Volatility Forecast of BSE Ltd., Broad Indices

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Abstract

Volatility plays a very important role in any financial market around the world. Accurate forecasting of volatility is essential for taking wise and timely decisions for transacting financial products and to manage other financial applications. The goal of any volatility model is to be able to forecast volatility. In this paper "VOLATILITY FORECAST OF BSE LTD. BROAD INDICES", focuses on volatility forecasting through three widely used time series volatility models namely, the Historical Variance, time series of univariate data, the Generalized Autoregressive Conditional Heteroscedastic Model (GARCH) and the Risk Metrics, Exponential Weighted Moving Average (EWMA) . The characteristics of these volatility models are explored using monthly data on the BSE broad indices for a period of 4 years. (Jan 2010 to Jan 2014). "VOLATILITY FORECAST OF BSE LTD. BROAD INDICES", analysis through GARCH(1,1) of BSE S&P, BSE MIDCAP, BSE SMALL CAP, BSE 100, BSE 200 and S&P 500 have shown the volatility ranging from 1.52 to 6.87%, whereas the same indices through Exponential Generalized Autoregressive Conditional Heteroscedastic Model (EGARCH)model has shown the volatility range from 4.55 to 10.59%.

Keywords: Volaitity forecast, BSE broad indices, Time series, Generalized Autoregressive Conditional Heteroscedastic Model (GARCH), Risk metrics, Exponential Weighted Moving Average (EWMA)

Introduction

The paper entitled "**VOLATILITY FORECAST OF BSE LTD. BROAD INDICES**" attempts to present the volatility forecast of the BSE broad indices for a period of one year from Jan 2014. The six BSE broad indices are widely chosen by the investors and forecasting volatility for the same carries significance for investment decisions. Hence the study is focused on forecasting the volatility of BSE S&P SENSEX, BSE SMALL CAP INDICES, BSE MID CAP INDICES, BSE 100, BSE 200 AND BSE 500 INDICES. BSE was established in 1875, BSE Ltd. (formerly known as Bombay Stock Exchange Ltd.), which is presently Asia's first Stock Exchange and one of India's leading exchange groups. Over the past 137 years, BSE has facilitated the growth of the Indian corporate sector by providing it an efficient capital-raising platform. More than 5000 companies are listed on BSE making it world's No. 1 exchange in terms of listed members. The companies listed on BSE Ltd command a total market capitalization of USD 1.32 Trillion as of January 2013. It is also one of the world's leading exchanges (3rd largest in December 2012) for Index options trading (Source: World Federation of Exchanges).

Research Methodology

- **Source of Data:** The data is collected from the bseindia.com and analyzed by using the NUMXL software Excel addin.
- **Objective:** To find out the BSE broad indices volatility.
- **Study period:** Period of 4 years from 2010 January to 2014 January is taken.
- **Techniques used:**
- **Log returns:** log returns are calculated for the

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monthly returns which can provide better values distribution prices between January 2010 and July 2014.

- **WMA:** A Weighted Moving Average (WMA) assigns a weighting factor to each value in the data series according to its age. The most recent data gets the greatest weight and each price value gets a smaller weight as it counts backward in the series.
- **EWMA:** is computed to estimate the next-day (or period) volatility of a time series and closely track the volatility as it changes. EWMA is basically a special form of an ARCH() model where the ARCH order is equal to the sample data size and the weights are exponentially declining at rate λ throughout time. (lambda 0.94).
- **Correlogram:** To find out the ACF and PACF to understand the lag order position and decide the model.
- **EGARCH (1,1):** Volatility forecasting through econometric models have gained wide popularity. Egarch analysis, the exponential general autoregressive conditional Heteroscedasticity (model by Nelson (1991) is another form of the GARCH model. The exponential general autoregressive conditional heteroskedastic (E-GARCH) model by Nelson (1991) is another form of the GARCH model. Formally, an EGARCH(p,q):

$$x_t = \mu + a_t$$

$$\ln \sigma_t^2 = \alpha_0 + \sum_{i=1}^{p} \alpha_i \left(|\epsilon_{t-i}| + \gamma_i \epsilon_{t-i} \right) + \sum_{j=1}^{q} \beta_j \ln \sigma_{t-j}^2$$

$$a_t = \sigma_t \times \epsilon_t$$

$$\epsilon_t \sim P_v(0,1)$$

Where:
- x_t is the time series value at time t.
- μ is the mean of GARCH model.
- a_t is the model's residual at time t.
- σ_t is the conditional standard deviation (i.e. volatility) at time t.
- p is the order of the ARCH component model.
- $\alpha_0, \alpha_1, \alpha_2, ..., \alpha_p$ are the parameters of the ARCH component model.
- q is the order of the GARCH component model.
- $\beta_1, \beta_2, ..., \beta_q$ are the parameters of the GARCH component model.

$|\epsilon_t|$ are the standardized residuals:

$$|\epsilon_t| \sim i.i.d$$

$$E[\epsilon_t] = 0$$

$$VAR[\epsilon_t] = 1$$

P_v is the probability distribution function for ϵ_t. Currently, the following distributions are supported:

Normal distribution P_{\nu} = N(0,1)

Student's t-distribution

$$P_v = t_v(0,1)$$

$$\nu > 4$$

Generalized error distribution (GED)

$$P_v = GED_v(0,1)$$

$$\mu > 1$$

The E-GARCH model differs from GARCH in several ways. For instance, it used the logged conditional variances to relax the positiveness constraint of model coefficients. EGARCH (p,q) model has 2p+q+2 estimated parameters.

EGARCH_VL (alphas, betas, innovation, v)
Alphas are the parameters of the ARCH(p) component model (starting with the lowest lagi).
Betas are the parameters of the GARCH(q) component model (starting with the lowest lag).
Innovation is the probability distribution model for the innovations/residuals (1=Gaussian, 2=t-Distribution, 3=GED). If missing, a gaussian distribution is assumed.
1   Gaussian or Normal Distribution (default)
2   Student's t-Distribution
3   Generalized Error Distribution (GED)

V is the shape parameter (or degrees of freedom) of the innovations/residuals probability distribution function.

The EGARCH long-run average log variance is defined as:

$$\ln V_L = \frac{\alpha_0 + r_i \times \sum_{i=1}^{p} \alpha_i}{1 - \sum_{j=1}^{q} \beta_j}$$

Where:
Gaussian distributed innovations/shocks:

GED distributed innovations/shocks.

$$\eta - \sqrt{\frac{\pi}{2}}$$

Student's t-Distributed innovations/shocks.

$$r_i = \frac{\Gamma(2/v)}{\sqrt{\Gamma(1/v) \times \Gamma(3/v)}}$$

The time series is homogeneous or equally spaced.

$$\eta = \frac{\sqrt{v-2} \times \Gamma\left(\frac{v-1}{2}\right)}{\sqrt{\pi} \times \Gamma\left(\frac{v}{2}\right)}$$

The number of gamma-coefficients must match the number of alpha-coefficients.

The number of parameters in the input argument - alpha - determines the order of the ARCH component model.

The number of parameters in the input argument - beta - determines the order of the GARCH component model.

GARCH MODEL (1,1):
An autoregressive moving average model (ARMA model) is assumed for the error variance, the model is a generalized autoregressive conditional heteroskedasticity (*GARCH in Excel*, Bollerslev(1986)) model.

$$x_t = \mu + a_t$$

$$\sigma_t^2 = \alpha_o + \sum_{i=1}^{p} \alpha_i a_{t-i}^2 + \sum_{j=1}^{q} \beta_j \sigma_{t-j}^2$$

$$a_t = \sigma_t \times \epsilon_t$$

$$\epsilon_t \sim P_v(0,1)$$

Where:

- x_t is the time series value at time t.
- μ is the mean of GARCH in Excel model.
- a_t is the model's residual at time t.
- σ_t is the conditional standard deviation (i.e. volatility) at time t.
- p is the order of the ARCH component model.
- $\alpha_o, \alpha_1, \alpha_2, ..., \alpha_p$ are the parameters of the ARCH component model.
- q is the order of the GARCH component model.
- $\beta_1, \beta_2, ..., \beta_q$ are the parameters of the GARCH component model.
- $|\epsilon_t|$ are the standardized residuals:

$$|\epsilon_t| \sim i.i.d$$
$$E|\epsilon_t| = 0$$
$$VAR|\epsilon_t| = 1$$

P_v is the probability distribution function for ϵ_t.

P_v Normal distribution: $P_v \quad N(0,1)$

Student's t-distribution: $P_v = t_v(0,1) , v > 4$

Generalized error distribution (GED): $P_v \quad GED_v(0,1)$

Review of Literature

Padhi (2005) explained the stock market volatility at the individual script level and at the aggregate indices level. The empirical analysis has been done by using ARCH, GARCH model and ARCH in Mean model and it is based on daily data for the time period from January 1990 to November 2004. The analysis reveals 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 is persistent for all the five aggregate indices and individual company. Karmakar (2006) measured the volatility of daily stock return in the Indian stock market over the period of 1961 to 2005. Using GARCH model, he found strong evidence of' time varying volatility. He also used the TGARCH model to test the asymmetric volatility effect and the result suggests the asymmetry in volatility. Rao, Kanagaraj and Tripathy (2008) attempts to determine the impact of individual stock futures on the underlying stock market volatility in India by applying both GARCH and ARCH model for a period of seven years from June 1999 to July 2006. This study includes stock of 10 companies i.e Reliance, SBI, TISCO, ACC, MTNL, TATA Power, TATA Tea, BHEL, MAHINDRA & MAHINDRA and ITC. The results suggest that stock future derivatives are not responsible for increase or decrease in spot market volatility and conclude that there could be other market factors that have helped the increase in Nifty volatility. Vuyyuri and Roy (2003) modelled the monthly volatility of market indices (Sensex & S&PCNX-Nifty) of Indian capital markets using eight different univariate models. Out-of-sample forecasting performance of these models has been evaluated using different symmetric, as well as asymmetric loss functions. The GARCH (1, 1) model has been found to be the overall superior model based on most of the symmetric loss functions, though ARCH has been found to be better than the other models for investors who are more concerned about under predictions than over predictions.

The data analysis is presented in the following order:

1. Tables showing monthly log returns of all six BSE BROAD INDICES followed by graphs. WMA and EWMA are calculated for finding out the stationarity.
2. Descriptive statistics of the selected sample.
3. Stationarity, distribution and Arch values are computed to find out white noise, distribution and arch effect.
4. Corrrelogram analysis is made to find the best fit model.
5. Garch and EGARCH models are used and calibrated to understand the goodness of fit.
6. Volatility forecasting is done through GARCH_vl and EGARCH_vl functions.
7. Graphs are prepared to present the term structure and standard deviation.

