

“Derivative trading and structural breaks in volatility in India: an ICSS approach”

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DERIVATIVE TRADING AND STRUCTURAL BREAKS IN VOLATILITY IN INDIA: AN ICSS APPROACH

Abstract

Researchers argue that ignoring the structural breaks in the time-series variance can cause significant upward biases in the degree of persistence in estimated GARCH models. Against this backdrop, the present study empirically examines the effect of stock futures on the underlying stock's volatility in India by incorporating the structural breaks with the help of ICSS test and AR (1)-GARCH (1, 1) model for 30 most liquid and actively traded underlying stocks and their associated futures contracts. The study period ranges from the 1st January 2000 or the listing date of the particular stock (whichever is prior) till 31st March 2019. The study contributes to the on-going debate regarding the effect of derivatives on the underlying stock market's volatility in two ways. Firstly, by taking into consideration the breaks in the volatility and, secondly, studying the effect of single stock futures will allow us to evaluate company-specific response to futures trading directly. The study offers a mixed outcome for the stocks under consideration. However, there is evidence of a decline in unconditional volatility for the majority of the stocks. The overall findings indicate that trading in stock futures may not have any detrimental effect on the underlying stock's volatility.

Keywords

stock futures, volatility, AR (1)-GARCH (1, 1), underlying, cash market, futures market

JEL Classification

G11, G14

INTRODUCTION

Volatility modeling of the financial asset is one of the critical aspects of economic research as it guides the investors on the risk associated with the investment. In India, derivatives trading started in the year 2000 with the launch of futures contracts on the Nifty Index of NSE and Sensex Index of Bombay Stock Exchange (BSE). Options trading began in the Indian markets in June 2001. Ever since then F&O segment is surging in terms of the number of contracts traded, volume, and offering of new products. The F&O segment of the NSE surpassed the equity market from 2019 to 2020, with an average daily turnover of ₹ 2,37,590,973 Cr, as compared to ₹ 6,81,983 Cr in the cash segment (derivatives updates on NSE website, www.nseindia.com, 2019). NSE outperformed the US-based CME group to claim its No.1 ranking in terms of derivatives trading with more than 6 billion contracts traded volume in 2019 (Das & Sahgal, 2020). Derivatives were introduced to offer a hedging mechanism and enhance the liquidity, thereby increasing the market's overall efficiency. The effect of the listing of derivatives on the underlying market's volatility and, thus, its job in increasing or decreasing the underlying markets' volatility has remained an intense subject of empirical and analytical interest.

Questions about the effect of derivatives trading on underlying market volatility have been empirically addressed in two ways. Firstly, by

analyzing variation in volatility over the pre- and post-derivatives trading phases and, secondly, by measuring the effect of derivatives trading on the behavior of the underlying markets by comparing the performance with proxies. Moreover, most studies examining the effect of derivatives on the underlying market volatility used some type of GARCH model with dummy variable regressors¹. However, this approach is based on the underlying presumption that any changes detected during the post-derivatives phase are caused by derivatives trading alone.

An increase in volatility could be the outcome of various other events, such as the initiation of a rolling settlement system, circuit breakers, and changes in regulations, and so on. If the structural breaks in variances of the examined time-series are ignored, the degree of persistence of the GARCH model estimate may be significantly biased. Several studies, such as Diebold (1986), Granger and Hyung (1999), Mikosch and Starica (2000), Diebold and Inoue (2001), have stated that neglecting the structural breaks can lead to spurious GARCH model estimation. The primary reasons for such structural breaks could be the changes in the mechanism of exchange rate systems, global financial markets crisis, or the evolution of the stock markets. The shocks produced by these significant economic or political events may cause a deviation in the financial time-series (Andreou & Ghysels, 2002; Wang & Moore, 2009).

1. LITERATURE REVIEW

The derivatives market and its effect on the underlying market volatility are debated again and again with supporting and countering theories.

1.1. Increased volatility due to futures trading

Wats (2017) examined the effect of the derivatives contracts' expiration on the underlying market's volatility using the GARCH family models. He concluded that spot market volatility has increased during the expiry days and week after the listing of the derivatives. Other studies that find a significant increase in the Index return volatility following the listing of futures include Harris (1989), Brorsen (1991), Lee and Ohk (1992), Antoniou and Holmes (1995), Yao (2016).

1.2. Decreased volatility due to futures trading

Others argue that futures' listing potentially reduces the spot market's volatility, thus stabilizing the market. One of the clarifications for the destabilizing theory is that trades in the derivatives market destabilize the underlying market by providing an alternative route for the transmission and reflection of data in the cash market (Cox & Ross, 1976; Ross, 1989). Gulen and Mayhew (2000)

studied the effect of index futures on the volatility of the international equity markets by taking the sample of 21 European nations by applying the BEKK model and GJR-GARCH. They found that the volatility of the underlying market has declined for most of the countries under study.

Similarly, Yilgor, Lidvine, and Mebounou (2016), Chiraz (2016), Bhaumik, Karanasos, and Kartsaklas (2016) used different GARCH family models such as Markov-Switching GARCH, ARFI GARCH, EGARCH, and TGARCH. They found the evidence indicating the decline in the underlying market volatility after listing the derivatives trading. Several studies like Pilar and Rafael (2002), Bandivadekar and Ghosh (2003), Thenmozhi (2002), Raju and Karande (2003), Sarangi and Patnaik (2007) have reported a significant decline in the underlying market volatility in India.

1.3. Mixed evidence/no impact of futures trading

Using the GARCH (1, 1) model, Rahman (2001) investigated the effect of trading in index futures on the volatility of Dow Jones Industrial Average (DJIA) component stocks and observed no variation in conditional volatility. Mallikajunappa and Afzal (2008), Thenmozhi (2002), Kavussanos, Visvikis, and Alexakis (2008) argued that improvement in the volatility cycle was not due to the listing

¹ See Chan (1991), Reyes (1996), Pericli and Koutmos (1997), Mckenzie, Brailsford, and Faff (2001), Tse (1999), Rahman (2001), Gulen and Mayhew (2000), Bandivadekar and Ghosh (2003), Pok and Poshakwale (2006), and Ryoo and Smith (2006).

of derivatives, but due to many other factors, such as the improved distribution of information and greater transparency.

Due to the increase in the speed of information flow, the stock prices have become more sensitive to the recent innovation in the post-derivative period. Bohl, Salm, and Wilfling (2009), C. Lee, Stevenson, and M. Lee (2014) employed Markow-Switching GARCH, which endogenously identified the distinct volatility regimes, to analyze the effect of derivatives on the volatility and found no influence on the spot market. Mallikajunappa and Afzal (2008), Sarangi and Patnaik (2007) applied the GARCH model with dummy variables and did not find any significant effect of derivatives on the underlying market volatility.

Moreover, the literature is inconclusive about whether the listing of derivatives leads to an increase or decrease in the underlying market's volatility. The vast majority of the studies, which are found in the arena of derivative segments, are concentrated on the effect of index futures on the underlying market. A limited number of studies have been undertaken in the area of single stock futures. Indian studies based on stock futures focus on conceptual clarity or cover only a short period. Research focusing on the index analysis does not consider the stock-specific characteristics, which could also play a significant role in the formation of the volatility.

The present study empirically examines the effect of stock futures on India's underlying stock's volatility by incorporating structural breaks. The study contributes to the on-going debate regarding the effect of derivatives on the underlying stock market's volatility in two ways. Firstly, by reinvestigating the issue by applying a distinct analytical technique, which is based on the methodology used by Aggarwal, Inclan, and Leal (1999), Andreou and Ghysels (2002), Malik and Hassan (2004), Kang, Jung, Park, and Yoon (2007). The study attempts to model the underlying stock's volatility with stock futures by considering the breaks in the volatility. It aims at identifying the structural breaks, if any, in the stock prices by applying the ICSS test of Inclan and Tiao (1994). Secondly, studying the effect of single stock futures will allow us to directly evaluate company-specific responses to futures trading, in contrast to the market-wide effect gained from research with index futures.

2. METHOD

The Individual Stock Futures (ISF) has proved to be a hugely successful financial instrument on Indian bourses, and NSE has continued to account for the majority of total volumes traded in the ISF segment all over the world. The resulting sample for this study comprises 30 most liquid and actively traded underlying stocks on which futures contracts are available. These 30 stock futures contribute to around

Table 1. List of selected stocks and their volume

Source: <https://www1.nseindia.com>

| Stock | Volume | | | Stock | Volume | | |
|------------|-----------|---------|--------|-----------|-----------|---------|--------|
| | Contracts | | | | Contracts | | |
| | Futures | Options | Total | | Futures | Options | Total |
| ASHOKLEY | 928 | 1,673 | 2,601 | INFRATEL | 3,358 | 1,383 | 4,741 |
| AUROPHARMA | 1,674 | 2,003 | 3,677 | INFY | 1,759 | 2,441 | 4,200 |
| AXISBANK | 3,645 | 3,697 | 7,342 | ITC | 1,050 | 1,287 | 2,337 |
| BHARTIARTL | 11,550 | 13,551 | 25,101 | JUSTDIAL | 1,371 | 1,179 | 2,550 |
| CIPLA | 1,236 | 1,025 | 2,261 | KOTAKBANK | 1,261 | 803 | 2,064 |
| GLENMARK | 4,891 | 5,215 | 10,106 | LT | 1,309 | 1,322 | 2,631 |
| GRASIM | 2,895 | 1,610 | 4,505 | MARUTI | 1,729 | 3,598 | 5,327 |
| HDFC | 1,469 | 1,418 | 2,887 | RELIANCE | 7,010 | 15,910 | 22,920 |
| HDFCBANK | 2,234 | 1,423 | 3,657 | SBIN | 3,579 | 4,940 | 8,519 |
| HEROMOTOCO | 1,865 | 2,769 | 4,634 | TATAELXSI | 1,447 | 610 | 2,057 |
| IBULHSGFIN | 3,827 | 1,527 | 5,354 | TATASTEEL | 3,581 | 4,489 | 8,070 |
| ICICIBANK | 3,781 | 3,536 | 7,317 | TCS | 1,451 | 2,877 | 4,328 |
| IDEA | 4,913 | 7,224 | 12,137 | VEDL | 1,796 | 1,860 | 3,656 |
| INDIGO | 1,369 | 853 | 2,222 | YESBANK | 10,764 | 6,420 | 17,184 |
| INDUSINDBK | 1,759 | 1,049 | 2,808 | ZEEL | 2,053 | 1,602 | 3,655 |

70–80% of the total trading volume of the F&O segment of NSE, excluding the index futures. The majority of them are also part of the S&P Nifty Index, the Benchmark Index of NSE. The data extracted for 30 stocks have been procured from the Bloomberg database. The study period will range from the 1st January 2000 or the listing date of the particular stock (whichever is prior) till 31st March 2019.

