns during the study period. Hence, the data of auto stocks for a selected period from April 24, 2003 to September 7, 2015 were taken for the study. The study period spanned over a period of roughly 12.5 years, involving around 3089 number of data points, which provides rich data set for analytical purposes.

The reason for specifically choosing this study period was to capture the crucial three bull and bear phases of the Indian equity market as only during this period the market has experienced three bull and three bear phases. Nifty index travelled from 927.80 to 6287.85 (24.04.2003 to 08.01.2008 – Ist bull phase) and dived to 2573.15 from its peak of 6287.85 due to the global economic meltdown (09.01.2008 to 09.03.2009 – Ist bear phase). It started its uptrend from 2573.15 to 6312.45 as a part of its recovery due to various measures taken by the Indian government, United States, and Europe (10.03.2009 to 05.11.2010 – IInd bull phase) and again touched 4544.20 points roughly within a year from its recent high 6312.45 (06.11.2010 to 20.12.2011- IInd bear phase). Nifty index again travelled from its recent low 4544.20 to 8952.35 due to global and domestic economic recovery (21.12.2011 to 29.01.2015 – IIIrd bull phase), and experienced the bear trend again from 8952.35 to 7588.25 (30.01.2015 to 07.09.2015 – IIIrd bear phase). Hence, it was felt that choosing this period would be the ideal choice to estimate both the symmetric and asymmetric volatility.

Hypotheses Framed

The following hypotheses were framed (null and alternative hypothesis) for the study :

- **H01:** There is no stationarity in the return series of the auto sector stocks selected for the study.
- **Ha1:** There is stationarity in the return series of the auto sector stocks selected for the study.
- **H02 :** There is no ARCH effect in the return series of the stocks selected for the study.
- **Ha2 :** There exists ARCH effect in the return series of the stocks selected for the study.
- **H03 :** There is no volatility in the return series of the auto sector stocks selected for the study.
- **Ha3 :** There exists volatility in the return series of the auto sector stocks selected for the study.
- **H04 :** There is no leverage effect in the return series of the stocks selected for the study.
- **Ha4 :** There is evidence of leverage effect existing in the return series of the stocks selected for the study.

Tools Used for Analysis

We have applied various statistical tools like descriptive statistics, Augmented Dickey Fuller Test (ADF test), Phillips - Perron test (PP test), ARCH-LM test, and GARCH family models using E-views 7.1 version. Volatility has been estimated on the returns of the auto sector stocks selected for the study from the daily returns. For this purpose, the daily closing prices of the respective stocks were collected, and the closing prices were adjusted for the corporate activities like bonus issue, stock split, and so on. These adjusted closing prices were used to calculate the daily returns, and it was calculated as a log of first difference, calculated as $R_t = (\log P_t - \log P_{t-1}) \times 100$, where R_t is the logarithmic daily return on the selected stock for time T, P_t is the closing price of the selected stock at time T, and P_{t-1} is the corresponding price in the period at time T-1.

To specify the distributional properties of the stocks selected for the study, descriptive statistical tools like average, standard deviation, skewness, kurtosis, and Jarque-Bera statistics were applied (Table 1). For any further analysis, it is important that the financial time series data should be stationary in nature. In order to find this, ADF test (Augmented Dickey Fuller Test) and Phillips - Perron test (PP test) were applied and the return series of the stocks selected for the study was stationary in nature and shown in the Table 2.

Before estimating volatility by using GARCH family models, it is necessary to identify whether there has been substantial evidence of the presence of heteroskedasticity (ARCH effect) in the residuals of return series of the stocks selected for the study. In order to test whether the ARCH effect exists or not in the residuals of the return series, residual diagnostics test was conducted, which is lag range multiplier test for autoregressive conditional heteroskedasticity (ARCH) in the residuals and the results retrieved are shown in the Table 3. In order to explore the most suitable model to specify the level of symmetric volatility of the selected stocks, GARCH models with various orders like GARCH (1,1), GARCH (1, 2), GARCH (2, 1), and GARCH (2, 2) were employed. In the process of selecting the best fitting model, as per the decision rule, the Akaike information criterion (AIC) and Schwarz information criterion values were taken into consideration along with the log likelihood values, wherever need arose. The results obtained from these models are exhibited in the Table 4.