Table 1: BSE S&P INDEX

Month	Open	High	Low	Close	% RET	WMA	EWMA
10-Jan	17,473.45	17,790.33	15,982.08	16,357.96	#N/A	#N/A	
10-Feb	16,339.32	16,669.25	15,651.99	16,429.55	0.44%	#N/A	
10-Mar	16,438.45	17,793.01	16,438.45	17,527.77	6.47%	0.44%	0.00%
10-Apr	17,555.04	18,047.86	17,276.80	17,558.71	0.18%	3.45%	3.02%
10-May	17,536.86	17,536.86	15,960.15	16,944.63	-3.56%	2.36%	2.12%
10-Jun	16,942.82	17,919.62	16,318.39	17,700.90	4.37%	0.88%	1.40%
10-Jul	17,679.34	18,237.56	17,395.58	17,868.29	0.94%	1.58%	2.01%
10-Aug	17,911.31	18,475.27	17,819.99	17,971.12	0.57%	1.47%	2.03%
10-Sep	18,027.12	20,267.98	18,027.12	20,069.12	11.04%	1.34%	1.92%
10-Oct	20,094.10	20,854.55	19,768.96	20,032.34	-0.18%	2.56%	2.54%
10-Nov	20,272.49	21,108.64	18,954.82	19,521.25	-2.58%	2.25%	3.12%
10-Dec	19,529.99	20,552.03	19,074.57	20,509.09	4.94%	1.77%	2.97%
11-Jan	20,621.61	20,664.80	18,038.48	18,327.76	-11.25%	2.06%	3.15%
11-Feb	18,425.18	18,690.97	17,295.62	17,823.40	-2.79%	0.95%	3.05%
11-Mar	17,982.28	19,575.16	17,792.17	19,445.22	8.71%	0.68%	4.18%
11-Apr	19,463.11	19,811.14	18,976.19	19,135.96	-1.60%	0.87%	4.23%
11-May	19,224.05	19,253.87	17,786.13	18,503.28	-3.36%	0.72%	4.48%
11-Jun	18,527.12	18,873.39	17,314.38	18,845.87	1.83%	0.73%	4.37%
11-Jul	18,974.96	19,131.70	18,131.86	18,197.20	-3.50%	0.52%	4.36%
11-Aug	18,352.23	18,440.07	15,765.53	16,676.75	-8.73%	0.15%	4.23%
11-Sep	16,963.67	17,211.80	15,801.01	16,453.76	-1.35%	-0.62%	4.21%
11-Oct	16,255.97	17,908.13	15,745.43	17,705.01	7.33%	-1.66%	4.62%

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11-Nov	17,540.55	17,702.26	15,478.69	16,123.46	-9.36%	-1.03%	4.53%
11-Dec	16,555.93	17,003.71	15,135.86	15,454.92	-4.23%	-1.59%	4.71%
12-Jan	15,534.67	17,258.97	15,358.02	17,193.55	10.66%	-2.36%	5.09%
12-Feb	17,179.64	18,523.78	17,061.55	17,752.68	3.20%	-0.53%	5.09%
12-Mar	17,714.62	18,040.69	16,920.61	17,404.20	-1.98%	-0.03%	5.56%
12-Apr	17,429.96	17,664.10	17,010.16	17,318.81	-0.49%	-0.92%	5.44%
12-May	17,370.93	17,432.33	15,809.71	16,218.53	-6.56%	-0.83%	5.30%
12-Jun	16,217.48	17,448.48	15,748.98	17,429.98	7.20%	-1.10%	5.14%
12-Jul	17,438.68	17,631.19	16,598.48	17,236.18	-1.12%	-0.65%	5.25%
12-Aug	17,244.44	17,972.54	17,026.97	17,429.56	1.12%	-0.45%	5.37%
12-Sep	17,465.60	18,869.94	17,250.80	18,762.74	7.37%	0.37%	5.22%
12-Oct	18,784.64	19,137.29	18,393.42	18,505.38	-1.38%	1.09%	5.08%
12-Nov	18,487.90	19,372.70	18,255.69	19,339.90	4.41%	0.37%	5.21%
12-Dec	19,342.83	19,612.18	19,149.03	19,426.71	0.45%	1.52%	5.07%
13-Jan	19,513.45	20,203.66	19,508.93	19,894.98	2.38%	1.91%	5.01%
13-Feb	19,907.21	19,966.69	18,793.97	18,861.54	-5.33%	1.22%	4.85%
13-Mar	18,876.68	19,754.66	18,568.43	18,835.77	-0.14%	0.50%	4.74%
13-Apr	18,890.81	19,622.68	18,144.22	19,504.18	3.49%	0.66%	4.80%
13-May	19,459.33	20,443.62	19,451.26	19,760.30	1.30%	0.99%	4.66%
13-Jun	19,859.22	19,860.19	18,467.16	19,395.81	-1.86%	1.65%	4.58%
13-Jul	19,352.48	20,351.06	19,126.82	19,345.70	-0.26%	0.89%	4.44%
13-Aug	19,443.29	19,569.20	17,448.71	18,619.72	-3.82%	0.96%	4.34%
13-Sep	18,691.83	20,739.69	18,166.17	19,379.77	4.00%	0.55%	4.22%
13-Oct	19,452.05	21,205.44	19,264.72	21,164.52	8.81%	0.27%	4.21%
13-Nov	21,158.81	21,321.53	20,137.67	20,791.93	-1.78%	1.12%	4.19%
13-Dec	20,771.27	21,483.74	20,568.70	21,170.68	1.81%	0.60%	4.54%
14-Jan	21,222.19	21,409.66	20,343.78	20,513.85	-3.15%	0.72%	4.43%
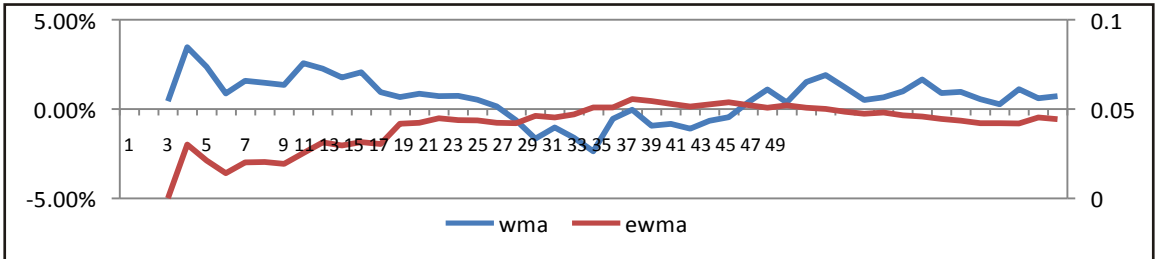
Graph 1: BSE S&P INDEX

Table 2: BSE 100

Month	Open	High	Low	Close	% ret	wma	ewma
10-Jan	5,343.39	5,479.32	4,924.25	5,050.54	#N/A	#N/A	
10-Feb	5,021.36	5,145.20	4,856.17	5,079.94	0.58%	#N/A	
10-Mar	5,131.29	5,459.67	5,128.21	5,394.12	6.00%	0.58%	0.00%
10-Apr	5,423.04	5,551.48	5,316.13	5,439.84	0.84%	3.29%	2.71%
10-May	5,410.90	5,423.35	4,935.68	5,243.91	-3.67%	2.48%	2.03%
10-Jun	5,231.30	5,509.89	5,098.68	5,476.70	4.34%	0.94%	1.25%
10-Jul	5,447.33	5,644.63	5,400.14	5,542.87	1.20%	1.62%	1.90%
10-Aug	5,583.58	5,739.15	5,536.06	5,584.08	0.74%	1.55%	1.94%
10-Sep	5,612.42	6,230.59	5,606.04	6,163.86	9.88%	1.43%	1.84%
10-Oct	6,193.48	6,432.74	6,097.53	6,171.18	0.12%	2.49%	2.35%
10-Nov	6,229.05	6,491.89	5,747.61	5,962.87	-3.43%	2.23%	2.82%
10-Dec	5,967.21	6,201.86	5,787.93	6,191.51	3.76%	1.66%	2.66%
11-Jan	6,219.56	6,241.93	5,456.59	5,550.03	-10.94%	1.85%	2.91%
11-Feb	5,574.59	5,643.69	5,209.44	5,370.50	-3.29%	0.79%	2.82%
11-Mar	5,408.53	5,889.22	5,393.29	5,855.53	8.65%	0.46%	3.95%
11-Apr	5,858.31	5,989.65	5,753.91	5,795.29	-1.03%	0.68%	4.02%
11-May	5,817.32	5,825.72	5,403.47	5,638.16	-2.75%	0.53%	4.31%
11-Jun	5,644.23	5,694.20	5,275.65	5,686.26	0.85%	0.60%	4.19%
11-Jul	5,717.27	5,791.78	5,524.40	5,531.70	-2.76%	0.31%	4.15%
11-Aug	5,568.18	5,602.55	4,797.15	5,062.17	-8.87%	-0.02%	4.02%
11-Sep	5,132.47	5,232.35	4,833.74	4,995.67	-1.32%	-0.82%	3.98%