2.1. Testing for ARCH effect

The ARCH test involves testing the existence of heteroscedasticity in the time-series data. Lagrange multiplier (LM) test by Engle helps in checking for ARCH effect. Let $\varepsilon_t = y_t - u_t$ be the residual series. The squared series ε_t^2 is utilized to implement the LM test for checking conditional heteroscedasticity. The null hypothesis is stated as follows:

$$H_0: \alpha_i = 0, i = 1, 2, \dots, q$$

versus

$$H_1: \alpha_i \neq 0, \text{ for at least one } i.$$

In the linear regression

$$\varepsilon_t^2 = \omega + \alpha_1 \varepsilon_{t-1}^2 + \dots + \alpha_q \varepsilon_{t-q}^2, t = q + 1, \dots, N,$$

where q is the length of ARCH lags, and N is the number of observations used in the regression equation.

The test statistic for LM test is defined by:

$$LM = NR^2,$$

where R^2 is the R -squared from the regression of ε_t^2 in the equation and defined by:

$$R^2 = \frac{\text{Regression sum of squares}}{\text{Total sum of squares}}.$$

2.2. Testing for multiple structural breaks (Iterated Cumulative Sums of Squares (ICSS) algorithm of Inclan and Tiao (1994))

Iterative Cumulative Sums of Squares (ICSS) algorithm proposed by Inclan and Tiao (1994) al-

lows for detecting multiple breakpoints in the variance in a time series. The idea behind the ICSS algorithm of Inclan and Tiao can be outlined in sequential steps. The unconditional variance of financial time-series is stationary until a sudden break is observed. After that, until the occurrence of the next structural break, the unconditional variance is stationary. This process repeats through time, generating multiple numbers of structural breaks in the unconditional variance in n observations:

$$\sigma_t^2 = \begin{cases} \tau_0^2 & 1 < t < i_1 \\ \tau_1^2 & i_1 < t < i_2 \\ \vdots & \vdots \\ \tau_M^2 & i_M < t < i_{M+1} \end{cases}$$

To estimate the number of changes and the point in time of variance shifts, a cumulative sum of squared residuals is used, $C_k = \sum_{t=1}^k \varepsilon_t^2$, $k = 1, 2, \dots, n$, where $\{\varepsilon_t\}$ is a series of uncorrelated random variables with zero mean and unconditional variance σ_t^2 . Inclan and Tiao define the statistic:

$$D_k = \frac{C_k}{C_n} - \frac{tk}{n}, k = 1, 2, \dots, n, D_0 = D_n = 0.$$

If no sudden changes occur during the entire sampling duration in the variance of the sequence, D_k oscillates about zero. If there are one or more sudden shifts in variance, then the D_k statistics will drift either above or below the zero. The ICSS algorithm helps in identifying breaks in variance of the time-series at different points in time.

2.3. Linking the structural breaks in volatility with trading in stock futures

First, the dates for the structural breaks in the stocks will be estimated. Later, these structural breaks were matched with the dates of the listing of stock futures on the individual stocks. If a structural break is found within six months of the listing of stock futures, it has been attributed as likely to derivative trading.

AR (1)-GARCH (1, 1) is a GARCH family model, in which the mean is determined by a first-order auto-regressive AR (1), with a GARCH (1, 1) error:

$$x_t = u_t + \sigma_t \varepsilon_t, E[\varepsilon_t] = 0, E[\varepsilon_t^2] = 1, \varepsilon_t \text{ i.i.d.},$$

$$\mu_t = \lambda X_{t-1},$$

$$\sigma_t^2 = a_0 + a(X_{t-1} - \mu_{t-1})^2 + b\sigma_{t-1}^2.$$

Once all the structural breakpoints are identified, dummy variables are created for each detected break. Each dummy variable is denoted with value one onwards from the identified location until the end of the data series and 0 elsewhere.

3. RESULTS

Table 2 displays the result of the ADF unit root test. All the variables are non-stationary at the lev-

el as the *p*-value is more than 0.05%. Therefore, the Unit Root Test is conducted in the first difference for all the variables. All the series are stationary at the first difference at 1% level of significance. The results of the ADF test indicate that all variables are integrated of the same order.

Table 3 depicts the ARCH test results for all 30 stocks traded at the cash segment of NSE. The standard diagnostic test of the Residuals from the model confirms the presence of ARCH effect. There is a presence of the ARCH effect in the closing return series of all the variables.

After detecting the structural breaks in the return series of selected highly traded 30 stocks, an attempt has been made to associate these structural

Table 2. Unit root test (augmented Dickey-Fuller test)

| Stock | Spot | | Futures | | Stock | Spot | | Futures | |
|------------|--------------------|-------------------------|---------------------|-------------------------|-----------|---------------------|-------------------------|----------------------|-------------------------|
| | ADF at level | ADF at first difference | ADF at level | ADF at first difference | | ADF at level | ADF at first difference | ADF at level | ADF at first difference |
| ASHOKLEY | -2.669 (-0.079) | -77.9823 (-0.00) | -1.8401 (-0.361) | -25.085 (-0.00) | INFRATEL | -1.903 (-0.330) | -252.625 (-0.000) | -1.840 (-0.361) | -251.084 (-0.000) |
| AUROPHARMA | -3.075 (-0.112) | -14.3857 (-0.000) | -3.067 (-0.114) | -14.026 (-0.000) | INFY | -2.8434 (-0.052) | -264.133 (-0.000) | -2.696 (-0.074) | -264.045 (-0.000) |
| AXISBANK | -2.407 (-0.139) | -216.989 (-0.000) | -2.473 (-0.121) | -218.720 (-0.000) | ITC | -1.793 (-0.389) | -435.009 (-0.000) | -1.887 (-0.333) | -297.513 (-0.000) |
| BHARTIARTL | -2.496 (0.116) | (-240.736) (-0.000) | -420.76 (-0.000) | -420.769 (0.000) | JUSTDIAL | -1.436 (-0.565) | -169.532 (-0.000) | -1.450 (-0.558) | -218.429 (-0.000) |
| CIPLA | -1.471 (-0.548) | -305.751 (-0.000) | -1.505 (-0.531) | -189.269 (-0.000) | KOTAKBANK | -2.743 (-0.072) | -254.133 (-0.000) | -2.596 (-0.064) | -254.045 (-0.000) |
| GLENMARK | -1.476 (-0.546) | -296.195 (-0.000) | -1.189 (-0.681) | -186.673 (-0.000) | LT | -2.496 (0.116) | -240.736 (-0.000) | -420.769 (-0.000) | -420.769 (0.000) |
| GRASIM | -1.903 (-0.330) | -252.625 (-0.000) | -1.840 (-0.361) | -251.084 (-0.000) | MARUTI | -1.683 (-0.389) | -435.009 (-0.000) | -1.797 (-0.333) | -298.513 (-0.000) |
| HDFC | -2.843 (-0.052) | -264.133 (-0.000) | -2.696 (-0.074) | -264.045 (-0.000) | RELIANCE | -1.803 (-0.320) | -242.625 (-0.000) | -1.740 (-0.351) | -241.084 (-0.000) |
| HDFCBANK | -2.283 (-0.177) | -174.557 (-0.000) | -2.256 (-0.186) | -169.916 (-0.000) | SBIN | -2.496 (0.116) | -240.736 (-0.000) | -420.769 (-0.000) | -420.769 (0.000) |
| HEROMOTOCO | -1.219 (-0.668) | -116.178 (-0.000) | -1.098 (-0.718) | -128.5 (-0.0001) | TATAELXSI | -1.471 (-0.548) | -305.751 (-0.000) | -1.505 (-0.531) | -189.269 (-0.000) |
| IBULHSGFIN | -0.992 (-0.758) | -161.898 (-0.000) | -0.692 (-0.846) | -162.498 (-0.000) | TATASTEEL | -1.476 (-0.546) | -296.195 (-0.000) | -1.189 (-0.681) | -186.673 (-0.000) |
| ICICIBANK | -1.783 (-0.389) | -425.009 (-0.000) | -1.897 (-0.333) | -298.513 (-0.000) | TCS | -1.903 (-0.330) | -252.625 (-0.000) | -1.840 (-0.361) | -251.084 (-0.000) |
| IDEA | -2.843 (-0.052) | -264.133 (-0.000) | -2.696 (-0.074) | -264.045 (-0.000) | VEDL | -2.283 (-0.177) | -174.557 (-0.000) | -2.256 (-0.186) | -169.916 (-0.000) |
| INDIGO | 0.895 (-0.995) | -195.973 (-0.000) | 0.538 (-0.988) | -277.977 (-0.000) | YESBANK | -1.211 (-0.668) | -116.178 (-0.000) | -1.098 (-0.718) | -128.5 (-0.000) |
| INDUSINDBK | -1.360 (-0.603) | -216.679 (-0.000) | -1.370 (-0.598) | -216.604 (-0.000) | ZEEL | -0.992 (-0.758) | -161.898 (-0.000) | -0.692 (-0.846) | -162.498 (-0.000) |

Note: () denote *p*-value.