To find out the magnitude of symmetric volatility of the stocks selected for the study, GARCH (1,1) model has been applied. For a stationary GARCH model, the volatility mean reverts to its long run level at rate given by the sum of ARCH and GARCH coefficients, which is generally closer to one for a financial time-series analysis. The average number of time period for the volatility to revert to its long run level was measured by half life of volatility shock and was calculated by applying, $L_{half} = (\ln (1/2)) / (\ln (\alpha + \beta))$, where α and β are the calculated ARCH and GARCH coefficients. The calculated values of mean reversion and the output from GARCH (1,1) model are exhibited in the Table 5.

To test the adequacy of the selected GARCH (1,1) model and to deduct whether ARCH effect exists or not in the residuals of the return series after the estimation of the GARCH (1,1) model, ARCH - LM test was conducted by using the residuals obtained after the application of the GARCH (1,1) model. The obtained results from ARCH - LM test should show no evidence of remaining ARCH effect in the residuals, which is a necessary input to indicate that the selected model is a perfect choice and has modeled the volatility pattern better than any other model. The results obtained from the ARCH - LM test are depicted in the Table 6.

In a financial market, if bad news has a more pronounced effect on volatility than good news of the same magnitude, such asymmetry has typically been attributed as leverage effect, and then the symmetric specification such as GARCH is not appropriate and cannot capture the asymmetric effect, since only squared residuals enter the equation and the signs of the residuals or shocks have no effect (by squaring the lagged error in GARCH, the sign is lost) on the conditional volatility. In other words, the model assumes the same effect for good and bad news. However, the fact of financial volatility is that negative shocks tend to have a larger impact on volatility than positive shocks. The main drawback of the symmetric GARCH model is that the conditional variance is unable to respond asymmetrically to the rise and fall in the stock returns. Hence, to examine the asymmetric effect of the financial time-series data, exponential GARCH (EGARCH) and threshold GARCH (TGARCH) models were applied. In order to account for the leverage effect observed in return series of the selected stocks, the asymmetric models which include EGARCH (1,1) and TGARCH (1,1) were employed, and the results found from these two models are depicted in the Table 7.

Analysis and Results

The Table 1 presents the descriptive statistics of the daily returns of the selected auto sector stocks of NSE. The mean returns for all the 13 stocks are positive, indicating the fact that the price of these stocks increased

Table 1. Descriptive Statistics of Auto Sector Stocks

S.No	Name of the Stock	Mean Return	Standard deviation	Skewness	Kurtosis	JarqueBera	p value
1	Amar Raja Batteries	0.001668	0.028725	0.339854	12.41203	9439.00	0.0000
2	Apollo Tyres	0.001011	0.027860	0.240424	6.917821	2001.450	0.0000
3	Ashok Leyland	0.000942	0.027506	-0.024260	7.469226	2566.127	0.0000
4	Bharat Forge	0.000968	0.025416	0.319163	7.335239	2466.625	0.0000
5	Bosch Ltd.	0.001336	0.018215	0.954731	13.23568	13926.83	0.0000
6	Eicher Motors	0.001739	0.027111	0.658168	10.37698	7213.260	0.0000
7	Exide Industries	0.001115	0.024824	0.493061	7.082344	2265.754	0.0000
8	Hero Motors	0.000846	0.020842	0.350863	8.089152	3390.257	0.0000
9	M&M	0.001267	0.024286	0.217722	9.590451	5603.823	0.0000
10	Motherson Sumi Systems	0.001704	0.028692	0.986374	11.25960	5639.765	0.0000
11	MRF	0.001201	0.024687	0.743287	9.525904	5754.50	0.0000
12	Tata Motors	0.000772	0.02718	-0.159739	6.798507	1866.593	0.0000
13	TVS Motor	0.000778	0.030627	0.377780	7.762122	2986.486	0.0000

