

The Impact of Derivatives on Stock Market Volatility: A Study of the Sensex Index

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Abstract
One of the most important issues that have engaged the financial managers and the academicians in Finance all over the world is the financial markets volatility and the need to forecast it accurately. The stock prices depend on the investment behavior which, in turn, is affected by the efficiency of volatility forecasting. The purpose of this paper is to examine the volatility in the Indian stock market after the introduction of futures contracts on the SENSEX index. To explore the time series properties Unit Root Test and ARCH LM test have been employed. GARCH (1, 1) model have been applied to study the impact on underlying volatility, for this sample period of 26 years has been taken. The results of this study indicate that the introduction of futures leads to a significant change in the spot market volatility of the SENSEX index and it is successful in reducing the volatility.
Keywords: Conditional volatility, Futures, GARCH, Market efficiency, Volatility, Volatility clustering.

Introduction

The modeling of asset returns volatility continues to be one of the important areas of financial research as it provides ample information on the risk patterns involved in investment and transaction processes. A number of works have been undertaken in this area. Given the fact that stock markets usually exhibit high levels of price volatility, which lead to erratic outcomes, it is important to examine the dynamics of volatility. With the introduction of derivatives in the equity markets in the late nineties in the major world markets, the volatility behavior of the stock market has become further complicated as derivatives open new avenues for hedging and speculation. The derivatives market was launched mainly with the twin objectives to transfer risk and to increase liquidity thereby ensuring better market efficiency. The examination of how far these objectives have materialized is important both theoretically and practically.

Many studies have revealed that the introduction of futures markets leads to a decline in the volatility of the underlying index. They support that this is because of the increase in the market liquidity. The investors can hedge their positions due to the improved market liquidity and thus, reduce their risk. In contrast, many studies concluded that the underlying volatility has not changed after the introduction of futures while other studies suggested that the volatility increased. This study examined the effect of the introduction of the futures markets in the Indian Stock Market on the volatility of an underlying index, the SENSEX. The data used is daily closing prices of SENSEX for the period between 1st April, 1991 and 31st March, 2016. For the analysis, the period of examination is separated into two sub-periods: the pre-introduction period and the post-introduction period.

In this paper, we attempt to study the volatility implications of the introduction of derivatives on the cash market. Through this study, we seek evidence regarding whether the listing of futures and options lead to any significant change in the volatility of the cash market in India. The period under analysis spans from 1st April, 1991 to 31st March, 2016. Furthermore, to allow for a non-constant error variance in the return series, GARCH model was applied in this study which is a more appropriate to describe the data collected. Therefore, the present work offers a valuable addition to the existing literature and should prove to be useful to investors as well as regulators.

Literature Review

Ma and Rao (1988) conducted a research study that found that options trading do not have a uniform impact on the volatility of underlying stocks. According to their research study stocks that have been originally volatile, that is, traded primarily by uninformed traders, get stabilized by the development of options and stocks that have been more stable become destabilized by options trading.

Kuserk (1995) studied the volatility of the S&P500 index after the introduction of stock index futures markets and found that the stock market volatility after in introduction of stock futures. The future markets may increase the market's depth and liquidity and therefore, it may decrease the volatility.

Antoniou and Holmes (1995) support that the arrival of futures trading depends on the information of the market speculators. If the speculators have perfect information, the futures introduction stabilizes the spot prices. Otherwise, there is a destabilizing effect.

Antoniou *et al.* (1998) studied volatility of stock market of Germany and Switzerland and they suggested that the futures trading have a significant negative effect on the volatility of the spot market.

Pilar and Rafael (2002) analysed the effect of the introduction of derivatives on the Ibex-35 Index using a dummy variable and a GJR model to test the impact of the introduction of derivative markets on the conditional volatility of the underlying asset. They found that although the asymmetry coefficient increased, the conditional volatility of the underlying index declined after derivatives were introduced.

