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Volatility Spillover Effects in Spot, Futures and Option Markets

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Article Info
Volume 83
Page Number: 10114 - 10127
Publication Issue:
May - June 2020

Article History
Article Received*: 19 November 2019*
Revised*: 27 January 2020*
Accepted*: 24 February 2020*
Publication*: 18 May 2020*

Abstract:
The aim of the paper is to find the volatility spillover effects across spot, futures and option markets. The NIFTY 50 index is taken into observation. The study period is from January 8, 2010 to October 25, 2019. The main findings of this paper are: a bidirectional volatility spillover effect is found between spot and futures market and is a bit stronger from spot side; no volatility spillover was found between spot and options market in which both call and put contracts are considered; a unidirectional shock volatility spillover was reflected from futures to call options contract but there were no price volatility spillover effects across these markets. Bivariate BEKK-GARCH model was implemented to find the volatility spillover effects among these markets. Later CCC-GARCH model was used to find the close proximity between the markets to check the robustness of our volatility spillover results obtained from bivariate BEKK-GARCH and the results from CCC GARCH supports the BEKK-GARCH results.

Keywords*: volatility spillover; MGARCH; bivariate BEKK-GARCH; CCC-GARCH*

1. Introduction

Volatility is defined as the rate at which the price of an observed entity or an index changes. This a very essential tool which helps to study the market. To achieve more gain with less risk one needs to know the future prices. One may conclude that knowing future price with the knowledge of past price will lead to a more effective decision when compared to that of decision taken without having much knowledge about the future value. Traditionally the investors, portfolio managers, market regulators and financial research analysts' before investing in any particular market never gave much importance to the inter-market linkage dependency. After the commencement of the equity derivatives in NSE they now had a broader spectrum of markets to study before they make any investment decisions. Hence the importance of study of volatility spillover effects came into picture here. Volatility spillover is nothing but the effect of change of price of an underlying stock or a contract in a market on the other underlying stock or a contract trading in a different market. The derivative market consists of option market and futures market. Many financial analysts believed that apart from spot and futures markets,

option market may have a tremendous potential to make impact on the investor's decisions. They also believed that the option market will add more insights on a particular underlying asset which is present in the other two markets which will ultimately help the investor or analysts to make a firm decision before taking a final call. Ironically, since the introduction of index option contracts in Indian market one may rarely find study conducted particularly on this market related to volatility or spillover effects. In this relation there are many studies conducted on Chinese and Korean markets, such as Kang, Cheong and Yoon (2013), Kim, K., & Lim, S. (2019), Li, S. (2015), Mohammadi, H., & Tan, Y. (2015), Hung, N. T. (2019). Aforementioned studies are conducted on spot and futures indices, spot and futures market in steel related commodities, spot and futures market in Chinese market CSI300 index, "spillover effects in equity markets in

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Mainland China, Hong Kong and the United States", "volatility spillover across equity markets between China and Southeast Asian countries respectively". Major studies which are performed are related to the price discovery. Studies of derivatives market is very common in developed economies. Atilgan et al. (2016) also conducted a survey on derivatives on the above topic including Market efficiency and structure . There are no studies which speaks about the volatility of these markets. Albeit there are studies conducted on the linkage of spot market volatility with the volume in the option and futures market (Chen and Wang 2017; Sarwar 2005) and (Bessembinder and Seguin 1992) respectively. Till now only one study has been performed by Seghal and Pandey (2015) which talks about the volatility spillover and price discovery. Their work and the shortcomings are discussed further in the Review of Literature section below. This study makes a contribution to the existing literature. The paper has been divided into six sections. Firstly, the topic is introduced followed by second section of RoL. The third section includes the data considered, the fourth section explains the methodology used for data analysis. The fifth section explains the results and finally the sixth and last section talks about the conclusion.