Table 2. Tests for Unit Root Problem in the Selected Stocks

S.No	Name of the Stock	Augmented Dickey Fuller Test			Phillips Perron Test		
		Intercept	Trend and Intercept	None	Intercept	Trend and Intercept	None
1	Amara Raja Batteries	-51.19818	-51.19032	-51.04818	-51.29797	-51.29022	-51.27846
2	Apollo Tyres	-53.72203	-53.71375	-53.72203	-53.72203	-53.72203	-53.7220
3	Ashok Leyland	-51.57045	-51.56250	-51.52195	-51.51887	-51.51078	-51.45096
4	Bharat Forge	-52.83284	-52.82880	-52.76759	-52.84322	-52.83852	-52.83226
5	Bosch Ltd.	-53.72070	-53.74611	-53.45248	-53.71935	-53.74368	-53.45212
6	Eicher Motors	-52.05687	-52.06257	-51.86724	-51.96234	-51.96562	-51.77720
7	Exide Industries	-54.81009	-54.87267	-54.71672	-54.92512	-55.02456	-54.78809
8	Hero Motors	-56.02681	-56.06389	-55.91015	-55.03066	-55.12894	-54.81628
9	M&M	-50.27951	-50.32149	-50.16269	-50.04882	-50.08278	-49.96553
10	Motherson Sumi Systems	-58.83445	-58.83961	-58.62423	-59.14209	-59.15638	-58.76838
11	MRF	-49.11891	-49.11175	-49.02719	-49.48886	-49.48095	-49.51659
12	Tata Motors	-50.85450	-50.86399	-50.82539	-50.68314	-50.69148	-50.66795
13	TVS Motor	-54.50612	-54.50756	-54.47741	-54.50332	-54.50714	-54.47987

Note. Test critical value @ 5% level is **-2.862279 for Intercept** ; @5% level is **- 3.411264 for Trend and Intercept**; @ 5% level is **-1.940927 for None**, *p* - values for all the above observations are < 0.05.

considerably during the study period. Eicher Motors delivered the highest returns (0.001739) followed by Motherson Sumi Systems (0.001704) and Tata Motors (0.000772) ; whereas, TVS Motor (0.000778) delivered comparatively lower returns during the study period. The values of standard deviation are comparatively higher for TVS Motor (0.030627) followed by Amara Raja Batteries (0.028725), Motherson Sumi (0.028692), and

Apollo Tyres (0.027860) and are found to be lower for Bosch Ltd. (0.018215) and Hero Motors (0.020842). The descriptive statistics show that the daily returns are positively skewed for all the stocks except for Ashok Leyland (-0.024260) and Tata Motors (-0.159739), which explains that the returns of these stocks increased more often than it decreased, and there was a high probability of earning returns which was greater than the mean returns. The kurtosis data depicted in the table shows that all the stocks selected for the study are having K value greater than 3, which implies that the return series are fat tailed, and they do not follow a normal distribution. This is further confirmed by the p - values of Jarque - Bera test statistics, which are less than 0.05 ($p < 0.05$).

The Table 2 shows the calculated test statistic values (at level) for all the selected stocks of the auto sector index of NSE using the Augmented Dickey Fuller test (ADF) and Philips Perron test (PP). The test critical values for both ADF and PP test at the 5% level are -2.862279 for the test equation - intercept, -3.411264 for the test equation - trend and intercept, and -1.94027 for the test equation - none and were compared with the calculated values. As per the decision rule to reject the null hypothesis when the variable has a unit root problem, the calculated absolute test statistic values for all the stocks are much higher than the absolute test critical values, and hence, the null hypothesis (H01) is rejected with the conclusion that the return series of all the selected auto sector stocks are stationary in nature - at level, accepting the alternate hypothesis Ha1.

The Table 3 exhibits the calculated coefficient values and the probability values of the stocks selected for the study and shows that they are statistically significant and all the calculated F - statistic values are higher than the observed R square values, which is a necessary condition to reject the null hypothesis of 'no ARCH effect in the return series.' Hence, it is proven that there exists heteroskedasticity - ARCH effect in the time series of the selected stocks, thereby rejecting the null hypothesis H02 and accepting the alternate hypothesis Ha2, which requires the application of GARCH family models to understand the volatility in the stocks.