| 11-Oct	4,950.13	5,372.23	4,794.95	5,334.14	6.56%	-1.75%	4.43%
11-Nov	5,295.02	5,349.84	4,651.21	4,831.73	-9.89%	-1.21%	4.34%
11-Dec	4,938.91	5,093.14	4,516.41	4,598.21	-4.95%	-1.75%	4.48%
12-Jan	4,616.42	5,215.05	4,560.67	5,202.65	12.35%	-2.48%	4.94%
12-Feb	5,198.68	5,658.18	5,171.83	5,406.46	3.84%	-0.54%	4.99%
12-Mar	5,393.04	5,520.13	5,155.64	5,315.15	-1.70%	0.06%	5.69%
12-Apr	5,320.66	5,411.04	5,177.60	5,268.41	-0.88%	-0.81%	5.59%
12-May	5,296.69	5,302.89	4,811.28	4,942.13	-6.39%	-0.79%	5.44%
12-Jun	4,931.16	5,283.02	4,786.41	5,279.22	6.60%	-1.10%	5.28%
12-Jul	5,290.08	5,356.98	5,046.93	5,229.16	-0.95%	-0.62%	5.36%
12-Aug	5,225.41	5,426.50	5,175.70	5,251.07	0.42%	-0.47%	5.43%
12-Sep	5,260.07	5,733.12	5,200.44	5,701.39	8.23%	0.31%	5.28%
12-Oct	5,706.23	5,825.42	5,583.93	5,620.99	-1.42%	1.10%	5.13%
12-Nov	5,619.91	5,914.16	5,567.27	5,908.97	5.00%	0.44%	5.33%
12-Dec	5,910.31	6,010.14	5,881.67	5,975.74	1.12%	1.68%	5.18%
13-Jan	5,998.53	6,172.30	5,997.95	6,091.49	1.92%	2.18%	5.15%
13-Feb	6,094.62	6,117.33	5,698.19	5,720.10	-6.29%	1.31%	4.99%
13-Mar	5,723.61	5,988.12	5,595.58	5,678.70	-0.73%	0.47%	4.86%
13-Apr	5,694.03	5,969.74	5,490.97	5,941.35	4.52%	0.55%	4.99%
13-May	5,931.90	6,246.37	5,928.66	5,991.11	0.83%	1.00%	4.84%
13-Jun	6,015.01	6,015.01	5,546.07	5,802.30	-3.20%	1.60%	4.80%
13-Jul	5,799.54	6,067.37	5,630.83	5,707.16	-1.65%	0.79%	4.66%
13-Aug	5,737.99	5,773.14	5,116.81	5,447.15	-4.66%	0.73%	4.60%
13-Sep	5,470.19	6,095.95	5,321.17	5,723.40	4.95%	0.31%	4.49%
13-Oct	5,739.12	6,280.66	5,684.77	6,270.72	9.13%	0.03%	4.52%
13-Nov	6,270.99	6,330.48	5,973.17	6,177.75	-1.49%	0.91%	4.53%
13-Dec	6,177.55	6,399.06	6,133.37	6,326.72	2.38%	0.37%	4.88%
14-Jan	6,343.75	6,381.76	5,998.01	6,071.02	-4.13%	0.48%	4.75%
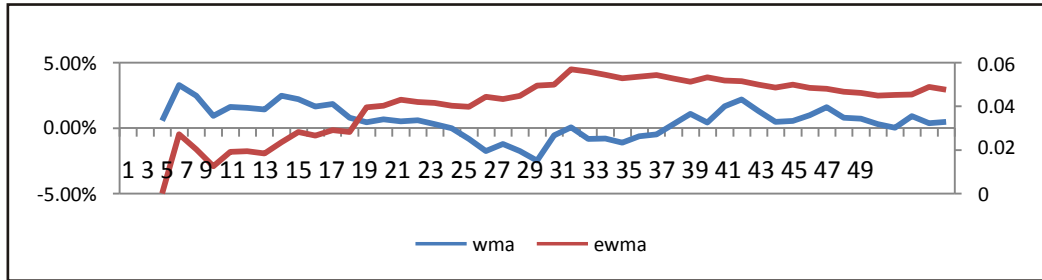
Graph 2: BSE 100

Table 3: BSE 200

Month	Open	High	Low	Close	%ret	wma	ewma
10-Jan	2,178.01	2,242.47	2,011.14	2,065.21	#N/A	#N/A	
10-Feb	2,053.93	2,103.13	1,990.25	2,071.72	0.31%	#N/A	
10-Mar	2,091.42	2,224.31	2,091.42	2,199.50	5.99%	0.31%	2.84%
10-Apr	2,210.53	2,267.07	2,175.22	2,230.17	1.38%	3.15%	2.84%
10-May	2,218.91	2,224.56	2,026.84	2,152.21	-3.56%	2.56%	2.33%
10-Jun	2,147.54	2,257.99	2,099.94	2,248.06	4.36%	1.03%	1.36%
10-Jul	2,237.38	2,319.47	2,219.05	2,281.63	1.48%	1.70%	2.06%
10-Aug	2,297.17	2,371.08	2,283.12	2,302.88	0.93%	1.66%	2.08%
10-Sep	2,313.81	2,557.24	2,313.75	2,530.47	9.42%	1.56%	1.97%
10-Oct	2,541.63	2,644.37	2,512.75	2,541.85	0.45%	2.54%	2.50%
10-Nov	2,562.44	2,671.95	2,354.94	2,451.45	-3.62%	2.31%	2.86%
10-Dec	2,453.00	2,538.19	2,366.71	2,533.90	3.31%	1.71%	2.64%
11-Jan	2,543.96	2,557.05	2,229.16	2,270.22	-10.99%	1.86%	2.91%
11-Feb	2,279.03	2,303.24	2,122.78	2,185.86	-3.79%	0.79%	2.75%
11-Mar	2,199.48	2,391.35	2,198.60	2,378.69	8.45%	0.45%	3.90%
11-Apr	2,379.69	2,441.31	2,349.55	2,363.68	-0.63%	0.65%	4.01%
11-May	2,371.58	2,375.99	2,204.88	2,301.65	-2.66%	0.48%	4.29%
11-Jun	2,303.82	2,319.15	2,155.87	2,314.65	0.56%	0.56%	4.16%
11-Jul	2,325.75	2,361.08	2,253.99	2,256.48	-2.55%	0.24%	4.11%
11-Aug	2,269.53	2,284.75	1,955.28	2,061.08	-9.06%	-0.09%	3.98%
11-Sep	2,086.41	2,131.58	1,968.11	2,028.27	-1.60%	-0.92%	3.92%
11-Oct	2,011.86	2,167.52	1,947.72	2,155.58	6.09%	-1.84%	4.39%

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11-Nov	2,141.49	2,163.27	1,880.74	1,953.03	-9.87%	-1.37%	4.31%
11-Dec	1,991.63	2,053.99	1,819.80	1,850.89	-5.37%	-1.89%	4.42%
12-Jan	1,857.46	2,102.54	1,835.84	2,097.94	12.53%	-2.62%	4.87%
12-Feb	2,096.51	2,289.67	2,087.61	2,190.92	4.34%	-0.66%	4.96%
12-Mar	2,186.05	2,237.66	2,092.37	2,157.89	-1.52%	0.02%	5.70%
12-Apr	2,161.45	2,197.57	2,100.07	2,136.82	-0.98%	-0.81%	5.62%
12-May	2,148.08	2,150.62	1,953.17	2,003.10	-6.46%	-0.84%	5.46%
12-Jun	1,998.91	2,139.50	1,940.89	2,138.10	6.52%	-1.16%	5.30%
12-Jul	2,142.59	2,171.00	2,046.69	2,114.47	-1.11%	-0.66%	5.39%
12-Aug	2,113.29	2,193.84	2,097.30	2,124.06	0.45%	-0.54%	5.45%
12-Sep	2,126.75	2,320.21	2,106.35	2,307.58	8.29%	0.25%	5.29%
12-Oct	2,312.66	2,358.00	2,260.96	2,276.15	-1.37%	1.08%	5.15%
12-Nov	2,276.46	2,391.64	2,254.73	2,389.51	4.86%	0.45%	5.36%
12-Dec	2,391.68	2,436.97	2,384.74	2,424.38	1.45%	1.68%	5.21%
13-Jan	2,435.31	2,498.11	2,435.31	2,461.12	1.50%	2.25%	5.16%
13-Feb	2,463.69	2,471.54	2,299.53	2,307.98	-6.42%	1.33%	5.01%
13-Mar	2,311.98	2,412.78	2,253.50	2,287.96	-0.87%	0.43%	4.88%
13-Apr	2,295.20	2,399.33	2,215.44	2,388.98	4.32%	0.49%	5.01%
13-May	2,384.85	2,509.17	2,384.85	2,409.22	0.84%	0.93%	4.87%
13-Jun	2,416.46	2,416.46	2,223.69	2,323.83	-3.61%	1.54%	4.82%
13-Jul	2,324.56	2,419.77	2,238.98	2,270.93	-2.30%	0.69%	4.67%
13-Aug	2,285.47	2,295.98	2,041.82	2,167.96	-4.64%	0.59%	4.63%
13-Sep	2,177.15	2,417.42	2,121.30	2,281.93	5.12%	0.17%	4.53%
13-Oct	2,288.56	2,494.21	2,267.48	2,490.49	8.75%	-0.09%	4.55%
13-Nov	2,492.65	2,515.46	2,383.74	2,463.86	-1.08%	0.75%	4.58%
13-Dec	2,467.32	2,547.57	2,449.47	2,530.58	2.67%	0.26%	4.89%
14-Jan	2,537.73	2,552.71	2,394.65	2,425.46	-4.24%	0.36%	4.75%
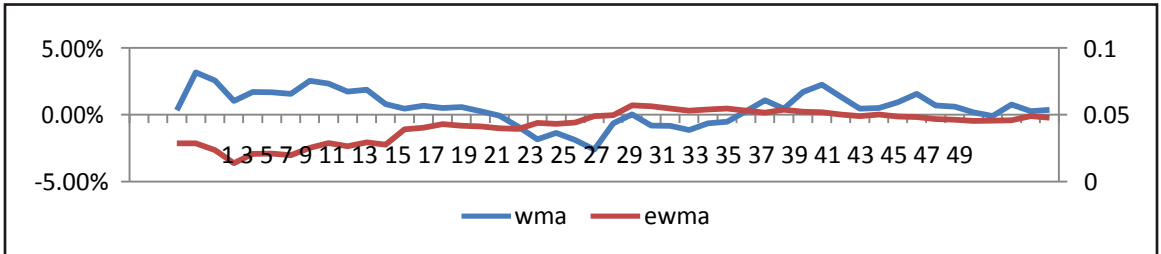
Graph 3: BSE 200