Rahman (2001) tried to examine the impact of index futures trading on the volatility of component stocks for the Dow Jones Industrial Average. The research study used a simple GARCH (1, 1) model to calculate the conditional volatility of intra-day returns. The empirical research results confirmed that there has been no change in conditional volatility from pre- to post-futures periods.

Bologna and Cavallo (2002) published a research in which they try to examined the effect of the introduction of stock index futures for the Italian Market. Their empirical research study's results have shown that the introduction of stock index futures affects the volatility of the spot market. In addition, the results from various GARCH (1, 1) models for post futures and pre-futures sub-periods suggest that the index futures market reduces volatility.

Robert and Michael (2002) investigated the impact of the introduction of stock index futures trading on the seasonality of daily returns of the underlying index for seven national markets. The results indicate reduced seasonality with respect to mean returns, thus leading to more efficiency in these markets.

Bandivadekarand Ghosh (2003) concluded that while the "futures effect" plays a definite role in the reduction of volatility in the case of S&P CNX Nifty, but in the case of BSE Sensex the effect is rather ambiguous as derivative turnover is considerably low.

Shembagaraman (2003) analyzed the impact of the introduction of derivative trading on spot market volatility of Nifty Index using data of contracts traded on stock index futures and options. The results suggested that futures and options trading have not led to any change in the volatility of the underlying stock index, but the nature of volatility have changed in the post-futures market. Moreover they didn't found any evidence of link between trading activity variables in the futures market and spot market volatility.

Sibani and Uma (2007) used OLS and GARCH techniques to capture the time-varying nature of volatility and volatility clustering phenomenon of the Nifty Index due to the introduction of futures trading. The results suggest that there are no significant changes in the volatility of the spot market of the Nifty Index, but the structure of volatility changes to some extent. The study also reported that new information is assimilated into prices more rapidly than before, and there is a decline in the persistence of volatility since the introduction of futures trading.

Mallikarjunappa and Afsal (2008) studied the impact of derivatives futures and options on stock market volatility using a broad based index i.e. S&P CNX Nifty. To account for heteroskedasticity in the return series GARCH (1, 1) model with the dummy variables has been used in the conditional variance equation. As the opposed to their previous research study, this study reported that derivatives have made no impact on the spot market volatility but the nature of the volatility patterns has altered during post-derivatives period. The post-derivatives period has shown that the sensitivity of the index returns to the market returns and any day-of-the-week effects have disappeared.

Gahlot , Datta & Kapil (2010) examined the impact of the derivatives trading on stock market volatility using closing prices of S&P CNX Nifty as well as closing prices of five derivative stocks and five non derivative stocks from April 1, 2002-March 31, 2005. The research study has employed GARCH model to capture nature of volatility over time and volatility clustering phenomenon of data. The research study has reported no significant change in the volatility of S &P CNX Nifty, but the structure of volatility has changed to the some extent. However, results showed mixed effect of derivatives on volatility in case of ten individual stocks.

Singh and Tripathi (2016) investigated currency futures impact on the volatility of exchange rate of Euro by including dummy variable in GARCH (1, 1) framework and found that after introduction of derivatives, the daily volatility during post derivative period has increased in comparison to pre derivative, which suggests that that derivatives introduction has not been successful in reducing the volatility.

Data Collection

The historical stock price time series data & the data have been collected from the official website of Bombay Stock Exchange of India i.e. www.bseindia.com.

The data set comprises of time series data Bombay Stock Exchange (BSE) of India. It has evolved over the years into its present status as the premier stock exchange in the country. The Bombay Stock Exchange Limited is the oldest stock exchange in Asia and has the greatest number of listed companies in the world; with 4700 listed as of August 2007. Daily closing stock prices have been used to find the impact of the derivatives trading on the Stock Market Volatility.