The results of GARCH (1,1), GARCH (1, 2), GARCH (2, 1), and GARCH (2, 2) models for the selected stocks are presented in the Table 4 for the purpose to select the best fit model to understand the nature of volatility. To select the best-fit model, the AIC and SIC values are compared with each other and the model with minimum AIC and SIC values would be selected as the best fit one. Both the AIC and SIC values of GARCH (1,1) model are

Table 3. Testing the Heteroskedasticity Effect in the Return Series of the Selected Stocks

S.No	Name of the Stock	*F* - statistic	Prob. *F*	Obs**R*-Squared	Prob.Chi-Square
1	Amara Raja Batteries	99.91810	0.0000	96.84136	0.0000
2	Apollo Tyres	27.58462	0.0000	27.35752	0.0000
3	Ashok Leyland	123.5369	0.0000	118.8501	0.0000
4	Bharat Forge	127.4765	0.0000	122.4896	0.0000
5	Bosch Ltd.	20.52112	0.0000	20.39854	0.0000
6	Eicher Motors	199.5029	0.0000	187.4881	0.0000
7	Exide Industries	54.12843	0.0000	53.22814	0.0000
8	Hero Motors	98.00627	0.0000	95.04554	0.0000
9	M&M	145.1190	0.0000	138.6791	0.0000
10	Motherson Sumi Systems	34.85597	0.0000	34.48831	0.0000
11	MRF	224.9711	0.0000	209.7934	0.0000
12	Tata Motors	359.2047	0.0000	321.8968	0.0000
13	TVS Motor	126.6315	0.0000	121.7097	0.0000

Table 4. Selection of Suitable Model to Estimate Volatility Using GARCH Models

Name of the Stock	GARCH (1,1)		GARCH (1,2)		GARCH (2,1)		GARCH (2,2)	
	AIC	SIC	AIC	SIC	AIC	SIC	AIC	SIC
Amara Raja Batteries	4.41266	4.40483	4.45137	4.40835	4.49375	4.41347	4.42746	4.40999
Apollo Tyres	4.38717	4.37933	4.39346	4.38546	4.41786	4.37935	4.39884	4.39665
Ashok Leyland	4.43849	4.43066	4.45448	4.44221	4.45448	4.43987	4.66735	4.44645
Bharat Forge	4.65192	4.64326	4.68356	4.69764	4.68356	4.67412	4.65119	4.66744
Bosch Ltd.	5.32468	5.31678	5.33564	5.38734	5.39804	5.31895	5.33793	5.33687
Eicher Motors	4.49304	4.48521	4.49762	4.49832	4.49314	4.48553	4.49997	4.48772
Exide Industries	4.62877	4.62094	4.64145	4.66742	4.65365	4.65932	4.63778	4.62113
Hero Motors	4.97216	4.96433	4.99954	4.97349	4.98329	4.96442	5.01794	5.15597
M&M	4.80772	4.79989	4.89007	4.80648	4.89269	4.80032	4.90026	4.88472
Motherson Sumi Systems	4.41732	4.40949	4.48732	4.42675	4.49572	4.39991	4.43671	4.41166
MRF	4.69255	4.68472	4.71267	4.69463	4.78432	4.69532	4.95639	4.68995
Tata Motors	4.55360	4.54578	4.59854	4.57634	4.59955	4.55783	4.56633	4.55964
TVS Motor	4.24170	4.23396	4.29657	4.28623	4.29657	4.27648	4.25333	4.24479

*Note.**Log likelyhood values - For Apollo Tyres : 6766.833 and 6711.472 for GARCH (1,1) and GARCH (2,1) models, respectively: For Bharat Forge : 8211.883 and 8187.562 for GARCH (1,1) and GARCH (2,1) models, respectively.