Table 4: S&P 500

Month	Open	High	Low	Close	% ret	wma	ewma
10-Jan	6,839.38	7,070.37	6,338.25	6,509.90	#N/A	#N/A	
10-Feb	6,477.83	6,639.59	6,280.99	6,518.38	5.97%	#N/A	
10-Mar	6,576.07	6,987.88	6,576.07	6,919.55	1.76%	5.97%	2.10%
10-Apr	6,952.74	7,140.21	6,863.81	7,042.68	-3.77%	3.87%	2.10%
10-May	7,009.94	7,028.13	6,396.74	6,782.37	4.47%	1.32%	4.51%
10-Jun	6,769.03	7,119.58	6,634.30	7,092.20	1.58%	2.11%	3.91%
10-Jul	7,061.59	7,321.41	7,009.83	7,205.22	1.17%	2.00%	3.92%
10-Aug	7,249.77	7,514.63	7,227.39	7,289.74	9.10%	1.86%	3.90%
10-Sep	7,322.52	8,064.87	7,322.52	7,984.45	0.65%	2.90%	3.10%
10-Oct	8,018.42	8,344.12	7,950.12	8,036.88	-4.00%	2.62%	3.55%
10-Nov	8,095.04	8,434.05	7,411.68	7,722.05	3.05%	1.88%	3.95%
10-Dec	7,726.39	7,975.22	7,421.12	7,961.06	-11.05%	2.00%	4.03%
11-Jan	7,989.28	8,038.74	6,999.44	7,128.29	-3.98%	0.81%	4.66%
11-Feb	7,152.97	7,222.02	6,647.92	6,850.40	8.22%	0.41%	5.56%
11-Mar	6,888.55	7,471.35	6,888.55	7,437.26	-0.14%	0.60%	5.27%
11-Apr	7,440.05	7,651.27	7,381.56	7,427.14	-2.64%	0.44%	5.44%
11-May	7,449.52	7,463.28	6,932.82	7,233.85	0.43%	0.54%	5.37%
11-Jun	7,240.14	7,291.32	6,789.01	7,265.32	-2.14%	0.20%	5.28%
11-Jul	7,296.61	7,417.00	7,103.90	7,111.31	-9.19%	-0.11%	5.17%
11-Aug	7,148.11	7,197.91	6,165.06	6,487.22	-1.58%	-0.97%	5.26%
11-Sep	6,559.20	6,711.06	6,208.73	6,385.76	5.74%	-1.86%	5.59%
11-Oct	6,338.96	6,796.79	6,135.65	6,763.26	-10.04%	-1.44%	5.37%
11-Nov	6,723.25	6,787.42	5,899.25	6,117.00	-5.69%	-1.94%	5.52%

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11-Dec	6,226.60	6,416.65	5,683.02	5,778.68	12.52%	-2.67%	5.92%
12-Jan	5,797.33	6,562.69	5,734.21	6,549.31	4.60%	-0.71%	5.80%
12-Feb	6,545.14	7,166.28	6,522.13	6,857.28	-1.43%	0.01%	6.37%
12-Mar	6,844.63	7,001.32	6,556.03	6,759.63	-0.91%	-0.80%	6.28%
12-Apr	6,769.94	6,887.06	6,585.99	6,698.51	-6.45%	-0.86%	6.11%
12-May	6,732.03	6,741.87	6,129.37	6,280.04	6.21%	-1.18%	5.98%
12-Jun	6,268.76	6,686.19	6,088.62	6,682.47	-1.16%	-0.70%	5.97%
12-Jul	6,695.99	6,797.05	6,407.78	6,605.70	0.40%	-0.61%	5.99%
12-Aug	6,602.82	6,848.80	6,560.62	6,632.34	8.30%	0.18%	5.81%
12-Sep	6,640.17	7,243.40	6,582.88	7,206.51	-1.22%	1.01%	5.60%
12-Oct	7,221.74	7,364.54	7,070.76	7,118.77	4.85%	0.43%	5.78%
12-Nov	7,120.24	7,478.35	7,057.34	7,472.45	1.45%	1.67%	5.60%
12-Dec	7,480.17	7,627.07	7,460.59	7,581.57	1.10%	2.26%	5.53%
13-Jan	7,613.36	7,792.70	7,600.10	7,665.74	-6.77%	1.31%	5.36%
13-Feb	7,673.22	7,697.72	7,138.74	7,163.69	-1.11%	0.36%	5.24%
13-Mar	7,175.22	7,478.62	6,976.75	7,084.96	4.15%	0.39%	5.37%
13-Apr	7,105.97	7,413.56	6,872.16	7,385.25	0.76%	0.81%	5.21%
13-May	7,374.61	7,748.63	7,374.61	7,441.89	-3.80%	1.41%	5.13%
13-Jun	7,463.18	7,465.12	6,868.43	7,164.06	-2.52%	0.58%	4.99%
13-Jul	7,166.52	7,444.46	6,888.21	6,985.56	-4.56%	0.47%	4.95%
13-Aug	7,027.92	7,060.53	6,301.27	6,673.96	5.05%	0.05%	4.85%
13-Sep	6,700.73	7,413.62	6,539.15	7,019.96	8.68%	-0.22%	4.83%
13-Oct	7,040.23	7,667.42	6,978.73	7,656.62	-0.77%	0.61%	4.83%
13-Nov	7,663.98	7,737.66	7,348.20	7,598.21	2.98%	0.14%	5.11%
13-Dec	7,609.06	7,862.72	7,558.21	7,828.34	-4.30%	0.27%	4.96%
14-Jan	7,850.35	7,902.67	7,401.20	7,499.02	#N/A	0.27%	4.86%
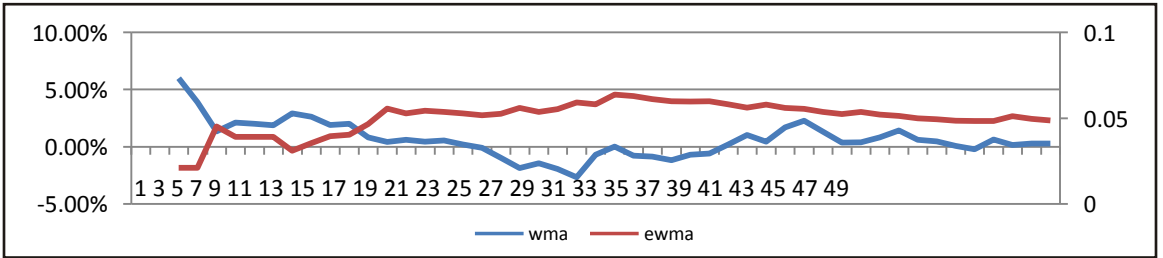
Graph 4: S&P 500

Table 5: BSE MID CAP

Month	Open	High	Low	Close	% ret	wma	ewma
10-Jan	6,746.69	7,153.87	6,276.91	6,509.80	#N/A	#N/A	
10-Feb	6,499.97	6,730.62	6,294.53	6,397.82	6.19%	0.65%	
10-Mar	6,429.54	6,839.83	6,429.54	6,806.18	5.41%	6.19%	0.39%
10-Apr	6,830.62	7,207.44	6,830.62	7,184.78	-4.99%	5.41%	3.94%
10-May	7,177.56	7,202.94	6,466.33	6,834.87	4.50%	0.21%	3.94%
10-Jun	6,830.92	7,198.91	6,734.06	7,149.21	3.55%	1.64%	3.78%
10-Jul	7,138.43	7,519.18	7,106.00	7,407.91	2.52%	2.12%	3.58%
10-Aug	7,438.57	7,918.03	7,438.57	7,596.84	6.22%	2.20%	3.52%
10-Sep	7,622.61	8,202.91	7,622.61	8,084.14	2.67%	2.87%	3.12%
10-Oct	8,112.29	8,521.43	8,112.29	8,302.56	-6.71%	2.84%	3.15%
10-Nov	8,302.56	8,791.10	7,339.55	7,764.02	0.50%	1.65%	3.82%
10-Dec	7,764.02	8,105.73	7,176.49	7,802.71	-12.75%	1.52%	4.38%
11-Jan	7,802.71	7,929.37	6,722.59	6,868.35	-7.48%	0.09%	5.06%
11-Feb	6,868.35	6,922.12	6,182.86	6,373.23	7.56%	-0.60%	6.22%
11-Mar	6,373.23	6,894.10	6,373.23	6,873.40	3.16%	0.08%	6.09%
11-Apr	6,873.40	7,309.29	6,873.40	7,094.26	-2.63%	-0.11%	6.08%
11-May	7,094.56	7,117.32	6,607.78	6,910.24	-0.82%	0.09%	6.01%
11-Jun	6,911.20	6,987.72	6,475.70	6,854.05	0.89%	-0.35%	5.91%
11-Jul	6,854.13	7,115.91	6,854.13	6,915.31	-9.74%	-0.57%	5.73%
11-Aug	6,915.46	6,987.82	6,014.18	6,273.60	-2.32%	-1.59%	5.75%
11-Sep	6,273.56	6,534.66	6,066.34	6,129.59	2.71%	-2.31%	6.09%
11-Oct	6,128.21	6,313.30	5,871.68	6,297.99	-11.25%	-2.30%	5.89%
11-Nov	6,297.99	6,341.71	5,459.92	5,627.69	-9.16%	-2.68%	5.90%

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11-Dec	5,627.75	5,804.38	5,073.25	5,135.05	13.41%	-3.49%	6.38%
12-Jan	5,135.05	5,895.72	5,101.95	5,871.70	8.41%	-1.31%	6.43%
12-Feb	5,870.43	6,654.98	5,870.09	6,386.82	-0.64%	0.02%	7.04%
12-Mar	6,384.39	6,534.36	6,149.74	6,346.38	-0.48%	-0.66%	7.13%
12-Apr	6,357.35	6,512.72	6,213.98	6,315.85	-6.68%	-0.97%	6.92%
12-May	6,343.48	6,370.98	5,802.33	5,907.95	4.08%	-1.31%	6.75%
12-Jun	5,907.96	6,156.07	5,734.24	6,153.72	-2.33%	-0.90%	6.71%
12-Jul	6,169.76	6,362.03	5,877.38	6,012.28	-0.12%	-1.17%	6.60%
12-Aug	6,014.73	6,208.92	5,936.51	6,005.02	9.56%	-0.36%	6.42%
12-Sep	6,008.33	6,628.85	6,004.87	6,607.29	-0.63%	0.63%	6.19%
12-Oct	6,618.44	6,778.70	6,495.04	6,565.99	4.99%	0.35%	6.44%
12-Nov	6,569.64	6,910.65	6,530.06	6,901.99	3.01%	1.70%	6.23%
12-Dec	6,922.96	7,157.66	6,919.55	7,112.89	-2.02%	2.72%	6.14%
13-Jan	7,123.32	7,391.34	6,831.14	6,970.88	-10.08%	1.43%	6.00%
13-Feb	6,973.52	7,016.83	6,283.68	6,302.78	-2.58%	-0.11%	5.89%
13-Mar	6,312.99	6,524.94	6,022.77	6,142.06	3.24%	-0.27%	6.22%
13-Apr	6,157.61	6,368.11	6,029.10	6,344.04	0.71%	0.04%	6.06%
13-May	6,350.41	6,661.12	6,332.82	6,389.47	-6.88%	0.65%	5.93%
13-Jun	6,409.37	6,468.98	5,778.97	5,964.50	-7.33%	-0.26%	5.77%
13-Jul	5,972.47	6,111.29	5,441.93	5,543.13	-4.48%	-0.68%	5.84%
13-Aug	5,553.96	5,606.72	5,118.74	5,300.40	5.61%	-1.04%	5.91%
13-Sep	5,312.48	5,744.17	5,269.87	5,605.98	8.57%	-1.37%	5.82%
13-Oct	5,624.30	6,115.28	5,593.99	6,107.35	3.51%	-0.60%	5.83%
13-Nov	6,117.51	6,355.01	6,063.27	6,325.58	5.83%	-0.73%	6.03%
13-Dec	6,339.90	6,707.87	6,297.65	6,705.56	-6.11%	-0.49%	5.90%
14-Jan	6,719.03	6,802.60	6,185.62	6,308.05	#N/A	-0.49%	5.91%
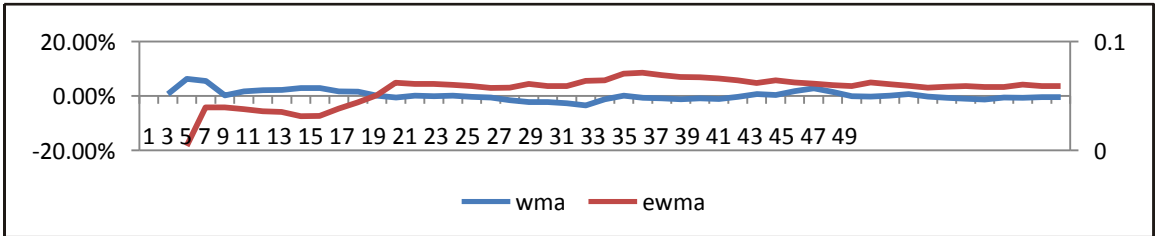
Graph 5: BSE MID CAP