The data has been analyzed over a span of 26 years starting from 1st April, 1991 to 31st March, 2016. Twenty six years is quite a very large time span to explore the impact of any policy implication. Engle and Mezrich (1995) suggested that at least eight years of data should be used for proper GARCH estimation. In order to study the impact of derivatives on Indian stock market volatility, the whole study period has been bifurcated as follows:

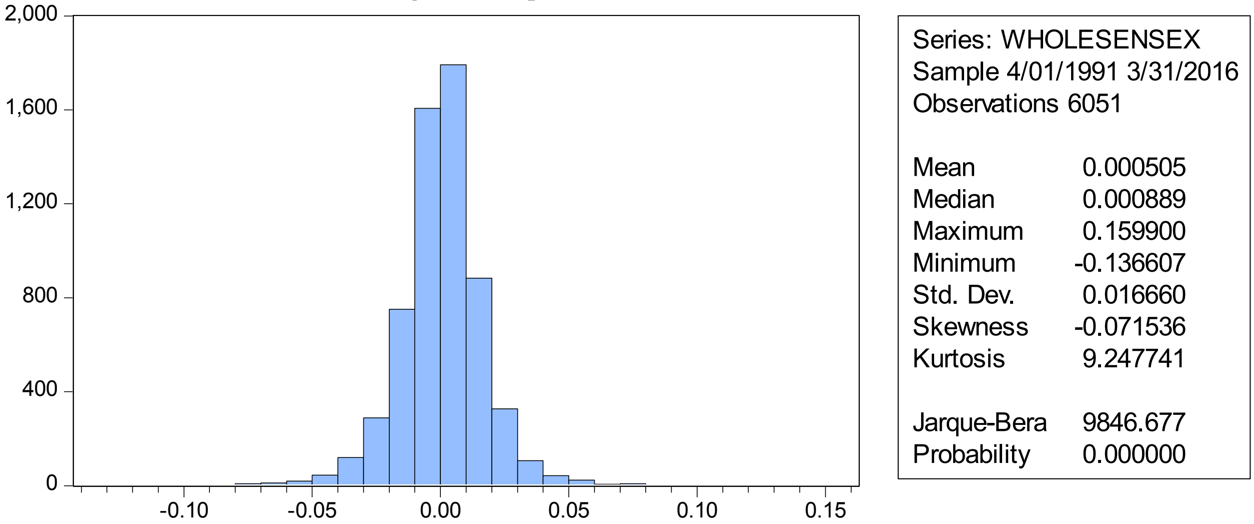
Pre derivatives period: 1st April 1991 - 9th November 2001
Post Derivatives period: 10th November 2001- 31st March 2016
Whole period: 1st April 1991- 31st March 2016

Derivatives trading started in Indian markets on 9th June 2000 with the launch of futures contract. The full set of equity derivatives products was only available in November 2001. Thus 9th November 2001 has been used as cut-off date to study the impact of introduction of derivatives on volatility. Thus, our whole study time span covers pre derivatives & post derivatives period. To maintain uniformity in data collection, data has been collected from year 1991 onwards.

Analysis of the Results

The descriptive statistics for SENSEX have been reported in figure 1 below. The descriptive statistics report that SENSEX series is not normally distributed as it has excess kurtosis (greater than 3). Further, the Jarque Bera test statistic which assumes normality rejects the null, for p value being low. The standard Deviation coefficient which is considered as a traditional measure of volatility has been reported as 0.016660 in fig 1.

Fig. 1 Descriptive Statistics of SENSEX



The daily closing price series has been converted into logarithmic returns by taking first differences. These closing prices have become stationary after they have been converted into log returns. The graph of the stationary SENSEX return series has been shown in fig. 2.