Table 3. Results of ARCH test

| Variables | p-value | Inference | Variables | p-value | Inference |
|------------|---------|-----------|-----------|---------|-----------|
| ASHOKLEY | 0.000 | Present | INFRATEL | 0.000 | Present |
| AUROPHARMA | 0.000 | Present | INFY | 0.000 | Present |
| AXISBANK | 0.000 | Present | ITC | 0.000 | Present |
| BHARTIARTL | 0.000 | Present | JUSTDIAL | 0.000 | Present |
| CIPLA | 0.000 | Present | KOTAKBANK | 0.000 | Present |
| GLENMARK | 0.000 | Present | LT | 0.000 | Present |
| GRASIM | 0.000 | Present | MARUTI | 0.000 | Present |
| HDFC | 0.000 | Present | RELIANCE | 0.000 | Present |
| HDFCBANK | 0.000 | Present | SBIN | 0.000 | Present |
| HEROMOTOCO | 0.000 | Present | TATAELXSI | 0.000 | Present |
| IBULHSGFIN | 0.000 | Present | TATASTEEL | 0.000 | Present |
| ICICIBANK | 0.000 | Present | TCS | 0.000 | Present |
| IDEA | 0.000 | Present | VEDL | 0.000 | Present |
| INDIGO | 0.000 | Present | YESBANK | 0.000 | Present |
| INDUSINDBK | 0.000 | Present | ZEEL | 0.000 | Present |

breaks with the listing dates of stock futures on individual stocks. The stocks, which have displayed similar patterns in terms of changes in persistence in volatility, unconditional volatility, and rate of adjustment to new information (measured by α), have been grouped. The detailed analysis after incorporating detected structural breaks into the AR (1)-GARCH (1, 1) Model is presented in Appendix. Stocks were divided into seven categories, viz. Panel A, Panel B, Panel C, Panel D, Panel E, Panel F, and Panel G. This classification is based on the influence of stock futures on the underlying volatility.

If a structural break is observed six months after listing the stock futures, it is associated with trading in futures. After this structural break date, the change in persistence of volatility, unconditional volatility, and rate of adjustment to new information (denoted by α) is observed and reported in Table 4. In the case of AUROPHARMA, ICICIBANK, and JUSTDIAL, the total persistence increases, while α and unconditional volatility declined for the period after this break (Panel A). On the contrary, ASHOKLEY, AXISBANK, HDFCBANK, INDUSINDBK, INFRATEL, RELIANCE, and TCS have shown a downfall in

Table 4. Impact of stock futures on the volatility of underlying stocks

| Stock | Impact on the volatility | | | |
|----------------|-----------------------------------------------------------|---------------------|----------|--------------------------|
| | If structural break associated with stock futures trading | Direction of impact | | |
| | | Persistence | α | Unconditional Volatility |
| Panel A | | | | |
| AUROPHARMA | Yes | ↓ | ↑ | ↑ |
| ICICIBANK | Yes | ↓ | ↑ | ↑ |
| JUSTDIAL | Yes | ↓ | ↑ | ↑ |
| Panel B | | | | |
| ASHOKLEY | Yes | ↓ | ↓ | ↓ |
| AXISBANK | Yes | ↓ | ↓ | ↓ |
| HDFCBANK | Yes | ↓ | ↓ | ↓ |
| INDUSINDBK | Yes | ↓ | ↓ | ↓ |
| INFRATEL | Yes | ↓ | ↓ | ↓ |
| RELIANCE | Yes | ↓ | ↓ | ↓ |
| TCS | Yes | ↓ | ↓ | ↓ |
| Panel C | | | | |
| BHARTIARTL | Yes | ↑ | ↑ | ↓ |
| INFY | Yes | ↑ | ↑ | ↓ |
| MARUTI | Yes | ↑ | ↑ | ↓ |

Table 4 (cont.). Impact of stock futures on the volatility of underlying stocks

| Stock | Impact on the volatility | | | |
|----------------|-----------------------------------------------------------|----------------------------------|----------------------------------|---------------------------------|
| | If structural break associated with stock futures trading | Direction of impact | | |
| | | Persistence | α | Unconditional Volatility |
| Panel D | | | | |
| CIPLA | Yes | ↓ | ↑ | ↓ |
| HDFC | Yes | ↓ | ↑ | ↓ |
| INDIGO | Yes | ↓ | ↑ | ↓ |
| LT | Yes | ↓ | ↑ | ↓ |
| Panel E | | | | |
| GRASIM | Yes | ↑ | ↓ | ↓ |
| HEROMOTOCO | Yes | ↑ | ↓ | ↓ |
| ITC | Yes | ↑ | ↓ | ↓ |
| SBIN | Yes | ↑ | ↓ | ↓ |
| TATASTEEL | Yes | ↑ | ↓ | ↓ |
| ZEEL | Yes | ↑ | ↓ | ↓ |
| Panel F | | | | |
| IDEA | Yes | ↑ | ↑ | ↑ |
| Panel G | | | | |
| GLENMARK | No | – | – | – |
| IBULHSGFIN | No | – | – | – |
| KOTAKBANK | No | – | – | – |
| TATAELXSI | No | – | – | – |
| VEDL | No | – | – | – |
| YESBANK | No | – | – | – |
| Total = 30 | Yes = 24 No = 6 | Increased = 10 Decreased = 14 | Increased = 11 Decreased = 13 | Increased = 4 Decreased = 20 |

the total persistence, unconditional volatility, and α (Panel B).

Panel C comprises of BHARTIARTL, INFY, and MARUTI. There is a decline in the unconditional volatility, but its persistence, as well as α , has increased after the occurrence of the structural break. Panel D consists of CIPLA, HDFC, INDIGO, and LT for which the total persistence and unconditional volatility have declined, but α has increased during the observed structural break in volatility. There is observed an increase in α , and reduction in the total persistence and the unconditional volatility of GRASIM, HEROMOTOCO, ITC, SBIN, TATASTEEL, and ZEEL for the period after the listing of stock futures (Panel E). However, no structural break is observed within six months after the listing of stock futures for GLENMARK, IBULHSGFIN, KOTAKBANK, TATAELXSI, and VEDL, and YESBANK (Panel G).

No structural break was observed within six months after listing the stock futures for six out

of thirteen stocks. Unconditional volatility has declined for twenty out of twenty-four stocks for which structural breaks were observed within six months after the listing of stock futures. It is noted that the unconditional volatility has declined for the majority of the stocks after the listing of futures contracts. Total persistence has risen for ten stocks while declined for fourteen stocks. On the other hand, α has increased for eleven stocks, while it has decreased for thirteen stocks.

4. DISCUSSION

Through this study, an attempt has been made to model the underlying stock's volatility with stock futures by taking into consideration the breaks in the volatility. Several studies, such as Diebold (1986), Granger and Hyung (1999), Mikosch and Starica (2000), Diebold and Inoue (2001), have stated that neglecting the structural breaks can lead to spurious GARCH model estimation. Therefore, Iterated Cumulative Sums of Squares (ICSS) algo-

rithm of Inclan and Tiao (1994) was applied for detecting the multiple structural breaks for 30 highly traded and liquid stocks.

If a break is observed within six months after the listing of stock futures, then unconditional volatility, the nature of changes in total persistence, and α have been examined. Reduction in the unconditional volatility was observed for twenty

out of thirty stocks after incorporating detected structural breaks into the AR(1)-GARCH(1,1) model. It is noted that the unconditional volatility has declined for the majority of the stocks after the listing of futures contracts. Total persistence has risen for ten stocks while declined for fourteen stocks. On the other hand, α has increased for eleven stocks, while it has decreased for thirteen stocks.

CONCLUSION

Through this analysis, any consistent patterns were not found in terms of changes in total persistence, unconditional volatility, and α for the underlying stocks for the period after the relevant breaks. The mixed outcome could be due to stock-specific characteristics, which could also play a significant role in the formation of the volatility. Consequently, the listing of stock futures may not have any clear effect on the underlying stock's volatility. The findings of the study reveal that the unconditional volatility has declined for the majority of the stocks after the listing of futures contracts. The analysis findings suggest that trading in stock futures may not have any detrimental effect on the underlying stock's volatility. These findings are in line with conclusions drawn by Badhani, Harish, and Chauhan (2008), Malik and Shah (2016).

AUTHOR CONTRIBUTIONS

Conceptualization: Sanjeeta Shirodkar.

Data curation: Sanjeeta Shirodkar.

Formal analysis: Sanjeeta Shirodkar.

Investigation: Guntur Anjana Raju, Sanjeeta Shirodkar.

Methodology: Guntur Anjana Raju, Sanjeeta Shirodkar

Project administration: Sanjeeta Shirodkar.

Resources: Guntur Anjana Raju.

Software: Guntur Anjana Raju, Sanjeeta Shirodkar.

Supervision: Guntur Anjana Raju.

Validation: Guntur Anjana Raju.

Visualization: Sanjeeta Shirodkar.

Writing – original draft: Sanjeeta Shirodkar.

Writing – review & editing: Guntur Anjana Raju.