2. Review of Literature

There are many studies conducted individually or in some combination of option, futures and spot markets. Majority of the such studies have been conducted over spot and futures market and not many studies can be found executed on option market. Of these studies' maximum are held on finding the lead-lag relationship between spot and future market for example studies such as Pizzi er al. (1998), Jackline and Deo (2011) and Gee and Karim (2005) shows that "there is a bidirectional relationship between spot and futures market". Koutyos and Tucker (1996) analyzed unpredictable spillover effects between spot and future market where they conduct their hypothesis using bivariate EGARCH stochastic model. S&P 500 based on DJIA, was the index which they took in their study. They concluded that the unpredictable spillover goes from futures market to the spot market and there was found no volatility spillover from spot market to futures market. Min and Najand (1999) investigate volatility spillover between cash and future market in Korean market. They also discussed about the presence of lead and lag relationship. They used SEM and VAR model for their research. The result they got was a strong volatility spillover effect is more pronounced for future volume than for spot. The results obtained coincided with that of Kawaller and Koch's (1990) but for the U.S. market. They highly emphasized that the results are highly dependent and sensitive on the sample size and sample period taken into consideration. Lafuente-Luengo (2009) talks about the lead-lag relationship. Here the author has used VAR to estimate the coefficients of the equations on S&P 500 cash and forwards market. The result here was also the same: "presence of a unidirectional causal relationship between future market volatility and spot market volatility". Arshanapalli and Doukas (1994) carried out a study on S&P 500 spot market and its futures to study unpredictable effects. They used the newly developed stochastic model ARCH for their study. Their results contradicted the previous conducted studies by showing no interdependencies between the two markets. Few studies have also considered univariate GARCH models as the stochastic model for finding the unpredictable spillover effects among the variables. One such study has been carried out by Rastogi, S. (2010), where he chose univariate EGARCH model to find the volatility spillover effects among six different countries' (including India) stock market. Rastogi, S., & Srivastava, V. K. (2011) in their study of "conditional volatility of Indian and US stock market". directed a comparative study and GARCH (1, 1) was the model used for the analysis. Some studies even constructed various models to find the volatility spillover effects such as what Ng. A (2000) carried out. The paper checks for

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the presence of the spillover effects from U.S. markets to the various Pacific-Basin countries' markets. There are many studies which are conducted on commodity markets across the global markets to find volatility spillover among different traded commodities. Seghal and Namita (2018), Shihabudheen and Padhi (2010), both the papers discussed about the "price discovery and volatility spillover effects in the Indian commodity market" using same stochastic model, i.e. bivariate EGARCH. Seghal and Namita (2018) found the unpredictable spillover in only three commodities (Soybean, Zinc and Natural gas). The spillover effect was stronger from spot to futures of these commodities. Whereas Shihabudheen and Padhi (2010) found the spillover effects from futures to spot except sugar which is the other way around. Although both of them have covered different commodities and have carried out the study in different time period. Sinha (2017) is one of the papers that uses multivariate GARCH model for studying the volatility spillover effects. The paper is particularly focused on the agricultural commodity Black Pepper. He implied BEKK-GARCH and DCC-GARCH to find the spillover effects between futures and spot market. They found a positive spillover effects between the two markets. Mohammadi, H., & Tan, Y. (2015) carried out a study where he studied about the unpredictable spillover effects across equity markets in mainland China, Hong Kong and the United States using different MGARCH models. The current paper's methodology is inspired by the same. Mahalik (2009) and Mahalik (2014) also discussed about the instability on Indian commodity index. They proved the spillover was more effective from futures to spot market.Rahayu (2015) finds no spillover effect from international to domestic coffee market of Indonesia. The author used GARCH model to achieve the results. Rastogi and Athaley (2019) discussed about the volatility integration in spot, futures and options markets, where he used GMM to capture the volatility integration in these markets. Kang, Cheong and Yoon (2013), Mishra, Swain and Malhotra (2007) and Namita (2012) concluded their studies by giving substantial proof of presence of unpredictable spillover effects in Korean spot and futures market, stock and foreign exchange market, FII and stock market of India respectively.One such paper BT Ewing (2016) analysed the spillover effect using both univariate and bivariate stochastic model between oil and stock market of U.S. The paper also considered the possibility of structural breaks making an impact on the results and they got a significant transmission between the markets when these breaks were included in the equations.Li, S. (2015) clinched that a "bi-directional volatility spillover effect exists between CSI300 futures and the spot market", but the former affects the latter more. The same results are observed by Yiuman (1999) but the markets under consideration were DJIA index and Futures market.Among different commodities market and indices few studies have studies on currency derivatives market too. Rastogi, .S (2011) conducted a study in Indian context, where the impact of exchange traded currency derivatives on the spot exchange rate volatility is found using GARCH (1, 1) model. In the Indian context, Pati and Rajib (2011) used bivariate BEKK GARCH to drive to the conclusion as a bidirectional volatility spillover between spot and futures. Similarly, Sakthivel and Kamaiah (2010) also got the same results but they used different stochastic model (VECM and Bivariate GARCH). There is no study which explores more than that in the Indian context except that of Sehgal and Pandey (2015) and Piyush Pandey (2014). They (Sehgal and Pandey (2015)) discussed about the price discovery and the volatility spillover effects between NSE spot, futures and option markets. This paper not only explore the depth of the unpredictable spillover effects in Indian context but is also one of the most important contribution to the existing literature, with some shortcomings, which are further discussed below. In their paper they decided to choose exponential GARCH (EGARCH) as the main stochastic model to