Table 5. Volatility Estimation by Using GARCH (1, 1) Model

Name of the Stock	ω	α	β	α + β	SIC	AIC	Log Likelihood	Volatility Persistence
Amar Raja Batteries	6.21E-05	0.129979	0.800564	0.930543	4.404835	4.412663	6806.120	9.628783
Apollo Tyres	3.55E-05	0.070940	0.886021	0.956961	4.379334	4.387177	6766.833	15.755980
Ashok Leyland	2.75E-05	0.074520	0.891362	0.965882	4.430667	4.438496	6845.941	19.967594
Bharat Forge	1.88E-05	0.080640	0.891175	0.971815	4.643269	4.651920	7173.667	24.244543
Bosch Ltd	4.48E-05	0.222210	0.669623	0.891833	5.316780	5.324680	8211.883	6.0549360
Eicher Motors	0.000208	0.208332	0.515461	0.723793	4.485211	4.493040	6930.020	2.144307
Exide Industries	8.95E-05	0.116691	0.738420	0.855111	4.620948	4.628776	7139.258	4.428376
Hero Motors	2.30E-05	0.073296	0.875080	0.948376	4.964336	4.972164	7668.591	13.077204
M&M	1.02E-05	0.074693	0.907810	0.982503	4.799893	4.807721	7415.102	39.267608
Motherson Sumi Systems	1.19E-05	0.032763	0.950785	0.983548	4.409498	4.417327	6813.309	41.783952
MRF	9.98E-05	0.166290	0.674052	0.840342	4.684723	4.692551	7237.568	3.9848336
Tata Motors	2.42E-05	0.084496	0.880475	0.964971	4.545780	4.553608	7023.386	19.439176
TVS Motor	6.99E-05	0.113286	0.814004	0.927290	4.233962	4.241701	6542.720	9.182104

Note. All the values are significant at the 5% level.

compared with the AIC and SIC values of all other models and it is found that GARCH (1,1) model is the best fit model for all the selected stocks except in the case of Apollo Tyres and Bharat Forge. In both the cases, the AIC values of GARCH (1,1) are lower than what it is for the remaining models, but the SIC values of GARCH (1,1) model (4.379334 for Apollo Tyres and 4.643269 for Bharat Forge) are higher when compared with the GARCH (2,1) model (4.379315 for Apollo Tyres and 4.674128 for Bharat Forge). Hence, an additional parameter - the log likelihood value - has been taken into account to decide the best fit model. The log likelihood values, a parameter to decide when there is a tie, reveal that the GARCH (1,1) is the best fit model for both the stocks, as per the guidelines, since GARCH (1,1) is having the highest log likelihood values (6766.833 for Apollo Tyres and 8211.883 for Bharat Forge) when compared with the values of GARCH (2,1) model (6711.472 for Apollo Tyres and 8187.562 for Bharat Forge) .

The Table 5 shows the estimates of the GARCH (1,1) model for all the selected stocks of the auto sector of NSE. The values of all the parameters (ω, α, and β) are positive, which satisfy the condition $\omega \geq 0, \alpha \geq 0, \beta \geq 0$ to specify that the model is well defined to understand the volatility of the selected stocks. All the coefficients of lagged squared residuals (α) are positive and significant at the 5% level, showing that the news about previous volatility (past squared residuals term) has an explanatory power on current volatility. All the coefficient (β) values of lagged conditional variance are also positive and significant at the 5% level, and specify that past volatility of stock returns is significantly influencing current volatility. The sum of ARCH and GARCH coefficient ($\alpha + \beta$) values, which is a measure of persistence of variance, of all the selected stocks of the auto sector, is closer to unity (1) except in the case of Eicher Motors (0.723793), MRF (0.840342), Exide Industries (0.855111), and Bosch Ltd. (0.891833), indicating that there is a significant persistence in volatility. Hence, the null hypothesis H03 is rejected and the alternate hypothesis of Ha3 has been accepted. The large sum of these coefficient values implies a large positive or a large negative return, which will lead to a future forecast of the variance to be high for a protracted period. The volatility persistence is very high in the case of Motherson Sumi Systems (41.78395) followed by M & M (39.26760) and Bharat Forge (24.24454), which implies that these stocks experienced high level of volatility lasting for many days during the study period, and the volatility persistence is low in the case of Eicher Motors (2.14430) and Exide Industries (4.42837), revealing very low level of volatility lasting for a very short period.