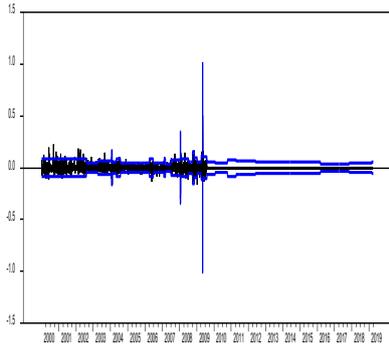
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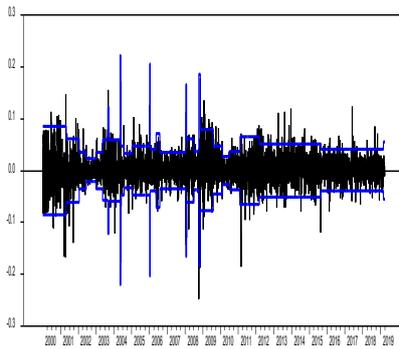
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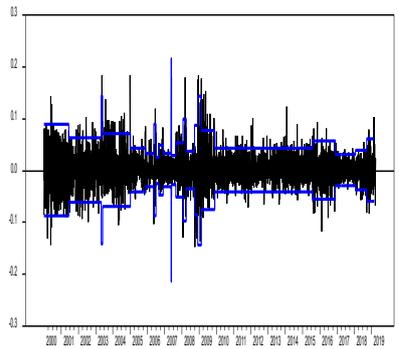
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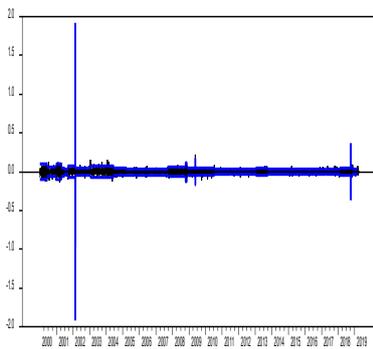
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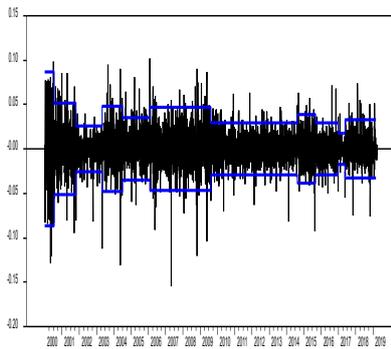
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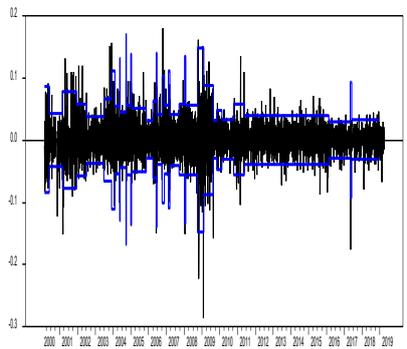
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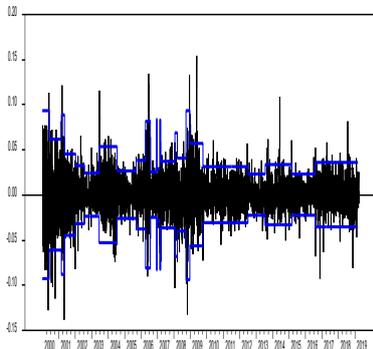
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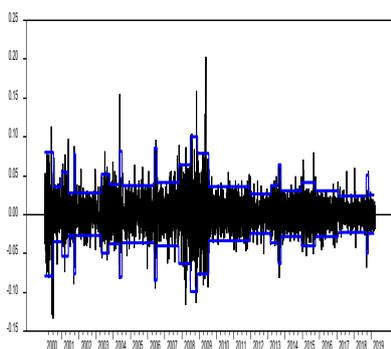
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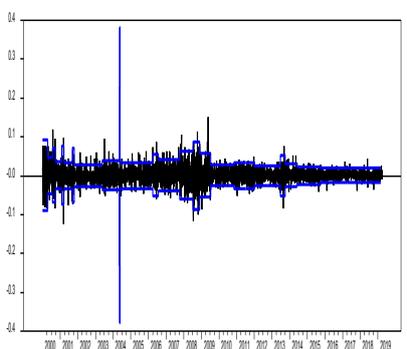
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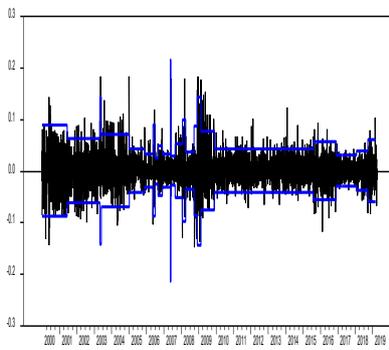
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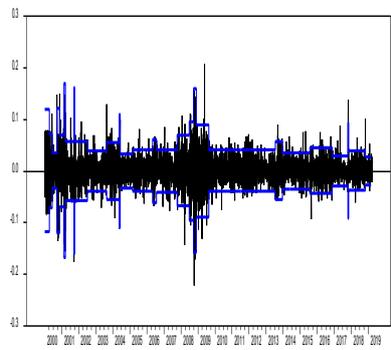
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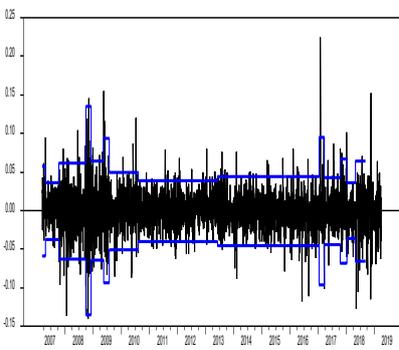
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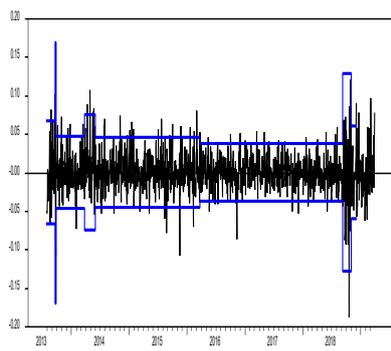
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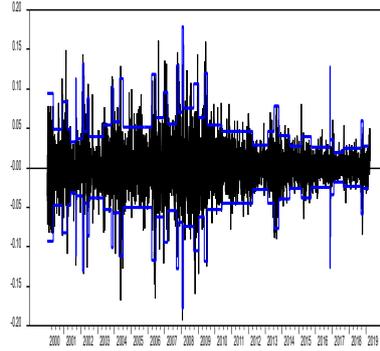
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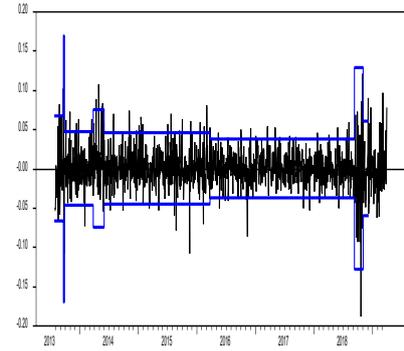
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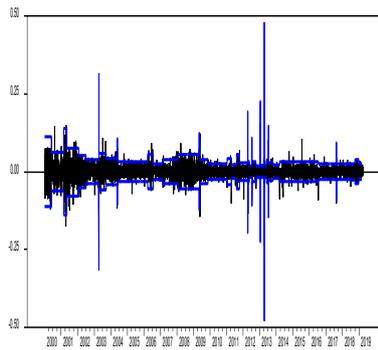
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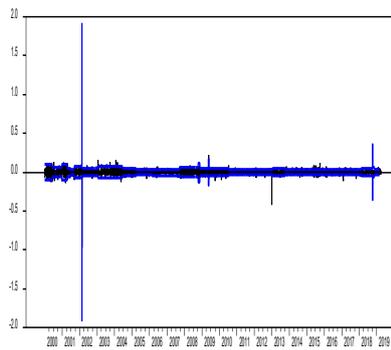
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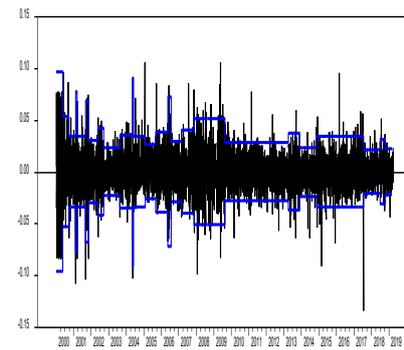
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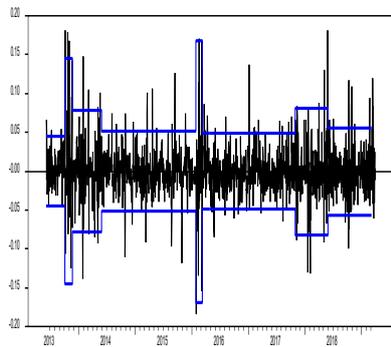
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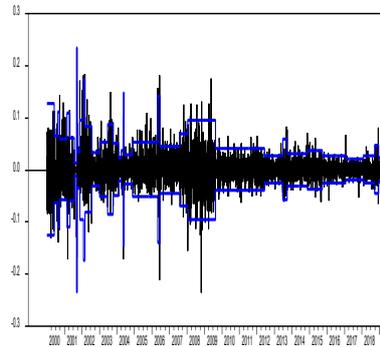
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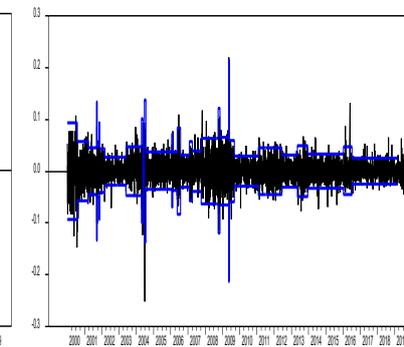
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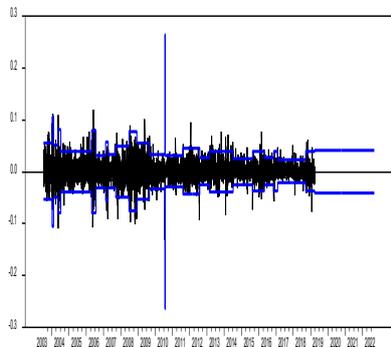
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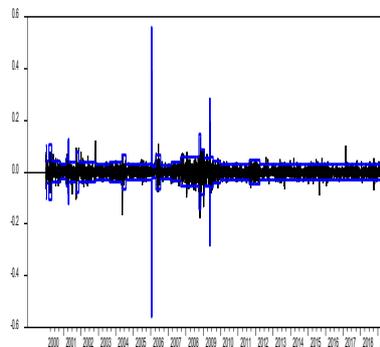
KOTAKBANK



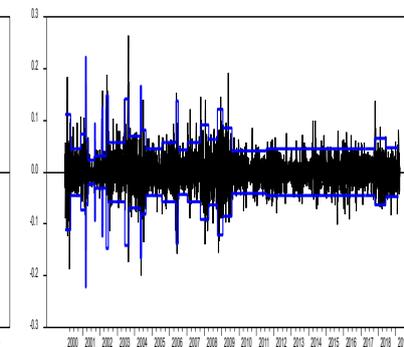
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MARUTI