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discover the unpredictable between any of the markets. There was a strong bidirectional short-term volatility spillover effect found from the spot side when compared between the spot and futures in the short term. The same instability was observed in the long run as well. When it comes to Options and Spot Pair, it was confirmed that there was a unidirectional short-term spillover from options to spot and in the long period it was unidirectional spillover effect from spot to options but only for the second and third moments. When it came to futures and options pair only long-term bidirectional spillover effects was observed. There was a shortcoming of the above-mentioned paper: the findings using multivariate stochastic model was considered a difficult choice. The main purpose of their paper was to find the relation between the price discovery and the unpredictable spillover results among the markets. This is where our paper comes into picture where our paper solely concentrates on the volatility spillover effects. We also have considered multivariate model to find the conditional correlation between the markets which was absent in Sehgal and Pandey (2015) paper. The main purpose of using a multivariate model to check the robustness of the results obtained from a bivariate model. In addition to the previous short-comings we have also considered a different sample period for the study. Also, the extraction of futures data is different from what they have used. Piyush Pandey (2014) also used the same stochastic model for his study and got the results indicating that it is the options market which is leading when it comes to risk hedging.

Our study examines the long-term highly instable spillover effects from one market to another by taking two markets at a time and analyzing the association among them using different stochastic models which are discussed in the methodology used section. The main hypothesis which is tested is as follow:

H1: Presence of long-term volatility spillover effect, i.e. $b12 \neq 0$, $b21 \neq 0$.

3. Data

The data is collected from NSE official website. The observed period is from January 8, 2010 to October 25, 2019. NIFTY 50 was the observed index. For spot rates, weekly closing prices of NIFTY 50 index was taken. For futures rates, weekly closing prices of NIFTY 50 futures index was taken. For every weekly price there will be three different expiry date; the present month, the next month and next to next month. Hence there are three different prices on any date. A simple average is taken of these three prices. In options we took the prices of the same dates as that of spot's and futures. Option market has two types of contracts- call and put. The prices of the individual contracts were determined by using Vega weighted average (Black-Scholes Option Pricing model) method. Rastogi and Athaley (2019) used the similar data extraction method for options and future prices. The prices of these contracts were extracted from the NIFTY 50 options index from NSE official website. National Stock Exchange (NSE) is the first stock exchange which brought the fully automated screen based electronic trading system in India in 1992. Presently it is the leading stock exchange in the country with market capitalization of more than US$2.27 trillion (NSE, 2019). The equity segment of NSE started operating from November 1994. As the market capitalization was growing the NSE commenced the equity derivatives segment in June 2000 with the launch of index futures contracts and the index options contracts in June 2001 (NSE, 2019).

4. Methodology

In order to find the unpredictable spillover effects between the above-mentioned markets (spot, futures, options) we first measure the descriptive statistics which is mentioned in Table 1. To start with we first carried out Jarque-Bera test (Jarque, 1987). JB test helps one determine the null hypothesis, i.e. to check if the time series is normal distributed or not. Now to test the stationarity we used Augmented Dickey Fuller (ADF) (Dickey and Fuller, 1981) and Phillips–Perron (PP) (Phillips and Perron, 1988)

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tests. The ARCH LM test was ran on the time series data to recognize presence of ARCH effect or volatility clustering. We have used multivariate GARCH model to perform the analysis.

4.1 Multivariate GARCH models

Bauwens, Laurent and Rombouts (2006) beautifully describes the advancement in the multivariate ARCH models developed over time. The paper discusses the importance and the applications of various multivariate GARCH models. The most important application of multivariate GRACH models are to study the relations between the markets in terms of volatilities and co-volatilities. MGARCH (Multivariate Generalized Autoregressive Conditional Heteroscedasticity) answers many questions like whether a shock on a particular market affects the volatility on the other market, if the past volatility of a market increases or decreases volatility of the same market in future, is volatility spillover effects long-term or short-term basis, and more such questions. Bivariate-BEKK GARCH model is chosen to find the shock and price volatility between the markets and later multivariate CCC-GARCH is implemented to check the robustness of our conditional correlations between the aforementioned markets.