Table 6: BSE SMALL CAP

					% ret	wma	ewma
10-Jan	8,393.77	9,118.00	7,926.82	8,232.68	#N/A	#N/A	
10-Feb	8,248.53	8,631.19	7,973.57	8,067.40	5.19%	#N/A	0.00%
10-Mar	8,085.87	8,634.96	8,085.87	8,497.43	8.02%	5.19%	1.41%
10-Apr	8,523.51	9,293.70	8,523.51	9,207.14	-7.44%	6.61%	3.50%
10-May	9,201.89	9,260.50	8,160.50	8,547.16	5.95%	1.93%	6.14%
10-Jun	8,555.98	9,132.52	8,451.15	9,071.20	3.02%	2.93%	5.85%
10-Jul	9,072.30	9,558.99	9,064.30	9,348.97	2.03%	2.95%	5.73%
10-Aug	9,375.33	10,022.13	9,375.33	9,540.56	7.13%	2.80%	4.98%
10-Sep	9,561.98	10,375.90	9,561.98	10,245.71	3.38%	3.41%	4.90%
10-Oct	10,268.65	10,918.41	10,268.65	10,597.59	-8.39%	3.41%	5.82%
10-Nov	10,597.59	11,366.68	9,233.62	9,744.71	-0.77%	2.10%	6.34%
10-Dec	9,744.71	10,229.86	8,617.43	9,670.31	-13.16%	1.81%	7.13%
11-Jan	9,670.31	9,920.58	8,333.93	8,477.82	-8.11%	0.45%	8.04%
11-Feb	8,477.82	8,551.45	7,471.77	7,817.32	4.48%	-0.26%	7.79%
11-Mar	7,817.32	8,228.02	7,730.46	8,175.89	6.39%	-0.32%	7.41%
11-Apr	8,175.89	8,976.17	8,175.89	8,715.31	-5.66%	-0.46%	7.54%
11-May	8,713.47	8,744.52	7,999.23	8,235.72	-0.97%	-0.31%	7.45%
11-Jun	8,237.06	8,381.73	7,753.00	8,156.60	1.81%	-0.89%	7.17%
11-Jul	8,159.30	8,536.87	8,159.30	8,305.58	-15.24%	-0.99%	7.37%
11-Aug	8,306.84	8,377.62	6,892.98	7,131.48	-3.57%	-2.43%	8.00%
11-Sep	7,131.90	7,421.17	6,873.20	6,881.08	1.35%	-3.32%	7.74%
11-Oct	6,879.21	6,997.39	6,638.86	6,974.61	-13.44%	-3.49%	7.74%
11-Nov	6,974.90	7,007.29	5,914.55	6,097.26	-9.40%	-3.91%	8.14%

11-Dec	6,099.34	6,248.81	5,460.31	5,550.14	15.23%	-4.63%	7.96%
12-Jan	5,551.77	6,504.14	5,540.30	6,463.30	5.96%	-2.26%	8.64%
12-Feb	6,464.29	7,263.11	6,464.29	6,859.97	-3.42%	-1.09%	8.57%
12-Mar	6,870.15	6,914.90	6,434.17	6,629.38	2.02%	-1.75%	8.30%
12-Apr	6,641.72	6,982.30	6,641.72	6,764.62	-7.58%	-2.11%	8.14%
12-May	6,787.38	6,844.92	6,202.13	6,271.00	4.26%	-2.27%	8.01%
12-Jun	6,283.46	6,547.61	6,132.10	6,543.75	-1.48%	-1.84%	7.88%
12-Jul	6,552.00	6,870.17	6,355.15	6,447.89	-0.82%	-2.11%	7.64%
12-Aug	6,456.47	6,687.31	6,336.09	6,395.09	9.29%	-0.91%	7.35%
12-Sep	6,399.94	7,045.06	6,388.01	7,017.89	-0.41%	0.16%	7.53%
12-Oct	7,026.62	7,252.49	6,949.96	6,989.17	4.02%	0.02%	7.27%
12-Nov	6,993.11	7,287.09	6,975.15	7,275.65	1.42%	1.47%	7.12%
12-Dec	7,283.14	7,525.68	7,283.14	7,379.94	-4.23%	2.37%	6.94%
13-Jan	7,388.39	7,696.74	7,049.69	7,074.07	-13.09%	0.75%	6.87%
13-Feb	7,081.69	7,114.58	6,192.07	6,206.22	-6.69%	-0.83%	7.32%
13-Mar	6,198.16	6,378.13	5,708.41	5,804.65	3.66%	-1.11%	7.22%
13-Apr	5,812.49	6,137.88	5,812.49	6,021.16	-1.30%	-0.97%	7.09%
13-May	6,027.98	6,243.54	5,935.92	5,943.46	-5.18%	-0.45%	6.89%
13-Jun	5,950.67	6,018.92	5,544.60	5,643.52	-6.07%	-1.23%	6.76%
13-Jul	5,647.85	5,787.89	5,257.96	5,311.06	-2.28%	-1.62%	6.67%
13-Aug	5,328.60	5,407.88	5,085.56	5,191.25	5.16%	-1.74%	6.47%
13-Sep	5,201.42	5,557.91	5,185.13	5,466.24	7.57%	-2.08%	6.44%
13-Oct	5,489.69	5,905.11	5,468.09	5,896.11	3.39%	-1.42%	6.57%
13-Nov	5,913.90	6,140.96	5,880.96	6,099.52	7.14%	-1.47%	6.43%
13-Dec	6,117.84	6,567.03	6,117.84	6,551.13	-4.49%	-0.99%	6.53%
14-Jan	6,570.08	6,716.80	6,164.27	6,263.35	#N/A	-0.99%	6.53%
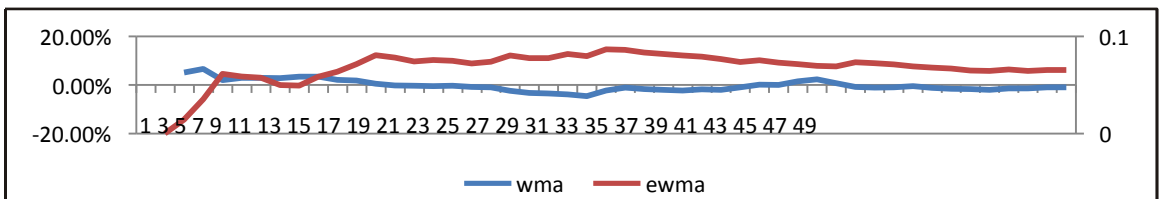
Graph 6: BSE SMALL CAP

As shown in the above tables and graphs the BSE indices exhibit both positive and negative values of the mean and standard deviation but are significantly not different as the p values are higher at 5% significance level. The table below presents the descriptive statistics of the six indices of BSE LTD.

Table 7: Descriptive Statistics of BSE Broad Indices

		average	stdev	skewness	excess kurtosis	median	min	max	Q 1:	Q 3:
1	BSE S&P	0.00472	0.05	0.08	0.02	0.02%	-11.25%	11.04%	-2.64%	3.62%
	P values	25.80%		41.79%	37.38%					
2	BSE 100	0.003834	0.051378	0.12	-0.06	0.002684	-0.10938	0.123501	-0.02867	0.039679
	P values	30.38%		38%	34%					
3	BSE 200	0.00335	0.051418	0.09	-0.08	0.003817	-0.10988	0.125289	-0.02884	0.043246
	P values	32.69%		41%	33%					
4	S&P 500	0.002982	0.052057	0.04	-14%	0.004025	-0.11049	0.125184	-0.03202	0.04309
	P values	34.82%		46%	30%					
5	BSE MIDCAP	-0.0003	0.051418	-0.18	-0.60	0.004971	-0.12755	0.134055	-0.04735	0.042861
	P values	48.66%		31.42%	14.42%					
6	BSE SMALL CAP	-0.00539	0.067855	-0.26	-0.34	-0.0041	-0.15241	0.152317	-0.05419	0.043711
	P values	29.45%		0.25	0.23					

The table no. 7 presents the descriptive statistics of the BSE Broad Indices. BSE S&P's average is 0.05, standard deviation is 0.05 and skewness is 0.08 and excess kurtosis is positive which indicates distribution has a slightly leptokurtic distribution. The BSE MID CAP AND BSE SMALL CAP has shown negative averages and negative excess kurtosis which indicates platykurtic distribution. The remaining indices also have recorded positive mean and negative mean values negative excess skewness and are representing slightly platykurtic distribution. In sum, it can be concluded that the data represents the distribution is positively skewed and the density distribution has negative excess kurtosis for all indices selected in the sample except BSE S&P Sensex indices has positive density distribution.