RELIANCE



SBIN

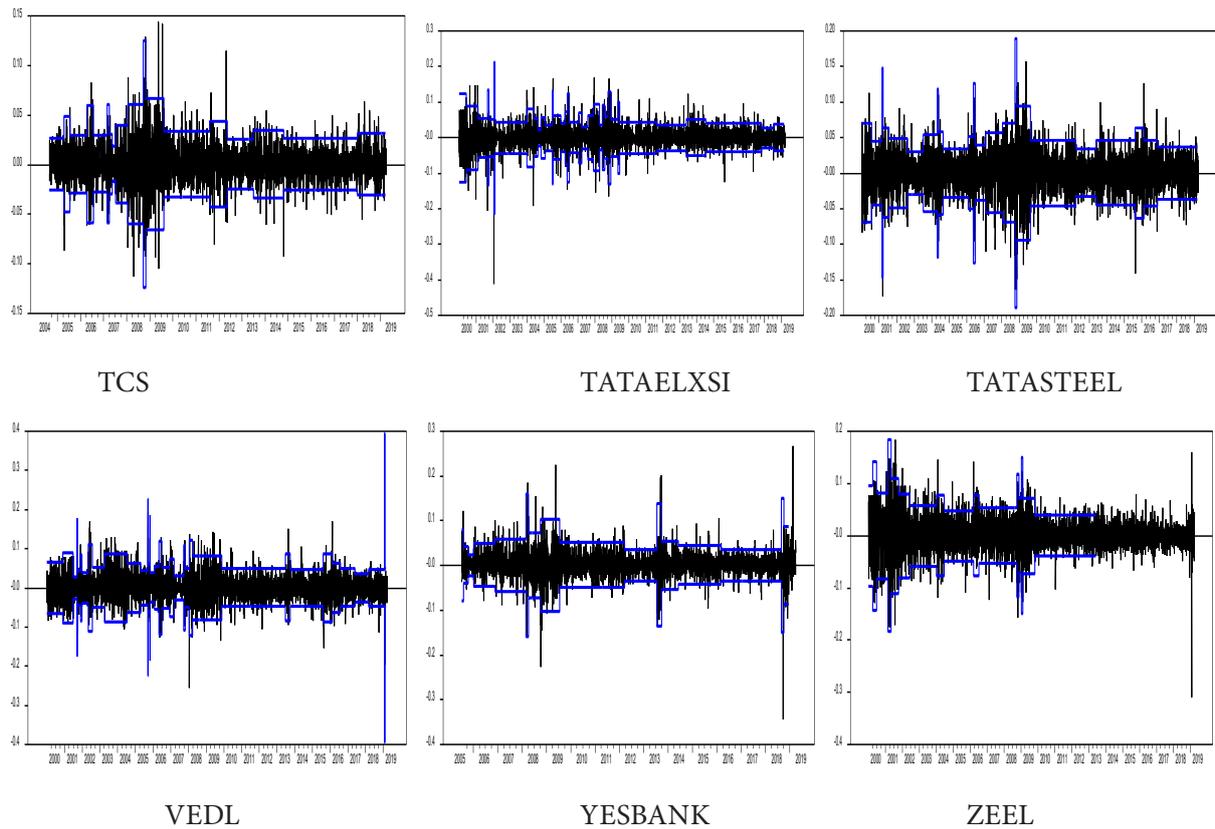


Figure 1. Multiple Structural Breaks (Iterated Cumulative Sums of Squares (ICSS) algorithm of Inclan and Tiao (1994))

| Period | ω | α | β | Total Persistence: ($\alpha+\beta$) | Unconditional Volatility: $\omega/(1-\alpha-\beta)$ |
|---------------------------------------------------------------|----------|----------|---------|------------------------------------------|--------------------------------------------------------|
| Volatility Breaks in ASHOKLEY | | | | | |
| Date of commencement of Derivative trading: 20-04-2005 | | | | | |
| 05/07/2002_30/12/2004 | 1.311 | 0.194 | 0.669 | 0.864 | 9.611 |
| 31/12/2004_17/11/2005 | 0.717 | 0.165 | 0.764 | 0.928 | 9.994 |
| 18/11/2005_29/09/2008 | 1.830 | 0.157 | 0.630 | 0.786 | 8.553 |
| 30/09/2008_02/11/2009 | -0.021 | 0.109 | 0.898 | 1.007 | 3.062 |
| 03/11/2009_10/02/2010 | 0.513 | 0.038 | 0.868 | 0.906 | 5.461 |
| 11/02/2010_20/05/2011 | 0.732 | 0.155 | 0.718 | 0.872 | 5.719 |
| 21/05/2011_16/02/2016 | 0.684 | 0.060 | 0.762 | 0.823 | 3.856 |
| 17/02/2016_02/06/2017 | 0.954 | 0.366 | 0.397 | 0.763 | 4.021 |
| 03/06/2017_29/03/2019 | 1.270 | 0.067 | 0.449 | 0.516 | 2.623 |
| Volatility Breaks in AUOPHARMA | | | | | |
| Date of commencement of Derivative trading: 12-05-2005 | | | | | |
| 05/01/2000_30/04/2001 | 12.687 | 0.411 | -0.084 | 0.327 | 18.856 |
| 10/05/2001_17/09/2003 | 0.064 | 0.087 | 0.910 | 0.997 | 22.097 |
| 18/09/2003_11/05/2004 | 4.754 | 0.043 | 0.425 | 0.468 | 8.938 |
| 12/05/2004_05/08/2005 | 0.071 | -0.076 | 1.063 | 0.987 | 5.376 |
| 06/08/2005_09/01/2006 | 3.321 | 0.076 | 0.353 | 0.429 | 5.818 |
| 10/01/2006_15/01/2008 | 0.492 | 0.113 | 0.761 | 0.874 | 3.899 |
| 16/01/2008_04/08/2009 | 0.962 | 0.057 | 0.882 | 0.940 | 15.928 |
| 05/08/2009_09/02/2010 | 2.761 | -0.091 | 0.581 | 0.490 | 5.409 |
| 10/02/2010_09/02/2011 | 1.707 | 0.043 | 0.341 | 0.384 | 2.770 |

| Period | ω | α | β | Total Persistence: ($\alpha+\beta$) | Unconditional Volatility: $\omega/(1-\alpha-\beta)$ |
|----------------------------------------------------------------|----------|----------|---------|------------------------------------------|--------------------------------------------------------|
| 10/02/2011_07/03/2012 | 1.148 | 0.152 | 0.741 | 0.893 | 10.707 |
| 08/03/2012_28/08/2015 | 1.129 | 0.042 | 0.790 | 0.831 | 6.690 |
| 29/08/2015_29/03/2019 | 0.550 | 0.076 | 0.784 | 0.861 | 3.951 |
| Volatility Breaks in AXISBANK | | | | | |
| Date of commencement of Derivative trading: 20-04-2005 | | | | | |
| 05/01/2000_16/11/2001 | 3.256 | 0.310 | 0.540 | 0.850 | 21.713 |
| 17/11/2001_01/01/2003 | 0.142 | 0.266 | 0.784 | 1.051 | -2.803 |
| 02/01/2003_06/06/2005 | 0.172 | 0.096 | 0.888 | 0.984 | 10.853 |
| 07/06/2005_18/01/2006 | 3.323 | 0.085 | 0.411 | 0.497 | 6.601 |
| 19/01/2005_18/01/2008 | 2.728 | 0.259 | 0.453 | 0.712 | 9.478 |
| 19/01/2008_18/08/2009 | 2.281 | 0.079 | 0.815 | 0.894 | 21.560 |
| 19/08/2009_07/06/2012 | 1.175 | 0.146 | 0.558 | 0.704 | 3.962 |
| 08/06/2012_20/11/2014 | 0.056 | 0.039 | 0.940 | 0.979 | 2.657 |
| 21/11/2014_24/09/2015 | 0.840 | 0.032 | 0.703 | 0.735 | 3.169 |
| 25/09/2015_31/01/2017 | 1.287 | -0.019 | 0.264 | 0.245 | 1.705 |
| 01/02/2017_29/03/2019 | 1.037 | 0.276 | 0.123 | 0.400 | 1.726 |
| Volatility Breaks in BHARTIARTL | | | | | |
| Date of commencement of Derivative trading : 20-04-2005 | | | | | |
| 05/01/2000_22/11/2001 | 3.995 | 0.197 | 0.462 | 0.658 | 11.698 |
| 23/11/2001_20/01/2003 | 1.738 | 0.367 | 0.372 | 0.739 | 6.649 |
| 21/01/2003_14/06/2004 | 1.967 | 0.023 | 0.808 | 0.831 | 11.613 |
| 15/06/2004_22/07/2005 | 2.967 | 0.059 | 0.465 | 0.524 | 6.234 |
| 23/07/2005_19/09/2007 | 0.620 | 0.134 | 0.710 | 0.843 | 3.959 |
| 20/09/2007_10/10/2008 | 2.520 | 0.004 | 0.678 | 0.682 | 7.925 |
| 11/10/2008_27/05/2009 | 1.247 | 0.444 | 0.575 | 1.019 | -64.730 |
| 28/05/2009_12/07/2010 | 3.565 | 0.257 | 0.166 | 0.423 | 6.175 |
| 13/07/2010_10/01/2013 | 2.566 | 0.110 | 0.274 | 0.384 | 4.166 |
| 11/01/2013_29/03/2019 | 2.790 | 0.058 | 0.089 | 0.147 | 3.272 |
| Volatility Breaks in CIPLA | | | | | |
| Date of commencement of Derivative trading: 02-07-2001 | | | | | |
| 05/01/2000_19/07/2000 | 13.355 | 0.229 | 0.021 | 0.249 | 17.791 |
| 20/07/2000_23/10/2001 | 1.187 | 0.049 | 0.772 | 0.820 | 6.605 |
| 24/10/2001_28/04/2003 | 0.779 | 0.046 | 0.466 | 0.513 | 1.599 |
| 29/04/2003_06/07/2004 | 1.756 | 0.187 | 0.476 | 0.663 | 5.214 |
| 07/07/2004_02/02/2006 | 1.546 | 0.100 | 0.384 | 0.484 | 2.994 |
| 03/02/2006_18/08/2009 | 0.745 | 0.135 | 0.729 | 0.864 | 5.466 |
| 19/08/2009_15/08/2014 | 0.946 | 0.014 | 0.549 | 0.562 | 2.162 |
| 16/08/2014_03/09/2015 | 0.217 | 0.011 | 0.930 | 0.941 | 3.664 |
| 04/09/2015_28/12/2016 | 1.343 | 0.252 | 0.138 | 0.390 | 2.201 |
| 29/12/2016_23/05/2017 | 0.210 | 0.197 | 0.547 | 0.744 | 0.818 |
| 24/05/2017_29/03/2019 | 0.530 | 0.144 | 0.646 | 0.790 | 2.527 |
| Volatility Breaks in GLENMARK | | | | | |
| Date of commencement of Derivative trading: 28-09-2013 | | | | | |
| 25/02/2000_11/12/2001 | 0.396 | 0.058 | 0.907 | 0.965 | 11.238 |
| 12/12/2001_05/07/2002 | 0.479 | -0.120 | 1.060 | 0.940 | 8.007 |
| 06/07/2002_30/12/2004 | 1.311 | 0.194 | 0.669 | 0.864 | 9.611 |
| 31/12/2004_17/11/2006 | 0.717 | 0.165 | 0.764 | 0.928 | 9.994 |
| 18/11/2006_29/09/2008 | 1.830 | 0.157 | 0.630 | 0.786 | 8.553 |
| 30/09/2008_02/11/2009 | -0.021 | 0.109 | 0.898 | 1.007 | 3.062 |
| 03/11/2009_10/02/2010 | 0.513 | 0.038 | 0.868 | 0.906 | 5.461 |
| 11/02/2010_20/05/2011 | 0.732 | 0.155 | 0.718 | 0.872 | 5.719 |
| 21/05/2011_16/02/2016 | 0.684 | 0.060 | 0.762 | 0.823 | 3.856 |
| 17/02/2016_02/06/2017 | 0.954 | 0.366 | 0.397 | 0.763 | 4.021 |
| 03/06/2017_29/03/2019 | 1.270 | 0.067 | 0.449 | 0.516 | 2.623 |