The Table 6 exhibits the results obtained after applying the ARCH LM test from the residuals of GARCH (1,1) model for the selected stocks. Since all the calculated F - statistics values are lesser than the observed R - square values and the probability values are greater than 0.05 ($p > 0.05$), this confirms the absence of auto regressive

Table 6. Checking Adequacy of GARCH (1,1) Model Using ARCH - LM Test

S.No	Name of the Stock	F - statistic	Prob. F	Obs*R^2	Prob. chi-square
1	Amara Raja Batteries	1.157432	0.2821	1.157748	0.2819
2	Apollo Tyres	0.155519	0.6933	0.155612	0.6932
3	Ashok Leyland	2.777363	0.0957	2.776663	0.0956
4	Bharat Forge	3.219049	0.0729	3.217776	0.0728
5	Bosch Ltd	0.203936	0.6516	0.204055	0.6515
6	Eicher Motors	0.018297	0.8924	0.018309	0.8924
7	Exide Industries	0.034018	0.8537	0.034040	0.8536
8	Hero Motors	1.867655	0.1718	1.867736	0.1717
9	M&M	1.372324	0.2415	1.372603	0.2414
10	Motherson Sumi Systems	0.824370	0.3640	0.824685	0.3638
11	MRF	1.060727	0.3031	1.061050	0.3031
12	Tata Motors	1.433493	0.2313	1.433757	0.2312
13	TVS Motor	1.327442	0.2494	1.327732	0.2492

Table 7. Leverage Effect Estimation Using EGARCH (1,1) and TGARCH (1,1) Models

Name of the Stock		Mean Equation	Variance Equation				AIC	SIC	Log
		μ	ω	α	β	γ			Likelihood
Amara Raja Batteries	EGARCH	0.001819	-0.734435	0. 25155	0.923263	-0.008520	4.409077	4.399291	6801.591
	TGARCH	0.001759	6.43E-05	0.113993	0.796025	0.038623	4.413247	4.403462	6808.021
Apollo Tyres	EGARCH	0.001192	-0.523973	0.168881	0.944641	-0.030692	4.390851	4.381065	6773.496
	TGARCH	0.001257	4.65E-05	0.054848	0.859452	0.062383	4.391063	4.381277	6773.823
Ashok Leyland	EGARCH	0.000966	-0.611851	0.203565	0.936592	-0.028970	4.439133	4.429348	6847.924
	TGARCH	0.001021	3.86E-05	0.062793	0.862794	0.054466	4.441829	4.432044	6852.080
Bharat Forge	EGARCH	0.001248	-0.349626	0.182925	0.971586	-0.026868	4.656036	4.646251	7182.280
	TGARCH	0.001154	1.63E-05	0.056570	0.900607	0.039290	4.653869	4.644084	7178.939
Bosch Ltd.	EGARCH	0.001468	-1.373867	0.379632	0.863582	-0.073038	5.337889	5.328104	8233.356
	TGARCH	0.001537	4.79E-05	0.159362	0.647306	0.171138	5.331469	5.321684	8223.459
Eicher Motors	EGARCH	0.002234	-2.438166	0.409727	0.706254	-0.07395	4.500817	4.491032	6943.010
	TGARCH	0.002230	0.000200	0.142312	0.515879	0.181299	4.498815	4.489029	6939.923
Exide Industries	EGARCH	0.001087	-0.980090	0.200344	0.888192	-0.025162	4.627341	4.617556	7138.046
	TGARCH	0.001118	8.05E-05	0.075597	0.760707	0.069593	4.631026	4.621241	7143.727
Hero Motors	EGARCH	0.000470	-0.715945	0.185474	0.925817	-0.004833	4.973372	4.963586	7671.452
	TGARCH	0.000633	2.63E-05	0.070593	0.863205	0.014463	4.971703	4.961918	7668.880
M&M	EGARCH	0.001213	-0.291911	0.163343	0.978167	-0.038121	4.807728	4.797943	7416.113
	TGARCH	0.001228	1.17E-05	0.052128	0.903545	0.048232	4.811220	4.801435	7421.496
Motherson Sumi	EGARCH	0.001294	-0.083409	0.054688	0.993963	-0.040822	4.424231	4.414445	6824.521
Systems	TGARCH	0.001369	5.03E-05	0.001456	0.972039	0.046886	4.433900	4.424114	6839.856
MRF	EGARCH	0.001552	-1.697311	0.325794	0.804502	-0.008452	4.686143	4.676358	7228.689
	TGARCH	0.001122	9.96E-05	0.165630	0.674373	0.001405	4.691904	4.682118	7237.569
Tata Motors	EGARCH	0.000787	-0.314102	0.158738	0.973979	-0.035888	4.550028	4.540242	7018.868
	TGARCH	0.000873	2.23E-05	0.053131	0.889752	0.049344	4.557469	4.547684	7030.339
TVS Motor	EGARCH	0.000898	-0.812203	0.243017	0.910356	-0.014535	4.236354	4.226569	6535.340
	TGARCH	0.000978	7.21E-05	0.104528	0.809090	0.024718	4.241691	4.231906	6543.567