4.2 BEKK-GARCH (1,1) model

The variance-covariance matrix H_t is represented as below:

$$H_t = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} for \quad i=1,2 \tag{1}$$

The variance of error term (H_t) of BEKK (1,1) model is represented as follows:

$$H_t = C_0^{'}C_0 + A_{11}^{'}\varepsilon_{t-1}\varepsilon_{t-1}^{'}A_{11} + B_{11}^{'}H_{t-1}B_{11} \tag{2}$$

where A_i and B_i are N×N parameter matrix C_0 is N×N upper triangular matrix.

We are implementing bivariate BEKK (1,1) model and the same can be represented by the following equations:

$$H_t = C_0^{'}C_0 + \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}^{'} \begin{pmatrix} \varepsilon_{1,t-1}^2 & \varepsilon_{1,t-1}\varepsilon_{2,t-1} \\ \varepsilon_{2,t-1}\varepsilon_{1,t-1} & \varepsilon_{2,t-1}^2 \end{pmatrix} \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} + \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix}^{'} \begin{pmatrix} h_{11,t-1} & h_{12,t-1} \\ h_{21,t-1} & h_{22,t-1} \end{pmatrix} \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} \tag{3}$$

The parameters in matrix A and B represents different kinds of volatility effects in their own market and cross market. The parameter a_{11}, a_{22}, b_{11}, b_{22} represents volatility effects in their own market respectively whereas a_{12}, a_{21}, b_{12}, b_{22} represents cross market volatility effects. From the equation (3) we can arrive at the conditional variance and conditional covariance equations. These equations are listed below:

$$h_{11,t} = c_1 + a_{11}^2\varepsilon_{1,t-1}^2 + 2a_{11}a_{21}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + a_{21}^2\varepsilon_{2,t-1}^2 + b_{11}^2h_{11,t-1} + 2b_{11}b_{21}h_{12,t-1} + b_{21}^2h_{22,t-1} \tag{4}$$

$$h_{22,t} = c_3 + a_{12}^2\varepsilon_{1,t-1}^2 + 2a_{12}a_{22}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + a_{22}^2\varepsilon_{2,t-1}^2 + b_{12}^2h_{11,t-1} + 2b_{12}b_{22}h_{12,t-1} + b_{22}^2h_{22,t-1} \tag{5}$$

$$h_{12,t} = c_2 + a_{11}a_{12}\varepsilon_{1,t-1}^2 + (a_{21}a_{12} + a_{11}a_{22})\varepsilon_{1,t-1}\varepsilon_{2,t-1} + a_{21}a_{22}\varepsilon_{2,t-1}^2 + b_{11}b_{12}h_{11,t-1}^2 + (b_{21}b_{12} + b_{11}b_{22})h_{12,t-1} + b_{21}b_{22}h_{22,t-1}^2 \tag{6}$$

4.3 CCC-GARCH model

Bollerslev (1990) described this model which permits for time-varying conditional variances and covariances. One limitation of this model is that it considers conditional correlations to be constant. The conditional variance matrix is shown below:

$$H_t = D_tRD_t = (\rho_{ij}\sqrt{h_{iit}h_{jjt}}) \tag{7}$$

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where D_t represents N×N matrix and R is a N×N time invariant correlation matrix, this matrix contains constant conditional correlations ρ_{ij} .

Here the D_t is represented by:

$$D_t = diag\ (h_{11t}^{1/2} \cdots h_{NNt}^{1/2}) \quad (8)$$

Also h_{iit} is any univariate GARCH model

$$h_{iit} = c_i + a_i \varepsilon_{i,t-1}^2 + b_i h_{ii,t-1} \quad (9)$$

$$h_{ijt} = \rho_{ij} \sqrt{h_{iit} h_{jjt}} \quad ; \quad i, \ j = 1 \ldots, 4. \quad (10)$$

and

$$R = (\rho_{ij}) \quad (11)$$

Equation (11) is a symmetric positive definite matrix with ρ_{ij} = 1, for all i.

The CCC model produces a simple model with a smaller number of assumptions and this it reduces number of unknown parameters to be determined.