Table 8: showing stationarity, distribution and Arch effect

|	White-noise	Normal Distributed	ARCH Effect?
BSE S&P	2.16%	96.59%	74.31%
	FALSE	TRUE	FALSE
BSE MIDCAP	25.26%	57.61%	75.13%
	TRUE	TRUE	FALSE
BSE SMALL CAP	40.85%	64.97%	99.91%
	TRUE	TRUE	FALSE

BSE 100	5.89%	91.97%	70.78%
	TRUE	TRUE	FALSE
BSE 200	9.20%	93.79%	76.02%
	TRUE	TRUE	FALSE
S&P 500	12.28%	93.38%	78.21%
	TRUE	TRUE	FALSE

The distribution of the data is further analyzed for studying the stationarity and trend. The reason for non stationarity is the presence is trend and integration (Unit root) between the observations themselves. Hence white noise is tested and the results indicated significant serial correlation for BSE S&P and the remaining have no serial correlation. The data is normally distributed which is proved through Jarque Bera test presented in the above table. The arch effect of all the samples included in the study reveals that there is no conditional heteroskedacity.

The correlogram analysis is made to find out the ACF and PACF of the selected samples to fit in the appropriate volatility forecasting model. The data has shown auto correlation only for the first two lags, but however exhibit no auto correlation which is evident from the arch effect. The following tables are presented to visualize the ACF and PACF values at different lag orders.

Table 9: Correlogram Analysis of BSE S&P

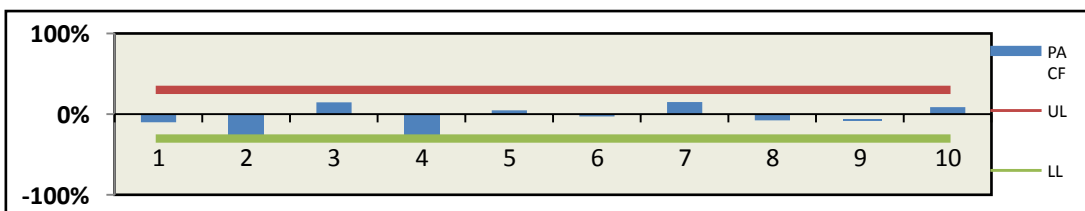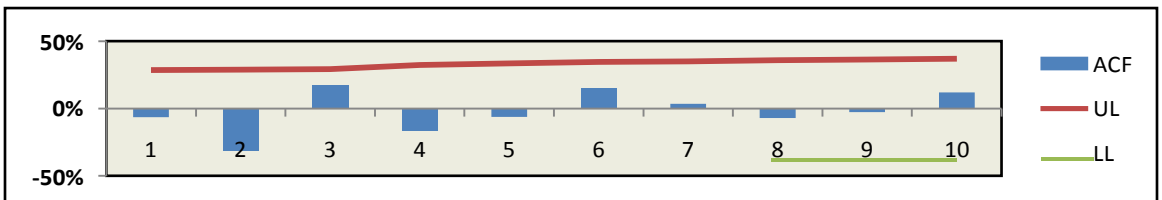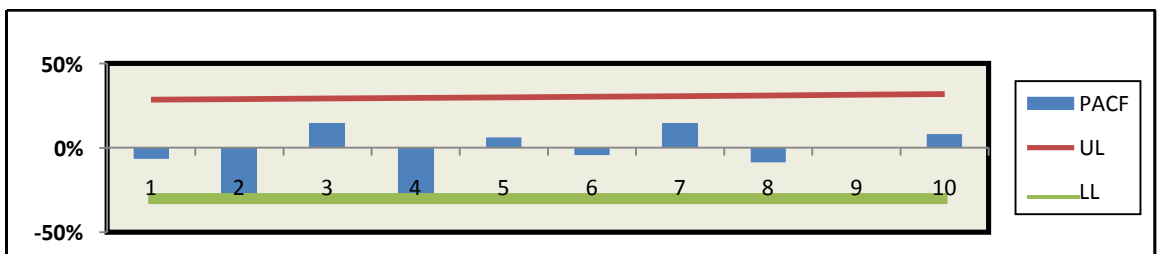| Lag	ACF	UL	LL	PACF	UL	LL
1	-15.63%	28.59%	-28.59%	-15.72%	28.59%	-28.59%
2	-31.66%	28.90%	-28.90%	-34.58%	28.90%	-28.90%
3	28.37%	29.91%	-29.91%	18.76%	29.22%	-29.22%
4	-15.64%	32.91%	-32.91%	-23.77%	29.55%	-29.55%
5	-11.21%	35.28%	-35.28%	0.88%	29.89%	-29.89%
6	19.98%	36.24%	-36.24%	1.45%	30.24%	-30.24%
7	4.34%	36.95%	-36.95%	15.19%	30.61%	-30.61%
8	-9.38%	38.27%	-38.27%	-2.22%	30.99%	-30.99%
9	0.35%	38.80%	-38.80%	-1.08%	31.38%	-31.38%
10	8.66%	39.48%	-39.48%	5.29%	31.79%	-31.79%
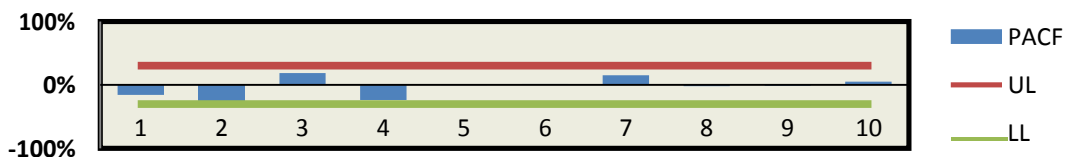
Graph 7: PACF of BSE S&P

Graph 8: ACF of BSE S&P
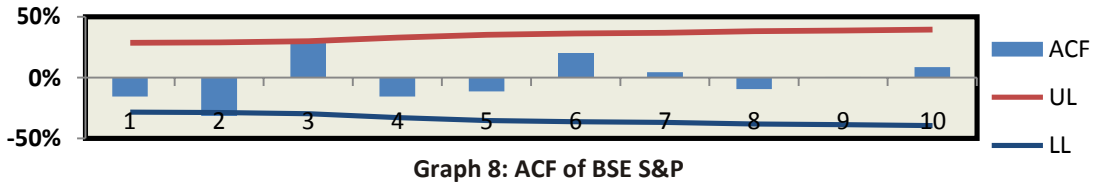
Table 10: Correlogram Analysis of BSE 100

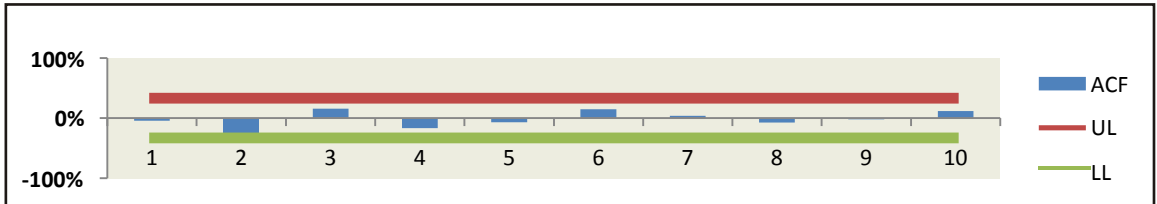| Lag	ACF	UL	LL	PACF	UL	LL
1	-9.89%	28.59%	-28.59%	-9.97%	28.59%	-28.59%
2	-32.17%	28.90%	-28.90%	-33.28%	28.90%	-28.90%
3	20.37%	29.50%	-29.50%	14.64%	29.22%	-29.22%
4	-16.72%	32.60%	-32.60%	-30.31%	29.55%	-29.55%
5	-6.74%	34.02%	-34.02%	4.84%	29.89%	-29.89%
6	16.75%	35.07%	-35.07%	-2.93%	30.24%	-30.24%
7	3.50%	35.59%	-35.59%	14.95%	30.61%	-30.61%
8	-7.90%	36.66%	-36.66%	-7.54%	30.99%	-30.99%
9	-1.98%	37.15%	-37.15%	-0.38%	31.38%	-31.38%
10	12.16%	37.77%	-37.77%	8.67%	31.79%	-31.79%
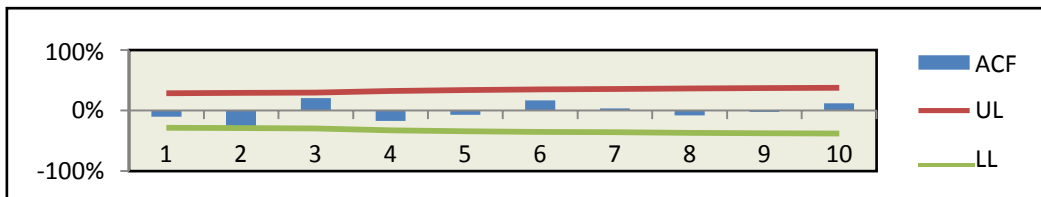
Graph 9: ACF of BSE100

Graph 10: PACF of BSE 100

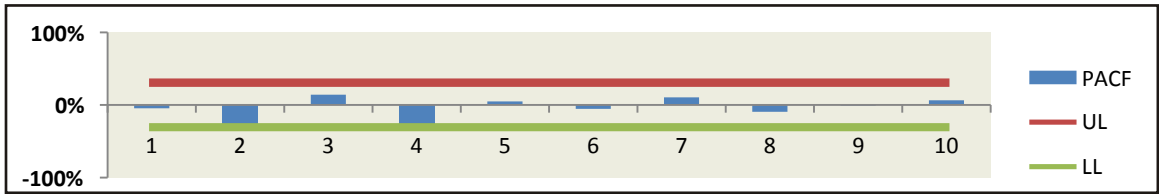**Table 11: Correlogram Analysis of BSE 200**

Lag	ACF	UL	LL	PACF	UL	LL
1	-6.49%	28.59%	-28.59%	-6.55%	28.59%	-28.59%
2	-31.42%	28.90%	-28.90%	-31.82%	28.90%	-28.90%
3	17.64%	29.34%	-29.34%	14.57%	29.22%	-29.22%
4	-16.40%	32.32%	-32.32%	-30.78%	29.55%	-29.55%
5	-6.11%	33.49%	-33.49%	6.22%	29.89%	-29.89%
6	15.10%	34.52%	-34.52%	-4.20%	30.24%	-30.24%
7	3.59%	35.02%	-35.02%	14.44%	30.61%	-30.61%
8	-7.08%	35.97%	-35.97%	-8.71%	30.99%	-30.99%
9	-2.55%	36.46%	-36.46%	0.19%	31.38%	-31.38%
10	11.93%	37.04%	-37.04%	8.11%	31.79%	-31.79%