*Note.** γ values are significant at the 5% level.

conditional heteroskedasticity effect in the residuals of the return series after the estimation of GARCH (1,1) model.

The Table 7 reports the results obtained from applying EGARCH (1,1) and TGARCH (1,1) models to capture the asymmetries in the return series of the selected auto sector stocks of NSE. The calculated values from EGARCH (1,1) model reveal that the leverage effect exists in the selected stocks during the study period. The calculated values of 'γ' - which is used to notify the leverage effect - are negative and statistically significant (p - values are less than 0.05) for all the stocks, which reveals that negative shocks have more impact than the positive shocks on the volatility of the selected stocks. Hence, the null hypothesis H04 is rejected and the alternate hypothesis Ha4 has been accepted. The calculated GARCH (β) values of all the stocks are positive and closer to unity (1), expressing the fact that the volatility persistence is explosive except in case of Bosch (0.863582), Eicher Motors (0.706254), Exide Industries (0.888192), and MRF (0.804502).

The results obtained from an alternative model - TGARCH (1,1) model also confirm that the leverage effect is present in the auto sector stocks during the study period. As per the decision rule, the calculated coefficient values of 'γ' for all the stocks are positive and significant at the 5%level. The calculated GARCH values (β) from this model also confirm that the volatility is persistent during the study period except in the stocks like Bosch (0.647306), Eicher Motors (0.515879), Exide Industries (0.760707), and MRF (0.674373).

To select the best fit model to understand the leverage effect, the values of Akaike information criterion (AIC), Schwarz information criterion (SIC), and log likelihood for both EGARCH (1,1) and TGARCH (1,1) were compared with each other and it is observed that EGARCH (1,1) is the most suitable one for the selected stocks, since the calculated AIC and SIC values from EGARCH (1,1) model are lower than the calculated values from TGARCH (1,1) model, except for the stocks like Bharat Forge, Bosch, Eicher Motors, and Hero Motors. However, to estimate the leverage effect of Bharat Forge, Bosch, Eicher Motors, and Hero Motors, as per the guidelines, TGARCH (1,1) is the suitable model when compared with the other alternative models.

Summary of Findings

(1) It is found that the return series of all the 13 selected stocks of the auto sector index of NSE do not have normal distribution. They are either positively or negatively skewed and the kurtosis values are greater than 3, which implies that the return series are leptokurtic in nature. The daily mean returns of these stocks are positive, and it is highest in case of Eicher Motors (0.001739) followed by Motherson Sumi Systems (0.001704), and lowest in case of Tata Motors (0.000772) and TVS Motor (0.000778).

(2) It is found from the results of Augmented Dickey Fuller test and Philips Perron test that the natural logarithmic values of daily return series of all the stocks selected for this study are stationary (at level) in nature. The calculated absolute test statistic values for all the stocks taken for the study are much higher than the absolute test critical values (MacKinnon critical value) at the 5% level, which rejects the null hypothesis as the variable has a unit root problem.

(3) The residual diagnostic tests conducted to find the presence of ARCH effect in the daily return series of all the selected stocks reveal that the ARCH effect exists in all the return series taken for this study. The calculated *F*-statistics values for all the selected stocks are well above the observed *R* - square values, and they are significant at the 1% level. The null hypothesis is rejected and proves that the return series of all the stocks have the ARCH effect. This necessitates the application of GARCH family models to understand the volatility patterns of the selected stocks.