5. Empirical Results

All empirical work is carried out using the RATS 9.0 software. Observing the time series graph (Figure 1 (a)) one can see that there is not much scope for any arbitrage in the spot and future market since they tend to move together. Time series return graphs are also reported (Figure 1 (b)). The general statistics are represented in Table 1. From the JB test Cash and forwards market accepts the null hypothesis where as for the options it rejects the null hypothesis. Results from unit root tests, i.e. ADF and PP for stationarity is mentioned in Table 2. The results clearly reject the null hypothesis that the series has any unit root, and therefore all the time series are stationary data series. And using AIC method the optimum lag length was found out to be 4. The results from LB Q presented in Table 1, confirms the rejection of the null hypothesis except from that of options, which means that except from options there is no autocorrelation present in the rest of the markets. Before running the MGARCH models on the time return series we need to confirm the presence of ARCH effects, hence we ran ARCH LM test on the return series data and the results are significantly convincing and hence there is a strong evidence of volatility clustering in the sample data, the statistics of the LM test are shown in Table 1. Below are the results discussed using various GARCH models.

Table 1. General Statistics

Variable	Spot	Futures	Call Option	Put Option
Mean	0.00111871	0.00112372	0.00124026	0.00675830
Median	0.00221809	0.00270271	-0.02392569	-0.00285644
Maximum	0.06971942	0.07482670	3.89560518	3.08347934
Minimum	-0.05781276	-0.05584017	-3.92103632	-2.98521521
SD	0.02116601	0.021354157	0.401570666	0.447682924
Skewness	0.058371	0.053569	0.017467	-0.158593
Kurtosis	0.160409	0.246990	48.807952*	14.094860
Jarque-Bera	0.734717	1.353009	35534.742229*	2964.921615*
LB	41.877	38.977	91.999*	143.837
ARCH	23.810*	29.080*	139.087*	107.961*

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* Denotes level of significance less than 5%

Table 2. Results of unit root test

Variables	ADF	PP
	T-statistic	T-statistic
Spot	-20.7049**	-20.7492**
Futures	-20.3662**	-20.4061**
Call Option	-30.2805**	-44.3233**
Put Option	-28.8428**	-39.0555**

* Denotes level of significance less than 5% and ** Denotes level of significance less than 1%

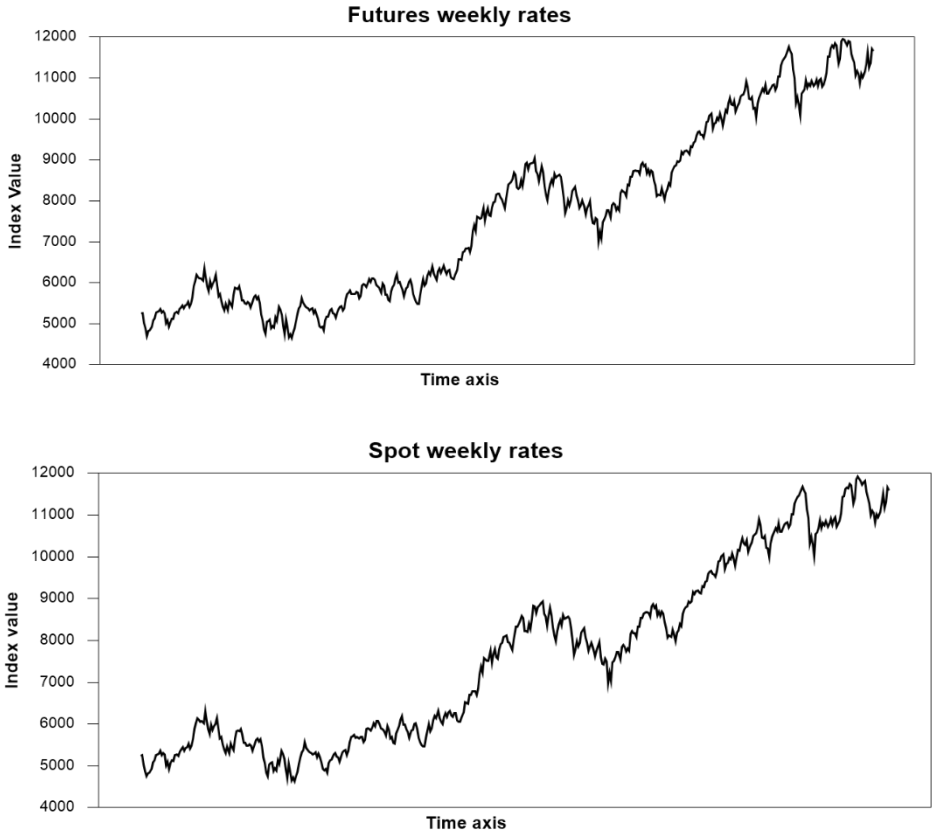

Figure 1 (a)