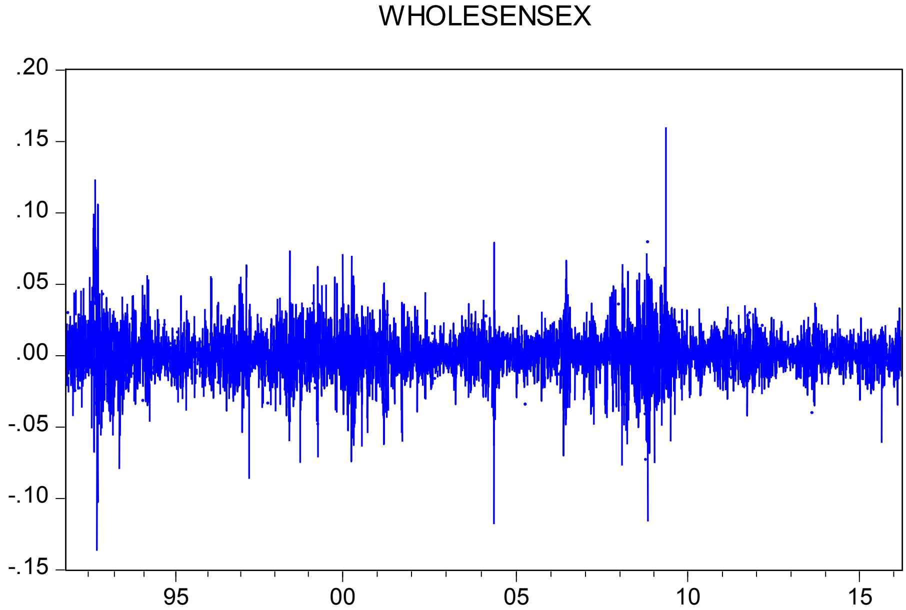


Fig. 2 Stationary SENSEX Series

From the above figure it can be seen that periods of high volatility are followed by periods of low volatility and periods of low volatility tend to followed by periods of low volatility for prolong period. The series exhibit a changing variance, volatility clustering and mean reversion.

The stationarity of the series has also been confirmed using ADF test statistic and Phillips-Perron test statistics in table 1 and 2 testing the hypothesis of non stationarity. The low p value in both the tests rejects the null of non stationarity.

Table – 1

Null Hypothesis: WHOLESENSEX has a unit root

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-71.05667	0.0001
Test critical values:	1% level	-3.431251	
	5% level	-2.861823	
	10% level	-2.566963	

*MacKinnon (1996) one-sided p-values.

Table – 2

Null Hypothesis: WHOLESENSEX has a unit root

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-70.99492	0.0001
Test critical values:	1% level	-3.431251	
	5% level	-2.861823	
	10% level	-2.566963	

*MacKinnon (1996) one-sided p-values.

Standard Deviation as a measure of volatility has certain drawbacks. So the GARCH model has been employed to detect changes in the level of volatility (unconditional variance) of the error terms. As a prior step for estimating GARCH equation, a mean equation needs to be formulated. The mean equation for GARCH (1, 1) has been formulated as ARMA (1, 1) model using Box Jenkins methodology. The results for mean equation have been enumerated in the table below:

Table – 3

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.000503	0.000227	2.219903	0.0265
AR(1)	-0.431337	0.097674	-4.416090	0.0000
MA(1)	0.523184	0.092267	5.670356	0.0000

The coefficients of AR, MA and constant terms are significant at 5%.

The squared residuals revealed significant correlation among the error terms with all Q(12) statistics being significant as is clear from low p values reported in the last column of the table 4.

Table – 4
Correlogram of Residuals Squared

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
|** |	|** |	1	0.247	0.247	370.00	
|* |	|* |	2	0.173	0.119	550.53	
|* |	|* |	3	0.211	0.156	820.74	0.000
|** |	|* |	4	0.227	0.146	1132.3	0.000
|* |	| |	5	0.152	0.044	1272.6	0.000
|* |	|* |	6	0.170	0.078	1448.3	0.000
|** |	|* |	7	0.213	0.112	1724.1	0.000
|* |	| |	8	0.111	-0.019	1799.3	0.000
|* |	| |	9	0.150	0.060	1936.1	0.000
|* |	| |	10	0.161	0.049	2093.4	0.000
|* |	| |	11	0.153	0.042	2235.4	0.000
|* |	| |	12	0.130	0.029	2337.8	0.000

These errors have been further tested using ARCH LM test at lag 1 reported in Table 5 below:

Table – 5
Heteroskedasticity Test: ARCH

F-statistic	393.7130	Prob. F(1,6047)	0.0000
Obs*R-squared	369.7681	Prob. Chi-Square(1)	0.0000

The ARCH LM Test has been used to check for heteroskedasticity testing the null hypothesis of no heteroskedasticity between the error terms. The results of ARCH LM Test have been found to be significant being p value for chi square distribution reported as zero. Thus, sufficient evidence for using GARCH model has been generated.