| Period | ω | α | β | Total Persistence: ($\alpha+\beta$) | Unconditional Volatility: $\omega/(1-\alpha-\beta)$ |
|---------------------------------------------------------------|----------|----------|---------|------------------------------------------|--------------------------------------------------------|
| Volatility Breaks in GRASIM | | | | | |
| Date of commencement of Derivative trading: 02-07-2001 | | | | | |
| 05/01/2000_04/10/2001 | 5.439 | 0.159 | 0.458 | 0.617 | 14.200 |
| 05/10/2001_17/06/2003 | 0.006 | -0.021 | 1.017 | 0.996 | 1.761 |
| 18/06/2003_16/07/2004 | 0.793 | 0.060 | 0.815 | 0.875 | 6.353 |
| 17/07/2004_12/09/2005 | 0.480 | 0.033 | 0.692 | 0.725 | 1.749 |
| 13/09/2005_13/03/2007 | 0.331 | 0.224 | 0.736 | 0.960 | 8.348 |
| 14/03/2007_21/01/2008 | 0.720 | 0.038 | 0.748 | 0.786 | 3.368 |
| 22/01/2008_06/10/2009 | 1.128 | 0.096 | 0.776 | 0.872 | 8.822 |
| 07/10/2009_03/07/2012 | 1.592 | 0.241 | 0.100 | 0.341 | 2.415 |
| 04/07/2012_25/07/2013 | 1.019 | 0.167 | 0.085 | 0.252 | 1.362 |
| 26/07/2013_10/03/2015 | 0.166 | 0.087 | 0.861 | 0.947 | 3.148 |
| 11/03/2015_05/08/2016 | 0.354 | 0.104 | 0.623 | 0.728 | 1.299 |
| 06/08/2016_29/03/2019 | 0.513 | 0.022 | 0.807 | 0.829 | 3.004 |
| Volatility Breaks in HDFCBANK | | | | | |
| Date of commencement of Derivative trading: 29-08-2003 | | | | | |
| 05/01/2000_05/01/2001 | 1.467 | 0.188 | 0.651 | 0.839 | 9.129 |
| 06/01/2001_09/10/2003 | 0.336 | 0.187 | 0.744 | 0.931 | 4.841 |
| 10/10/2003_11/05/2004 | 0.968 | -0.108 | 0.862 | 0.754 | 3.933 |
| 12/05/2004_18/05/2006 | 0.416 | 0.081 | 0.799 | 0.881 | 3.488 |
| 19/05/2006_27/06/2008 | 0.160 | 0.056 | 0.921 | 0.976 | 6.773 |
| 28/06/2008_22/12/2011 | 0.050 | 0.055 | 0.934 | 0.990 | 4.850 |
| 23/12/2011_06/08/2013 | 0.904 | 0.023 | 0.553 | 0.576 | 2.133 |
| 07/08/2013_06/10/2015 | 0.178 | 0.054 | 0.890 | 0.944 | 3.172 |
| 07/10/2015_29/03/2019 | 0.216 | 0.052 | 0.833 | 0.885 | 1.872 |
| Volatility Breaks in HDFC | | | | | |
| Date of commencement of Derivative trading: 02-07-2001 | | | | | |
| 05/01/2000_05/02/2001 | 0.602 | 0.241 | 0.724 | 0.965 | 17.222 |
| 06/02/2001_16/10/2001 | 1.111 | 0.386 | 0.474 | 0.860 | 7.939 |
| 17/10/2001_22/05/2003 | 0.501 | 0.306 | 0.484 | 0.791 | 2.393 |
| 23/05/2003_14/05/2004 | 1.487 | 0.145 | 0.448 | 0.593 | 3.656 |
| 15/05/2004_30/03/2006 | 0.548 | 0.028 | 0.770 | 0.798 | 2.712 |
| 31/03/2006_28/11/2008 | 0.352 | 0.103 | 0.855 | 0.958 | 8.337 |
| 29/11/2008_08/11/2010 | 0.036 | 0.045 | 0.941 | 0.985 | 2.477 |
| 09/11/2010_04/01/2012 | 3.047 | -0.064 | 0.009 | -0.055 | 2.889 |
| 05/01/2012_03/06/2014 | 0.032 | 0.039 | 0.948 | 0.986 | 2.355 |
| 04/06/2014_07/10/2015 | 0.598 | 0.024 | 0.521 | 0.545 | 1.314 |
| 08/10/2015_29/03/2019 | 0.407 | 0.057 | 0.461 | 0.517 | 0.843 |
| Volatility Breaks in HEROMOTOCO | | | | | |
| Date of commencement of Derivative trading: 31-01-2003 | | | | | |
| 05/01/2000_15/03/2001 | 0.263 | 0.071 | 0.893 | 0.964 | 7.290 |
| 16/03/2001_25/04/2003 | 0.427 | 0.266 | 0.707 | 0.973 | 15.935 |
| 26/04/2003_27/04/2004 | 0.073 | 0.082 | 0.900 | 0.981 | 3.916 |
| 28/04/2004_26/07/2005 | 0.149 | 0.047 | 0.919 | 0.966 | 4.339 |
| 27/07/2005_15/05/2006 | 0.767 | 0.074 | 0.639 | 0.713 | 2.671 |
| 16/05/2006_08/10/2007 | 0.305 | 0.015 | 0.919 | 0.935 | 4.669 |
| 09/10/2007_31/07/2009 | 0.569 | 0.079 | 0.875 | 0.954 | 12.340 |
| 01/08/2009_01/08/2011 | 0.271 | 0.060 | 0.861 | 0.921 | 3.418 |
| 02/08/2011_24/10/2017 | 0.215 | 0.071 | 0.874 | 0.946 | 3.953 |
| 25/10/2017_08/06/2018 | 0.484 | -0.111 | 0.976 | 0.865 | 3.582 |
| 09/06/2018_29/03/2019 | 0.179 | 0.081 | 0.869 | 0.950 | 3.598 |

| Period | ω | α | β | Total Persistence: ($\alpha+\beta$) | Unconditional Volatility: $\omega/(1-\alpha-\beta)$ |
|---------------------------------------------------------------|----------|----------|---------|------------------------------------------|--------------------------------------------------------|
| Volatility Breaks in ICICIBANK | | | | | |
| Date of commencement of Derivative trading: 31-01-2003 | | | | | |
| 05/01/2000_11/04/2000 | 0.748 | -0.161 | 1.133 | 0.972 | 26.559 |
| 12/04/2000_01/10/2001 | 8.059 | 0.329 | 0.179 | 0.508 | 16.380 |
| 02/10/2001_05/07/2002 | 1.035 | 0.153 | 0.716 | 0.869 | 7.885 |
| 06/07/2002_21/03/2003 | 0.198 | 0.054 | 0.897 | 0.950 | 3.989 |
| 22/03/2003_11/05/2004 | 2.431 | 0.143 | 0.498 | 0.641 | 6.771 |
| 12/05/2004_28/02/2005 | 0.043 | -0.054 | 1.041 | 0.987 | 3.219 |
| 29/02/2005_12/10/2007 | 0.526 | 0.062 | 0.822 | 0.884 | 4.531 |
| 13/10/2007_18/08/2009 | 0.778 | 0.109 | 0.857 | 0.966 | 22.936 |
| 19/08/2009_16/07/2013 | 0.106 | 0.042 | 0.930 | 0.973 | 3.868 |
| 17/07/2013_24/07/2015 | 0.034 | 0.003 | 0.985 | 0.988 | 2.970 |
| 25/07/2015_16/11/2016 | 3.588 | 0.050 | 0.198 | 0.249 | 4.776 |
| 17/11/2016_29/03/2019 | 2.071 | -0.008 | 0.357 | 0.349 | 3.181 |
| Volatility Breaks in IDEA | | | | | |
| Date of commencement of Derivative trading: 08-03-2007 | | | | | |
| 13/03/2007_10/08/2007 | 1.942 | -0.050 | 0.589 | 0.540 | 4.219 |
| 11/08/2007_15/05/2009 | 0.982 | 0.093 | 0.831 | 0.923 | 12.803 |
| 16/05/2009_06/08/2010 | 0.384 | 0.004 | 0.935 | 0.940 | 6.357 |
| 07/08/2010_04/06/2013 | 3.145 | 0.198 | 0.007 | 0.205 | 3.958 |
| 05/06/2013_12/01/2017 | 3.275 | 0.150 | 0.600 | 0.750 | 13.101 |
| 13/01/2017_29/03/2019 | 7.650 | 0.306 | -0.082 | 0.224 | 9.861 |
| Volatility Breaks in IBULHSGFIN | | | | | |
| Date of commencement of Derivative trading: 30-09-2010 | | | | | |
| 26/07/2013_19/09/2013 | 10.009 | 0.113 | -0.079 | 0.034 | 10.358 |
| 20/09/2013_02/06/2014 | 1.584 | 0.032 | 0.771 | 0.803 | 8.039 |
| 03/06/2014_22/03/2016 | 1.929 | 0.037 | 0.589 | 0.626 | 5.158 |
| 23/03/2016_01/11/2018 | 0.271 | 0.086 | 0.855 | 0.942 | 4.641 |
| 02/11/2018_29/03/2019 | 3.118 | -0.063 | 0.716 | 0.652 | 8.969 |
| Volatility Breaks in INDUSINDBK | | | | | |
| Date of commencement of Derivative trading: 29-10-2010 | | | | | |
| 05/01/2000_15/03/2001 | 2.278 | 0.189 | 0.655 | 0.844 | 14.638 |
| 16/03/2001_06/02/2002 | 2.859 | 0.356 | 0.041 | 0.397 | 4.743 |
| 07/02/2002_05/05/2003 | 0.372 | 0.081 | 0.855 | 0.937 | 5.862 |
| 06/05/2003_07/12/2006 | 1.365 | 0.118 | 0.754 | 0.872 | 10.630 |
| 08/12/2006_09/03/2007 | 0.969 | -0.211 | 1.177 | 0.966 | 28.330 |
| 10/03/2007_22/07/2009 | 0.736 | 0.094 | 0.872 | 0.966 | 21.552 |
| 23/07/2009_02/06/2010 | 3.850 | 0.260 | 0.223 | 0.483 | 7.450 |
| 03/06/2010_02/04/2012 | 5.351 | 0.184 | -0.181 | 0.002 | 5.364 |
| 03/04/2012_20/06/2014 | 0.049 | 0.057 | 0.933 | 0.989 | 4.644 |
| 21/06/2014_16/11/2016 | 0.362 | 0.034 | 0.808 | 0.842 | 2.292 |
| 16/11/2016_29/03/2019 | 0.127 | 0.101 | 0.833 | 0.935 | 1.957 |
| Volatility Breaks in INFRATEL | | | | | |
| Date of commencement of Derivative trading: 24-09-2015 | | | | | |
| 28/12/2012_07/06/2013 | 1.175 | 0.146 | 0.558 | 0.704 | 3.962 |
| 08/06/2013_20/11/2014 | 0.056 | 0.039 | 0.940 | 0.979 | 2.657 |
| 21/11/2014_24/09/2015 | 0.840 | 0.032 | 0.703 | 0.735 | 3.169 |
| 25/09/2015_31/01/2017 | 1.287 | -0.019 | 0.264 | 0.245 | 1.705 |
| 01/02/2017_29/03/2019 | 1.037 | 0.276 | 0.123 | 0.400 | 1.726 |
| Volatility Breaks in INDIGO | | | | | |
| Date of commencement of Derivative trading: 31-03-2017 | | | | | |
| 12/11/2015_22/01/2016 | 11.610 | 0.304 | -0.109 | 0.196 | 14.436 |
| 23/01/2016_16/02/2016 | 10.775 | -0.123 | 0.663 | 0.540 | 23.432 |
| 17/02/2016_19/08/2016 | 2.533 | -0.050 | 0.600 | 0.550 | 5.632 |