Graph 11: ACF of BSE 200

Graph No.12: PACF OF BSE 200

Table 12: Correlogram Analysis of S&P 500

Lag	ACF	UL	LL	PACF	UL	LL
1	-4.53%	28.90%	-28.90%	-4.51%	28.90%	-28.90%
2	-30.90%	29.22%	-29.22%	-31.05%	29.22%	-29.22%
3	15.89%	29.61%	-	14.26%	29.55%	-29.55%
4	-16.65%	32.55%	-32.55%	-31.81%	29.89%	-29.89%
5	-6.92%	33.58%	-33.58%	4.93%	30.24%	-30.24%

|						
6	14.77%	34.64%	-34.64%	-5.20%	30.61%	-30.61%
7	3.82%	35.17%	-35.17%	10.43%	30.99%	-30.99%
8	-7.54%	36.13%	-36.13%	-9.51%	31.38%	-31.38%
9	-2.06%	36.63%	-36.63%	-0.23%	31.79%	-31.79%
10	11.58%	37.24%	-37.24%	6.67%	32.22%	-32.22%

Graph 13: ACF of S&P 500

Graph 14: PACF of S&P 500

Table 13: Correlogram Analysis of BSE MID CAP

| Lag	ACF	UL	LL	PACF	UL	LL
1	15.39%	28.90%	-28.90%	15.38%	28.90%	-28.90%
2	-24.64%	29.22%	-29.22%	-27.96%	29.22%	-29.22%
3	-3.06%	30.20%	-30.20%	6.70%	29.55%	-29.55%
4	-17.38%	32.14%	-32.14%	-30.99%	29.89%	-29.89%
5	-12.49%	32.55%	-32.55%	-3.02%	30.24%	-30.24%
6	8.57%	33.64%	-33.64%	-3.30%	30.61%	-30.61%
7	4.91%	34.40%	-34.40%	-1.49%	30.99%	-30.99%
8	-8.72%	35.01%	-35.01%	-11.48%	31.38%	-31.38%
9	-2.61%	35.53%	-35.53%	-4.14%	31.79%	-31.79%
10	7.25%	36.17%	-36.17%	-0.45%	32.22%	-32.22%
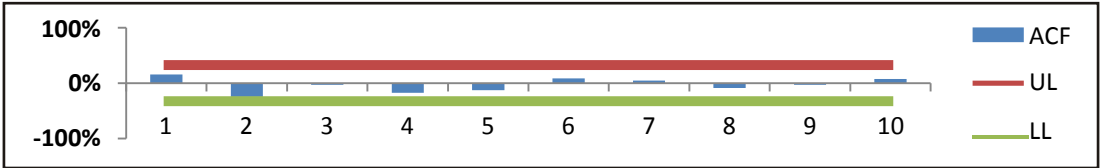
Graph 15: ACF of BSE MID CAP
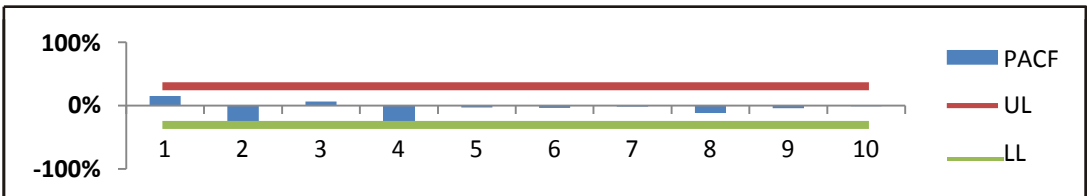
Graph 16: PACF of BSE MID CAP

Table 14: Correlogram Analysis of BSE SMALL CAP

Lag	ACF	UL	LL	PACF	UL	LL
1	11.31%	28.90%	-28.90%	11.26%	28.90%	-28.90%
2	-17.07%	29.22%	-29.22%	-18.40%	29.22%	-29.22%
3	12.23%	29.91%	-29.91%	17.04%	29.55%	-29.55%
4	-17.33%	31.03%	-31.03%	-29.09%	29.89%	-29.89%
5	-22.03%	31.78%	-31.78%	-8.89%	30.24%	-30.24%
6	10.86%	32.87%	-32.87%	2.35%	30.61%	-30.61%
7	0.71%	34.35%	-34.35%	-5.46%	30.99%	-30.99%
8	-13.74%	35.09%	-35.09%	-9.77%	31.38%	-31.38%
9	5.81%	35.55%	-35.55%	-0.35%	31.79%	-31.79%
10	0.77%	36.41%	-36.41%	-10.51%	32.22%	-32.22%
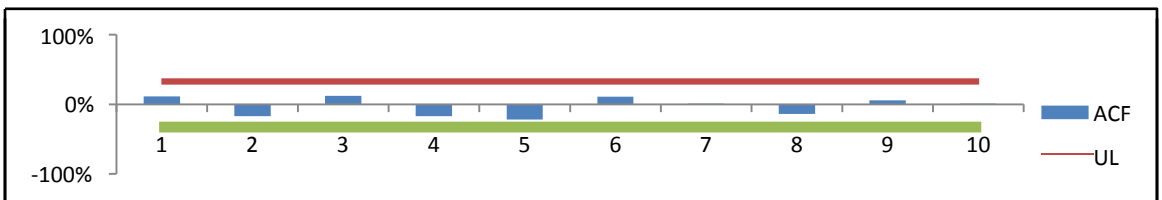
Graph 17: ACF of BSE SMALL CAP
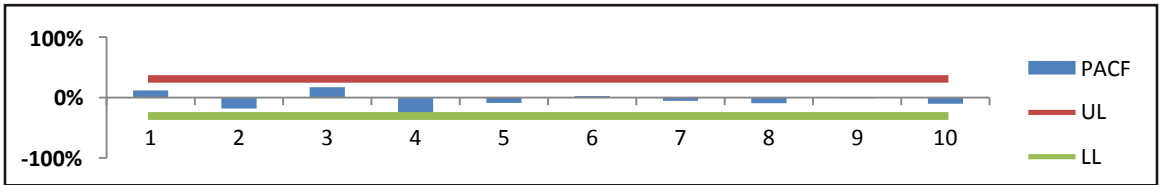
Graph 18: PACF of BSE SMALL CAP

Table 15: Egarch (1,1) analysis

BSE S&P	Param	Value	Goodness-of-fit		
	μ	-0.01	LLF	AIC	CHECK
	$á_0$	-1.46	84.05	-157.10	1.00
	$á_1$	-1.22			
	$ã_1$	0.52			
	$â_1$	0.60			
BSE MIDCAP	Param	Value	Goodness-of-fit		
	μ	0.00	LLF	AIC	CHECK
	$á_0$	-7.01	52.247947	-93.495894	1
	$á_1$	1.55			
	$ã_1$	-0.13			
	$â_1$	-0.28			
BSE SMALL CAP	Param	Value	Goodness-of-fit		
	μ	-0.01	LLF	AIC	CHECK
	$á_0$	-7.05	52.61080854	-94.22161707	1
	$á_1$	1.24			
	$ã_1$	-0.08			
	$â_1$	-0.28			
BSE 100	Param	Value	Goodness-of-fit		
	μ	-0.01	LLF	AIC	CHECK
	$á_0$	-1.04	81.28203341	-151.5640668	1
	$á_1$	-1.00			
	$ã_1$	0.26			
	$â_1$	0.70			
BSE 200	Param	Value	Goodness-of-fit		
	μ	0.00	LLF	AIC	CHECK
	$á_0$	-6.28	74.34	-137.69	1
	$á_1$	0.00			
	$ã_1$	-0.56			
	$â_1$	-0.06			
S&P 500	Param	Value	Goodness-of-fit		
	μ	0.01	LLF	AIC	CHECK
	$á_0$	-1.03	80.77601833	-150.5520367	1
	$á_1$	-1.08			
	$ã_1$	0.45			
	$â_1$	0.69			

The above table no. 15 represents the EGARCH (1, 1) model which is used to forecast the monthly volatility and calibrated to find out the exact values. Though the alpha and beta values are showing negative values but are still considered for the test because the egarch after calibration returned check value as 1.

Table 16: Showing the Residual Analysis

BSE S&P		AVG	STDEV	SKEW	KURTOSIS	Noise?	Normal?	ARCH?
		0.12	1.13	-0.547	0.275051	TRUE	TRUE	FALSE
	Target	0.00	1	0	0			
	SIG?	FALSE	FALSE	FALSE	FALSE			
BSE MIDCAP		AVG	STDEV	SKEW	KURTOSIS	Noise?	Normal?	ARCH?
		0.03	0.817	-0.245	1.113813	TRUE	TRUE	TRUE
	Target	0.00	1	0	0			
	SIG?	FALSE	TRUE	FALSE	FALSE			
BSE SMALL CAP		AVG	STDEV	SKEW	KURTOSIS	Noise?	Normal?	ARCH?
		0.02	0.88	-0.32	0.816192	TRUE	TRUE	FALSE
	Target	0.00	1	0	0			
	SIG?	FALSE	FALSE	FALSE	FALSE			
BSE 100		AVG	STDEV	SKEW	KURTOSIS	Noise?	Normal?	ARCH?
		0.19	1.022	-0.0016	-0.42858	TRUE	TRUE	FALSE
	Target	0.00	1	0	0			
	SIG?	FALSE	FALSE	FALSE	FALSE			
BSE 200		AVG	STDEV	SKEW	KURTOSIS	Noise?	Normal?	ARCH?
		0.00	1	0.085	-0.07689	TRUE	TRUE	FALSE
	Target	0.00	1	0	0			
	SIG?	FALSE	FALSE	FALSE	FALSE			
S&P 500		AVG	STDEV	SKEW	KURTOSIS	Noise?	Normal?	ARCH?
		-0.10	1.114	-0.0318	-0.62645	TRUE	TRUE	FALSE
	Target	0.00	1	0	0			
	SIG?	FALSE	FALSE	FALSE	FALSE			

The residual analysis has shown average and standard deviations are not significantly different from zero and the skewness is also not different from zero. The residuals skewness also shows that the data is symmetrical. The kurtosis figures in the residual analysis shows that the tails are normal. So far, the residuals have shown a Gaussian distribution. Examining the residual interdependence concern among the variables, serial correlation or linear first order dependence exhibited no significant serial correlation. The second order dependence (quadratic) shows insignificant correlation in the squared residuals or absence of an arch effect. As a result, the standardized residuals are independent and identically Gaussian distributed. Thus, the EGARH model assumption is met.