GARCH (1, 1) model

The generalized autoregressive conditional heteroscedasticity **(GARCH)** model was originally proposed by Bollerslev[1]. The simplest GARCH model is the GARCH (1, 1) model, which can be written as:

$$\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 \sigma_{t-1}^2$$

Parameter constraints:

$$\alpha_0 > 0$$
$$\alpha_1 > 0$$
$$\beta \geq 0$$

and $\alpha_1 + \beta < 1$

The result of the GARCH (1, 1) model has been reported in table 6 below:

[1] T. Bollerslev, "Generalized Autoregressive Conditional Heteroscedasticity," *Journal of Econometrics,* vol. 31, 1986, pp. 307–326.

Table – 6
GARCH = C(4) + C(5)*RESID(-1)^2 + C(6)*GARCH(-1)

	Variance Equation			
C	4.20E-06	4.58E-07	9.171863	0.0000
RESID(-1)^2	0.107226	0.005763	18.60622	0.0000
GARCH(-1)	0.880363	0.005701	154.4314	0.0000

To examine the level of volatility prevailing in the Indian currency market, GARCH (1, 1) equation has generated the values for different parameters. These parameter values have been found to be significant as p value is zero for the constant, the ARCH term & the GARCH term.

Table 6 shows the GARCH estimates with ARCH term represented by (α) alpha and GARCH term represented by (β) beta. ARCH component reflects the influence of random deviations in previous period error terms on σ which is a function of random error terms and realized variance of previous periods. Similarly, GARCH coefficient measures the part of the realized variances in the previous period that is carried over in to the current period. The sum of ARCH coefficient and GARCH coefficient (α + β) determines the short run dynamics of the resulting volatility time series. Particularly, a large ARCH error coefficient (α) means that volatility reacts intensely to market movements and a large GARCH error coefficient (β) indicates that shocks to conditional variance take a long time to die out. So volatility is persistence. Hence current volatility can be explained by past volatility that tends to persist overtime. If α is relatively high and β is relatively low, then volatility tends to be spikier.

From Table 6 it can be seen that both ARCH and GARCH parameters are statistically significant at the 5% significance level which means that the "news" parameter and the persistence coefficient are significant.
The level of volatility in the Indian stock market has been examined using unconditional variance using the formula:

$$Var\ \varepsilon_t = \frac{\alpha_0}{1-(\alpha_1+\beta_1)}$$

The value generated using GARCH (1, 1) has been put into the above equation and the level of volatility has been estimated. The result derived for the whole period is 0.000338, which is less than 0.05. So, it can be concluded that there is volatility in Indian stock market.

The results of the diagnostic tests showed that the GARCH models were correctly specified. Ljung-Box test was used to check for any remaining autocorrelations in squared standardized residuals from the estimated variance equation of GARCH (1, 1) model. If the variance equation was specified correctly, statistics Q (12) should not be significant. As it can be seen in the table 7 the Q-statistics for the standardized residuals were insignificant, suggesting the GARCH models were successful at modeling the serial correlation structure in the conditional means and conditional variances.

Table – 7
Correlogram of Standardized Residuals Squared

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
| |	| |	1	0.011	0.011	0.7567	
| |	| |	2	0.001	0.001	0.7656	
| |	| |	3	0.010	0.010	1.3714	0.242
| |	| |	4	0.007	0.007	1.6561	0.437
| |	| |	5	-0.007	-0.007	1.9638	0.580
| |	| |	6	0.009	0.009	2.4233	0.658
| |	| |	7	-0.007	-0.007	2.7352	0.741
| |	| |	8	-0.024	-0.023	6.0838	0.414
| |	| |	9	-0.021	-0.021	8.8385	0.264
| |	| |	10	0.012	0.012	9.6584	0.290
| |	| |	11	-0.008	-0.007	10.036	0.348
| |	| |	12	-0.024	-0.023	13.457	0.199

The Lagrange Multiplier (ARCH-LM) test was used to test the presence of remaining ARCH effects in the standardized residuals. ARCH-LM test statistic for GARCH (1, 1) model did not exhibit additional ARCH effects remaining in the residuals of the models. The results of ARCH LM Test have been found to be insignificant being p value for chi square distribution reported as more than 5%. This showed that the variance equation was well specified.