(4) In order to understand the best-fit model to estimate the volatility pattern of the selected auto sector stocks, Akaike information criterion, Schwarz information criterion, and log likelihood values from the results of GARCH (1,1), GARCH (1, 2), GARCH (2,1), and GARCH (2, 2) are considered and it is observed that GARCH (1,1) is the best-fit model for a majority of the selected stocks.

(5) From the calculations of GARCH (1,1) for auto sector stocks of NSE, it is found that there exists significant persistence in volatility among these stocks except in the case of Eicher Motors, Exide Industries, and Bosch. The volatility persistence is very high in the case of Motherson Sumi Systems (41.78395) followed by M & M (39.26760) and Bharat Forge (24.24454), which implies that these stocks experienced high level of volatility which lasted for many days during the study period, and it is lesser in the case of Eicher Motors (2.14430), Exide

(4.42837), and Bosch (6.05493), which reveals that very low level of volatility was experienced in these stocks which lasted for a very short period.

(6) It is found from the ARCH-LM test conducted to find out the presence of heteroskedasticty in the residuals obtained after application of GARCH (1,1) model in all the selected stocks that there is no evidence of ARCH effect remaining in the return series. This is an indication of perfection of the model as there is no ARCH effect remaining that needs to be modeled by any other GARCH model.

(7) It is found that the EGARCH (1,1) model is the most suitable model to understand the leverage effect of all the selected stocks of the auto sectoral index of NSE except Bharat Forge, Bosch, Eicher Motors, and Hero Motors. It is also found from the calculated values of EGARCH (1,1) model that the leverage effect exists in all the selected stocks during the study period. The calculated values of 'γ' are negative and statistically significant (*p* - values are less than 0.05) for all the stocks, which reveals that negative shocks have more impact than the positive shocks on the volatility of the selected stocks.

Conclusion

An attempt is made in this research work to frame a model for the volatility, leverage effect among the auto sectoral stocks of NSE. The daily closing prices of selected stocks for 12.5 years, starting from April 24, 2003 to September 7, 2015 (the period consisting of three bull and three bear phases) were collected and modeled by using the GARCH family models. These models were employed in this research work after confirming the unit root test, volatility clustering, and auto regressive conditional heteroskedasticity effect. While estimating the symmetric volatility, GARCH (1,1) model is found to be a better model as it was found by Padhi (2006) and Banumathy and Azhagaiah (2015), and the same was employed to address the volatility persistence. The findings of this study report that the Indian equity market exhibits the persistence of volatility and confirms that the majority of the selected stocks experienced a high level of volatility during the study period, and our findings are consistent with the findings of the study conducted by Karmakar (2005).

To investigate the presence of asymmetric volatility, named leverage effect, EGARCH (1,1) and TGARCH (1,1) models were employed. The results show that the coefficient has the expected sign both in the EGARCH (negative and significant) and TGARCH (positive and significant) models. The findings of the study reveal that the leverage effect exists in the Indian equity market, where a negative shock causes more volatility than the positive one of the same magnitude. In the process of selecting the best-fitting model among these, to understand the leverage effect, AIC and SIC values were used, which prove that EGARCH (1,1) model is the best fitted model to capture the asymmetric volatility for majority of the selected stocks as per the AIC and SIC criterion.

Our findings in this regard differ from the findings of the Banumathy and Azhagaiah (2015), who concluded that TGARCH (1,1) was the appropriate model to capture the asymmetric volatility. On a whole, this study concludes that the Indian equity market experienced symmetric volatility during the study period and it was not insulated from the leverage effect too. Any negative nature of information to the market delivers more volatility than the positive one of the same magnitude.

Research Implications, Limitations of the Study, and Scope for Further Research

A study of this kind would be more useful to the budding investors, who put their hard - earned money in the equity market to understand the level of volatility in the market and to know how to tide through the bumpy and volatile market situations.

This study suffers from the limitations of not including the analysis of the intraday volatility of the Indian equity market. Hence, a similar research may be conducted for a short term period by considering the intraday price behaviour within an hour interval, which could throw up different findings about the short term volatility and can give a better insight into the presence or absence of the leverage effect.

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