| Period | ω | α | β | Total Persistence: ($\alpha+\beta$) | Unconditional Volatility: $\omega/(1-\alpha-\beta)$ |
|---------------------------------------------------------------|----------|----------|---------|------------------------------------------|--------------------------------------------------------|
| 20/08/2016_27/04/2017 | 2.401 | 0.212 | -0.098 | 0.114 | 2.711 |
| 28/04/2017_29/03/2019 | 0.977 | 0.024 | 0.828 | 0.852 | 6.613 |
| Volatility Breaks in INFY | | | | | |
| Date of commencement of Derivative trading: 02-07-2001 | | | | | |
| 05/01/2000_27/02/2001 | 0.710 | 0.100 | 0.852 | 0.951 | 14.612 |
| 28/02/2001_03/11/2001 | 6.251 | -0.196 | 1.046 | 0.850 | 41.605 |
| 05/11/2001_17/05/2004 | 1.033 | 0.108 | 0.778 | 0.886 | 9.097 |
| 18/05/2004_28/03/2006 | 0.447 | 0.005 | 0.810 | 0.814 | 2.408 |
| 29/03/2006_24/07/2006 | 5.691 | 0.336 | -0.126 | 0.210 | 7.206 |
| 25/07/2006_01/05/2009 | 0.053 | 0.061 | 0.931 | 0.992 | 6.624 |
| 02/05/2009_12/07/2012 | 0.628 | 0.230 | 0.598 | 0.828 | 3.650 |
| 13/07/2012_11/01/2013 | 0.360 | 0.030 | 0.737 | 0.767 | 1.545 |
| 12/01/2013_13/03/2014 | 0.560 | 1.277 | 0.205 | 1.482 | -1.163 |
| 14/03/2014_18/07/2016 | 0.850 | -0.018 | 0.699 | 0.681 | 2.661 |
| 19/07/2016_3/29/2019 | 1.292 | 0.170 | 0.137 | 0.307 | 1.864 |
| Volatility Breaks in ITC | | | | | |
| Date of commencement of Derivative trading: 02-07-2001 | | | | | |
| 05/01/2000_07/02/2001 | -0.038 | -0.023 | 1.026 | 1.003 | 11.359 |
| 08/02/2001_09/11/2001 | 3.004 | 0.577 | 0.097 | 0.674 | 9.213 |
| 10/11/2001_21/05/2002 | 0.579 | 0.078 | 0.662 | 0.740 | 2.226 |
| 22/05/2002_01/02/2005 | 0.387 | 0.111 | 0.759 | 0.869 | 2.959 |
| 02/02/2005_05/09/2005 | 0.744 | 0.001 | 0.565 | 0.566 | 1.715 |
| 06/09/2005_12/11/2007 | 0.357 | 0.076 | 0.836 | 0.912 | 4.045 |
| 13/11/2007_25/08/2009 | 0.459 | 0.084 | 0.845 | 0.928 | 6.416 |
| 26/08/2009_10/11/2014 | 0.561 | 0.096 | 0.629 | 0.725 | 2.039 |
| 11/11/2014_20/07/2017 | 2.498 | 0.272 | -0.110 | 0.162 | 2.980 |
| 21/07/2017_29/03/2019 | 0.202 | 0.015 | 0.842 | 0.857 | 1.409 |
| Volatility Breaks in JUSTDIAL | | | | | |
| Date of commencement of Derivative trading: 02-04-2013 | | | | | |
| 12/07/2012_06/06/2013 | 0.360 | 0.030 | 0.737 | 0.767 | 1.545 |
| 07/06/2013_04/10/2013 | 0.296 | -0.186 | 1.113 | 0.927 | 4.057 |
| 05/10/2013_29/05/2014 | 1.163 | 0.056 | 0.877 | 0.933 | 17.414 |
| 30/05/2014_28/01/2016 | 5.033 | 0.366 | -0.084 | 0.282 | 7.013 |
| 29/01/2016_09/03/2016 | 3.886 | -0.478 | 1.427 | 0.950 | 77.137 |
| 10/10/2017_29/05/2018 | 2.735 | 0.242 | 0.632 | 0.873 | 21.582 |
| 30/05/2018_29/03/2019 | 2.368 | 0.094 | 0.608 | 0.702 | 7.942 |
| Volatility Breaks in KOTAKBANK | | | | | |
| Date of commencement of Derivative trading: 29-12-2005 | | | | | |
| 05/01/2000_16/11/2001 | 3.256 | 0.310 | 0.540 | 0.850 | 21.713 |
| 17/11/2001_01/01/2003 | 0.142 | 0.266 | 0.784 | 1.051 | -2.803 |
| 02/01/2003_18/11/2004 | 0.172 | 0.096 | 0.888 | 0.984 | 10.853 |
| 19/11/2004_04/05/2006 | 3.323 | 0.085 | 0.411 | 0.497 | 6.601 |
| 05/05/2006_18/01/2008 | 2.728 | 0.259 | 0.453 | 0.712 | 9.478 |
| 19/01/2008_18/08/2009 | 2.281 | 0.079 | 0.815 | 0.894 | 21.560 |
| 19/08/2009_07/06/2012 | 1.175 | 0.146 | 0.558 | 0.704 | 3.962 |
| 08/06/2012_20/11/2014 | 0.056 | 0.039 | 0.940 | 0.979 | 2.657 |
| 21/11/2014_24/09/2015 | 0.840 | 0.032 | 0.703 | 0.735 | 3.169 |
| 25/09/2015_31/01/2017 | 1.287 | -0.019 | 0.264 | 0.245 | 1.705 |
| 01/02/2017_29/03/2019 | 1.037 | 0.276 | 0.123 | 0.400 | 1.726 |
| Volatility Breaks in LT | | | | | |
| Date of commencement of Derivative trading: 02-07-2001 | | | | | |
| 05/01/2000_21/11/2001 | -0.038 | -0.023 | 1.026 | 1.003 | 11.359 |
| 22/11/2001_22/04/2004 | 0.041 | 0.031 | 0.956 | 0.987 | 3.098 |
| 23/04/2004_24/07/2006 | 1.172 | 0.283 | 0.532 | 0.815 | 6.352 |