Heteroskedasticity Test: ARCH

F-statistic	0.756096	Prob. F(1,6047)	0.3846
Obs*R-squared	0.756251	Prob. Chi-Square(1)	0.3845

Modeling with a dummy variable

An alternative modeling methodology to examine the spot market volatility after the introduction of futures contracts on the SENSEX index is the inclusion of a dummy variable in the previously examined GARCH (1, 1) model. This variable takes the value of '0' & '1' in the pre & post derivatives period respectively. If the dummy variable is significant then we conclude that the introduction of futures has influenced the volatility of the SENSEX. If the coefficient of the dummy is negative then, the volatility has decreased and if it is positive then the volatility has increased.

Any change in the unconditional variance of an asset price after derivatives has been detected by augmenting GARCH (1, 1) equation to include a dummy variable.

$$\sigma_t^2 = \alpha_0 + \alpha_1\varepsilon_{t-1}^2 + \beta_1\sigma_{t-1}^2 + \delta D$$

Where, D is dummy variable.

The result for GARCH (1, 1) model with a dummy variable has been given in Table 8:

Table – 8

GARCH = C(4) + C(5)*RESID(-1)^2 + C(6)*GARCH(-1) + C(7)*DUMMY

Variable	Coefficient	Std. Error	z-Statistic	Prob.
	Variance Equation			
C	9.68E-06	1.10E-06	8.807375	0.0000
RESID(-1)^2	0.106758	0.005979	17.85534	0.0000
GARCH(-1)	0.870042	0.006771	128.4937	0.0000
DUMMY	-5.14E-06	8.33E-07	-6.166479	0.0000

All the parameter values for GARCH (1, 1) have been found to be significant for p values being low. After the parameter values have been estimated using augmented GARCH (1, 1) equation, the unconditional variance has been estimated.

From table 8 it can be seen that the dummy variable is statistically significant at the 5% significance level. That means that the existence of futures markets has a very strong impact on the volatility of the SENSEX spot closing prices. The coefficient of the dummy variable is negative (-5.14E-05) which means that there is a negative effect of futures on stock market volatility. The negative effect is statistically significant, as mentioned above. Thus, the introduction of futures has decreased the volatility of the underlying spot prices of the SENSEX. Plus, the ARCH and GARCH coefficients are significant too, at the 5% significance level. That means that the "news" parameter and the "persistence" coefficient are also significant by applying this method

Conclusion

The main idea behind this analysis is to compare the volatility of the spot market volatility of the SENSEX before and after the introduction of futures trading. For this purpose, in order to capture the underlying volatility GARCH (1, 1) model has been used. The result from the GARCH model showed presence of volatility in the Indian stock market. In addition, we have included a dummy variable which takes the value 0 for the pre-introduction period and the value 1 for the period after the introduction of futures and we tested the significance and the value of this dummy. The results indicate that there is a great impact in the spot market volatility of the SENSEX index after the introduction of futures contracts because of the significance of the coefficient of the dummy with GARCH (1, 1) model. In addition, this impact is negative because the coefficient of the dummy is negative. Thus, it can be concluded that there is a decrease in volatility of the SENSEX after the introduction of futures. The results of the diagnostic tests confirms that the GARCH models were correctly specified as the values of Q statistics for the standardized residuals were insignificant and the ARCH-LM test statistic did not exhibit additional ARCH effects remaining in the residuals of the models. The study also indicated that the SENSEX index is non-normal and stationary.

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