Table 17: Garch (1,1)

BSE S&P	Param	Value	Goodness-of-fit		
	μ	0.0047	LLF	AIC	CHECK
	$\acute{a}_0$	0.0029	75.48	-144.96	1
	$\acute{a}_1$	0.0000			

	â$_1$	0.0000			
BSE MIDCAP	Param	Value	Goodness-of-fit		
	μ	-0.001	LLF	AIC	CHECK
	á0	0.003	65.38783494	-124.7756699	1
	á1	0.050			
	â1	0.112			
BSE SMALL CAP	Param	Value	**Goodness-of-fit**		
	μ	-0.005	LLF	AIC	CHECK
	á0	0.005	60.11	-114.21	1
	á1	0.000			
	â1	0.000			
BSE 100	Param	Value	Goodness-of-fit		
	μ	0.00380	LLF	AIC	CHECK
	á0	0.00306	74.12374497	-142.2474899	1
	á1	0.00000			
	â1	0.00000			
BSE 200	Param	Value	Goodness-of-fit		
	μ	0.00330	LLF	AIC	CHECK
	á0	0.00300	74.1574746	-142.3149492	1
	á1	0.00000			
	â1	0.00000			
S&P 500	Param	Value	**Goodness-of-fit**		
	μ	0.0051	LLF	AIC	CHECK
	á0	0.0000	149.80	-293.59	1
	á1	0.8706			
	â1	0.0450			

Table 18: Showing the Residual Analysis (GARCH (1,1)

| BSE S&P		AVG	STDEV	SKEW	KURTOSIS	Noise?	Normal?	ARCH?
		0.00	0.93	0.08	0.02	FALSE	TRUE	FALSE
	Target	0.00	1.00	0.00	0.00			
	SIG?	FALSE	FALSE	FALSE	FALSE			

|	SIG?	FALSE	FALSE	FALSE	FALSE			
BSE MIDCAP		0.02	1.012	-0.232	-0.596	TRUE	TRUE	FALSE
	Target	0.00	1	0	0			
	SIG?	FALSE	FALSE	FALSE	FALSE			
BSE SMALL CAP		0.00	0.99	-0.26	-0.34	TRUE	TRUE	FALSE
	Target	0.00	1.00	0.00	0.00			
	SIG?	FALSE	FALSE	FALSE	FALSE			
BSE 100		0.00	0.94	0.09	-0.08	TRUE	TRUE	FALSE
	Target	0.00	1.00	0.00	0.00			
	SIG?	FALSE	FALSE	FALSE	FALSE			
BSE 200		**0.00**	**1.131**	**0.777**	**1.086**	**FALSE**	**TRUE**	**FALSE**
	Target	0.00	1	0	0			
	SIG?	FALSE	FALSE	TRUE	FALSE			

Table 19: Monthly Volatility forecast Annual Volatility

	Egarch(1,1)	Garch(1,1)	Egarch(1,1)	Garch(1,1)
BSE S&P	4.85%	5.40%	16.80	18.71%
BSE MIDCAP	10.59%	6.02	36.68%	20.85
BSE SMALL CAP	9.36%	6.87	32.42%	23.80
BSE 100	4.88%	5.54	16.90%	19.19
BSE 200	5.14%	5.48	17.81%	18.98
S&P 500	4.55%	1.52	15.76%	5.27

The highest volatility is recorded by BSE MID CAP followed by BSE SMALL CAP as per the Egarch(1,1) analysis. The remaining four indices are in a range of 4.55% to 5.14%. As per the Garch (1, 1) analysis, a BSE SMALL CAP index has shown th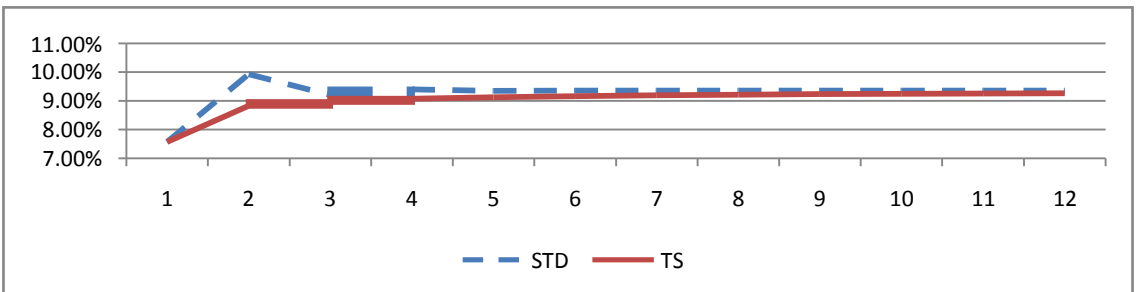e highest volatility followed BSE MID CAP indices. The lowest volatility is recorded by S&P 100 as per both the models. The long run volatility is calculated by multiplying the monthly volatility with square root of 12. (one year).
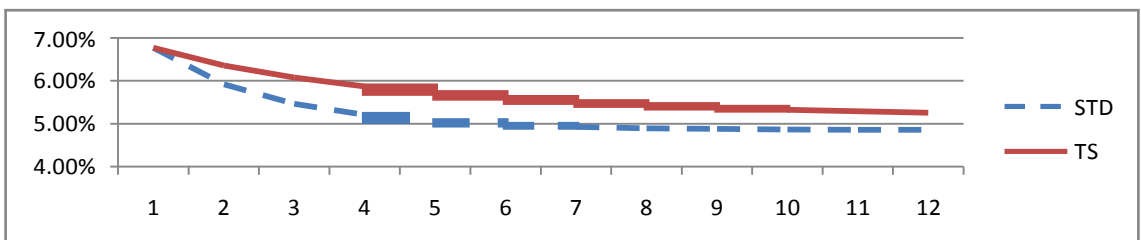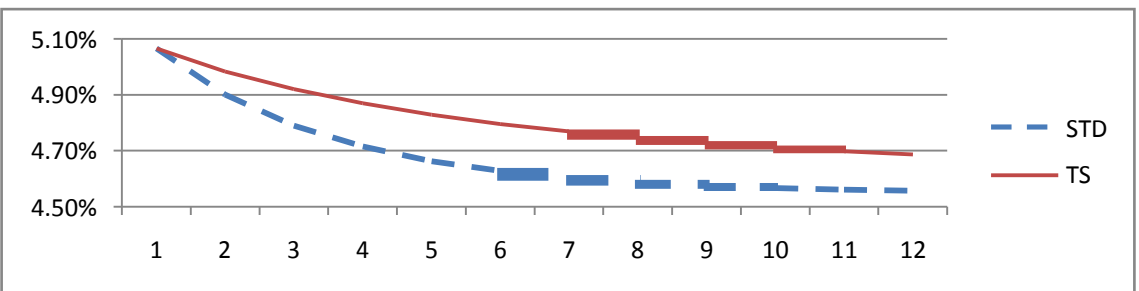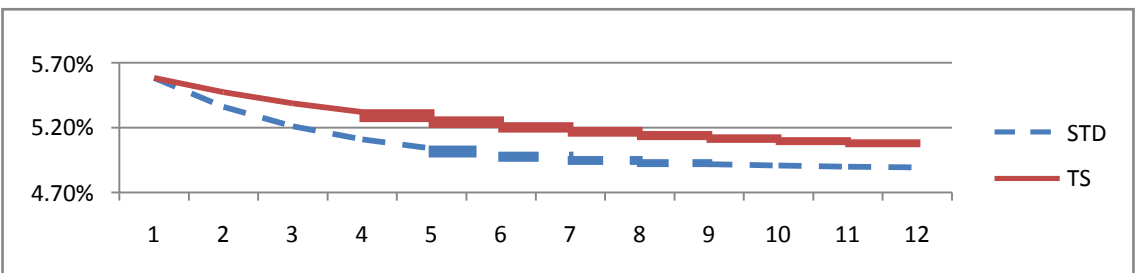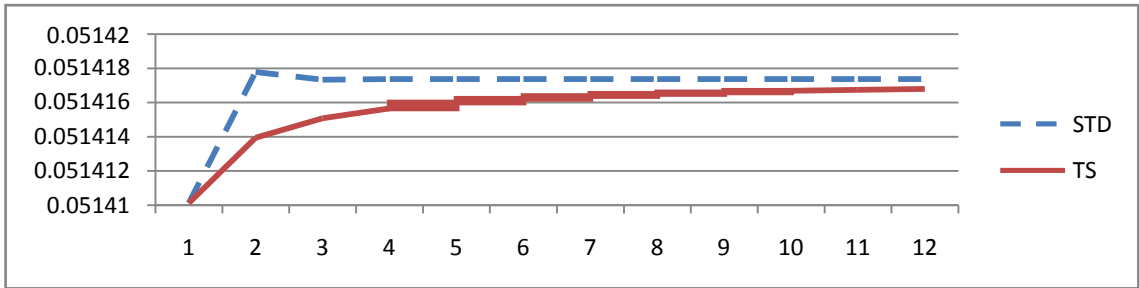

Graph 19: BSE S&P SENSEX
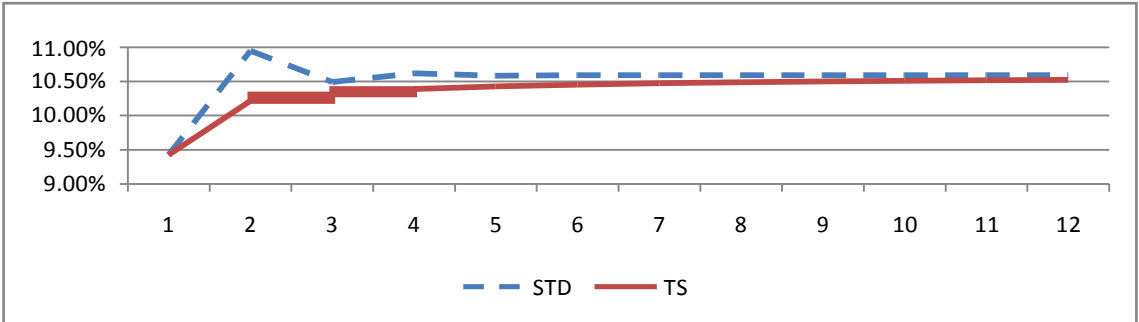
Graph 20: BSE MIDCAP

Graph 21: BSE SMALL CAP

Graph 22: S&P500

Graph 23: BSE 100

Graph 24: BSE 200

Conclusion

The analysis through GARCH (1,1) and EGARCH (1,1) forecasted volatility of the selected BSE BROAD indices and indicated BSE MIDCAP and BSE SMALL CAP has highest volatility. GARCH (1,1) model has shown low volatility than the EGARCH (1,1). Volatility forecasting through econometric techniques presents the forecast based on the past data, however, the volatility of stock markets are affected by many exogenous variables which are highly unpredictable. This analysis attempts to present risk metrics which helps to manage risks such as to measure the difference in actual and expected volatility which can act as an effective hedging tool, portfolio diversification and overall risk management.

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