| Period | ω | α | β | Total Persistence: ($\alpha+\beta$) | Unconditional Volatility: $\omega/(1-\alpha-\beta)$ |
|---------------------------------------------------------------|----------|----------|---------|------------------------------------------|--------------------------------------------------------|
| 25/07/2006_02/02/2007 | 1.070 | -0.072 | 0.602 | 0.531 | 2.278 |
| 03/02/2007_10/03/2008 | 0.540 | 0.205 | 0.742 | 0.947 | 10.227 |
| 11/03/2008_08/09/2009 | 6.429 | 0.237 | 0.380 | 0.617 | 16.790 |
| 09/09/2009_28/01/2011 | 2.361 | 0.120 | -0.251 | -0.131 | 2.087 |
| 29/01/2011_11/12/2013 | 0.071 | 0.049 | 0.935 | 0.985 | 4.583 |
| 12/12/2013_13/01/2016 | 1.073 | -0.009 | 0.621 | 0.612 | 2.765 |
| 14/01/2016_05/07/2016 | 2.895 | 0.753 | -0.085 | 0.668 | 8.710 |
| 06/07/2016_13/09/2019 | 1.767 | 0.047 | -0.054 | -0.007 | 1.755 |
| Volatility Breaks in MARUTI | | | | | |
| Date of commencement of Derivative trading: 08-07-2003 | | | | | |
| 15/03/2001_06/02/2002 | 2.859 | 0.356 | 0.041 | 0.397 | 4.743 |
| 07/02/2002_05/12/2003 | 0.372 | 0.081 | 0.855 | 0.937 | 5.862 |
| 06/12/2003_21/01/2005 | 0.187 | 0.098 | 0.866 | 0.964 | 5.223 |
| 22/01/2005_05/08/2009 | 0.526 | 0.083 | 0.853 | 0.937 | 8.304 |
| 05/08/2009_31/05/2010 | 0.048 | -0.065 | 1.045 | 0.980 | 2.422 |
| 01/06/2010_19/08/2011 | 0.118 | -0.024 | 0.986 | 0.962 | 3.140 |
| 20/08/2011_21/06/2013 | 2.590 | 0.232 | 0.087 | 0.319 | 3.804 |
| 22/06/2013_17/12/2014 | 2.754 | 0.147 | -0.080 | 0.067 | 2.951 |
| 18/12/2014_06/12/2016 | 0.547 | 0.195 | 0.602 | 0.798 | 2.703 |
| 07/12/2016_29/03/2019 | 0.025 | 0.031 | 0.955 | 0.986 | 1.830 |
| Volatility Breaks in RELIANCE | | | | | |
| Date of commencement of Derivative trading: 29-11-2001 | | | | | |
| 05/01/2000_28/02/2001 | 0.322 | 0.128 | 0.808 | 0.936 | 4.993 |
| 28/02/2001_21/12/2001 | 1.941 | 0.386 | 0.471 | 0.857 | 13.560 |
| 22/12/2001_02/08/2004 | 1.299 | 0.288 | 0.399 | 0.687 | 4.154 |
| 03/08/2004_24/07/2006 | 1.832 | 0.870 | 0.072 | 0.942 | 31.407 |
| 25/07/2006_24/12/2009 | 0.101 | 0.096 | 0.898 | 0.994 | 17.804 |
| 25/12/2009_22/08/2011 | 1.164 | -0.014 | 0.510 | 0.496 | 2.309 |
| 23/08/2011_02/04/2012 | 1.980 | -0.100 | 0.733 | 0.633 | 5.401 |
| 03/04/2012_29/03/2019 | 0.372 | 0.067 | 0.774 | 0.840 | 2.332 |
| Volatility Breaks in SBIN | | | | | |
| Date of commencement of Derivative trading: 02-07-2001 | | | | | |
| 05/01/2000_15/03/2001 | 0.263 | 0.071 | 0.893 | 0.964 | 7.290 |
| 16/03/2001_25/09/2001 | 0.427 | 0.266 | 0.707 | 0.973 | 15.935 |
| 26/09/2001_27/04/2004 | 0.073 | 0.082 | 0.900 | 0.981 | 3.916 |
| 28/04/2004_26/07/2005 | 0.149 | 0.047 | 0.919 | 0.966 | 4.339 |
| 27/07/2005_15/05/2006 | 0.767 | 0.074 | 0.639 | 0.713 | 2.671 |
| 16/05/2006_08/10/2007 | 0.305 | 0.015 | 0.919 | 0.935 | 4.669 |
| 09/10/2007_31/07/2009 | 0.569 | 0.079 | 0.875 | 0.954 | 12.340 |
| 01/08/2009_01/08/2011 | 0.271 | 0.060 | 0.861 | 0.921 | 3.418 |
| 02/08/2011_24/10/2017 | 0.215 | 0.071 | 0.874 | 0.946 | 3.953 |
| 25/10/2017_08/06/2018 | 0.484 | -0.111 | 0.976 | 0.865 | 3.582 |
| 09/06/2018_29/03/2019 | 0.179 | 0.081 | 0.869 | 0.950 | 3.598 |
| Volatility Breaks in TCS | | | | | |
| Date of commencement of Derivative trading: 23-08-2004 | | | | | |
| 27/04/2004_26/08/2004 | 0.149 | 0.047 | 0.919 | 0.966 | 4.339 |
| 27/08/2004_15/04/2005 | 0.634 | 0.012 | 0.608 | 0.619 | 1.666 |
| 16/04/2005_25/07/2006 | 0.463 | 0.169 | 0.709 | 0.878 | 3.796 |
| 26/07/2006_06/07/2007 | 1.290 | 0.342 | 0.159 | 0.501 | 2.588 |
| 07/07/2007_29/10/2008 | 0.333 | 0.116 | 0.856 | 0.971 | 11.669 |
| 30/10/2008_13/08/2009 | 11.142 | 0.241 | -0.171 | 0.070 | 11.982 |
| 14/08/2009_05/08/2011 | 1.133 | 0.134 | 0.460 | 0.594 | 2.794 |
| 06/08/2011_10/05/2012 | 0.168 | 0.041 | 0.921 | 0.961 | 4.366 |
| 11/05/2012_26/06/2013 | 0.021 | -0.041 | 1.030 | 0.988 | 1.823 |
| 27/06/2013_20/10/2014 | 0.808 | 0.027 | 0.692 | 0.719 | 2.873 |

| Period | ω | α | β | Total Persistence: ($\alpha+\beta$) | Unconditional Volatility: $\omega/(1-\alpha-\beta)$ |
|---------------------------------------------------------------|----------|----------|---------|------------------------------------------|--------------------------------------------------------|
| 21/10/2014_29/12/2017 | 1.048 | 0.151 | 0.232 | 0.383 | 1.699 |
| 30/12/2017_29/03/2019 | 0.363 | 0.047 | 0.799 | 0.846 | 2.353 |
| Volatility Breaks in TATAELXSI | | | | | |
| Date of commencement of Derivative trading: 26-02-2016 | | | | | |
| 05/01/2000_01/10/2001 | 0.369 | 0.029 | 0.953 | 0.982 | 20.001 |
| 02/10/2001_25/12/2003 | 3.042 | -0.007 | 0.590 | 0.584 | 7.307 |
| 26/12/2003_29/03/2006 | 1.135 | 0.211 | 0.675 | 0.886 | 9.962 |
| 30/03/2006_29/11/2007 | 0.331 | 0.080 | 0.880 | 0.959 | 8.164 |
| 30/11/2007_11/12/2008 | 5.212 | 0.284 | 0.498 | 0.782 | 23.918 |
| 12/12/2008_30/08/2011 | 0.938 | 0.222 | 0.644 | 0.865 | 6.976 |
| 31/08/2011_23/05/2013 | 1.213 | 0.019 | 0.608 | 0.627 | 3.251 |
| 24/05/2013_16/07/2014 | 10.945 | 0.049 | -0.712 | -0.663 | 6.581 |
| 17/07/2014_01/11/2017 | 0.357 | 0.027 | 0.882 | 0.910 | 3.944 |
| 02/11/2017_29/03/2019 | 0.959 | 0.072 | 0.568 | 0.641 | 2.670 |
| Volatility Breaks in TATASTEEL | | | | | |
| Date of commencement of Derivative trading: 02-07-2001 | | | | | |
| 05/01/2000_27/07/2000 | 3.121 | 0.193 | 0.559 | 0.752 | 12.592 |
| 28/07/2000_20/07/2001 | 1.703 | 0.276 | 0.534 | 0.810 | 8.986 |
| 21/07/2001_12/08/2002 | 1.010 | 0.084 | 0.750 | 0.834 | 6.066 |
| 13/08/2002_10/07/2003 | 1.885 | 0.270 | -0.044 | 0.226 | 2.436 |
| 11/07/2003_28/06/2006 | 0.155 | 0.092 | 0.888 | 0.979 | 7.480 |
| 29/06/2006_26/01/2007 | 0.250 | -0.002 | 0.923 | 0.921 | 3.177 |
| 27/01/2007_23/05/2013 | 0.089 | 0.079 | 0.912 | 0.990 | 8.987 |
| 24/05/2013_11/08/2015 | 0.262 | 0.061 | 0.887 | 0.948 | 4.996 |
| 12/08/2015_28/11/2016 | 0.233 | 0.007 | 0.955 | 0.962 | 6.183 |
| 29/11/2016_29/03/2019 | 5.508 | -0.035 | -0.640 | -0.674 | 3.289 |
| Volatility Breaks in VEDL | | | | | |
| Date of commencement of Derivative trading: 29-12-2006 | | | | | |
| 05/01/2000_24/12/2001 | 4.740 | 0.234 | 0.385 | 0.618 | 12.419 |
| 25/12/2001_07/04/2003 | 0.624 | 0.096 | 0.839 | 0.935 | 9.618 |
| 08/04/2003_08/03/2007 | 2.851 | 0.203 | 0.597 | 0.800 | 14.255 |
| 09/03/2007_26/03/2008 | 0.698 | 0.468 | 0.591 | 1.059 | -11.844 |
| 27/03/2008_08/08/2016 | 0.206 | 0.076 | 0.904 | 0.980 | 10.189 |
| 09/08/2016_29/05/2017 | 5.367 | -0.044 | 0.112 | 0.068 | 5.756 |
| 30/05/2017_29/03/2019 | 2.337 | -0.018 | 0.582 | 0.565 | 5.369 |
| Volatility Breaks in YESBANK | | | | | |
| Date of commencement of Derivative trading: 06-09-2007 | | | | | |
| 14/07/2005_03/02/2008 | 2.310 | 0.158 | 0.510 | 0.668 | 6.951 |
| 04/02/2008_16/03/2012 | 0.244 | 0.112 | 0.870 | 0.982 | 13.216 |
| 17/03/2012_03/03/2016 | 0.196 | 0.068 | 0.900 | 0.968 | 6.100 |
| 04/03/2016_24/08/2018 | 0.676 | 0.083 | 0.689 | 0.772 | 2.969 |
| 25/08/2018_29/03/2019 | 9.789 | -0.024 | 0.577 | 0.553 | 21.892 |
| Volatility Breaks in ZEEL | | | | | |
| Date of commencement of Derivative trading: 07-10-2010 | | | | | |
| 05/01/2000_12/10/2001 | 3.815 | 0.137 | 0.740 | 0.877 | 31.114 |
| 13/10/2001_08/01/2004 | 2.143 | 0.105 | 0.698 | 0.803 | 10.882 |
| 09/01/2004_02/10/2008 | 4.177 | 0.163 | 0.307 | 0.470 | 7.887 |
| 03/10/2008_28/10/2009 | 0.719 | 0.114 | 0.851 | 0.966 | 20.982 |
| 29/10/2009_09/06/2010 | 3.145 | 0.321 | 0.032 | 0.354 | 4.865 |
| 10/06/2010_29/11/2015 | 0.538 | 0.053 | 0.802 | 0.855 | 3.710 |
| 30/11/2015_05/10/2018 | 0.562 | 0.050 | 0.649 | 0.699 | 1.868 |
| 06/10/2018_29/03/2019 | 17.897 | 0.138 | -0.556 | -0.417 | 12.629 |