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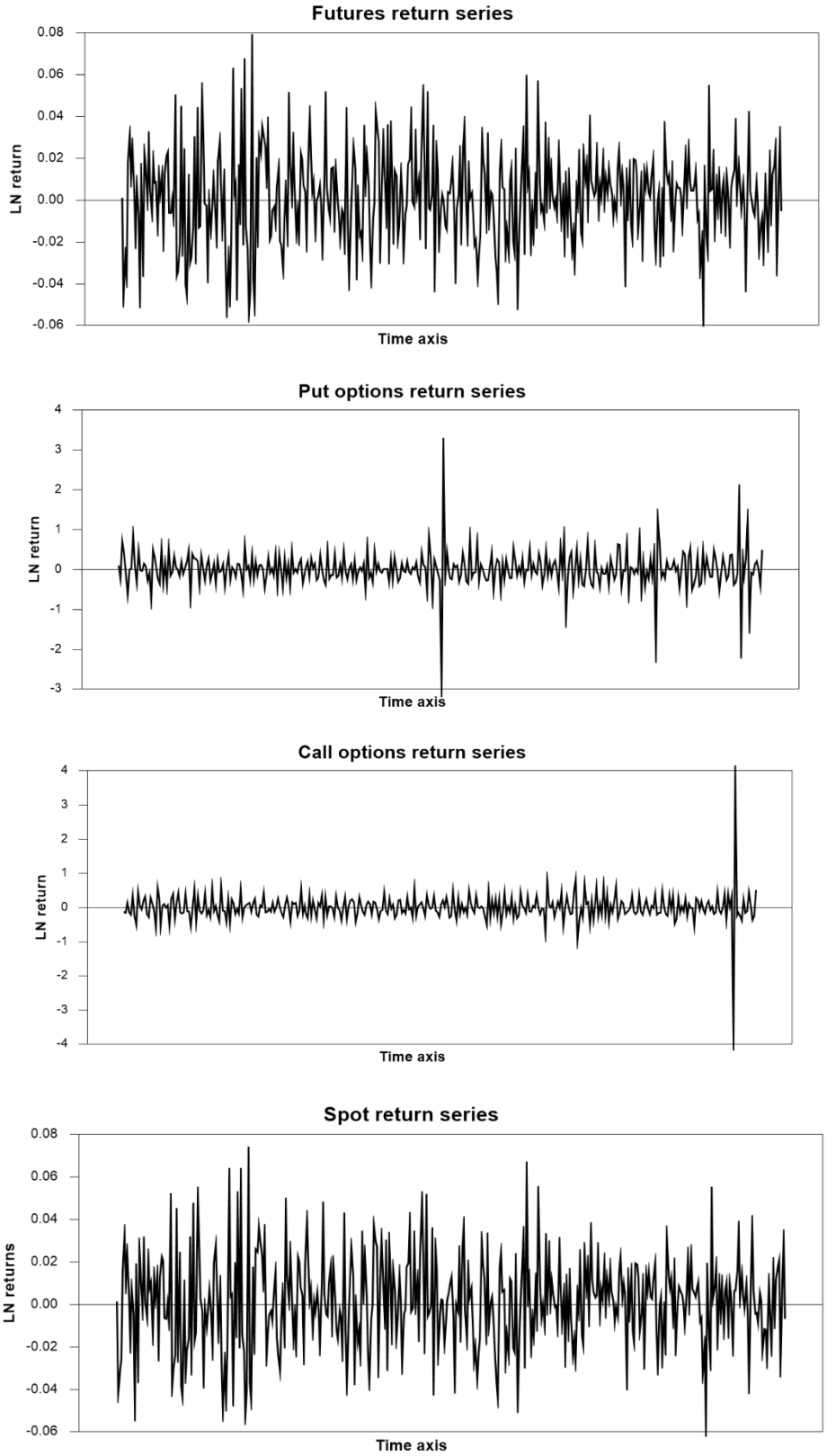

Figure 1 (b)

5.1 BEKK GARCH Estimation Results

Table 3 represents the estimates from BEKK model when spot and futures market is taken into consideration. Here A (i, j) and B (i, j) are the

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ARCH and GARCH parameters respectively associated with spot and futures market. The A (i, j) parameters represents the shock volatility spillover from market i to market j, which means if there is any negative news in market i then that news will affect the prices in market j. B (i, j) parameter reflects the price volatility spillover from market i to market j, which means if there is any price change in market i then that changes will affect the prices in market j (Mohammadi, H., & Tan, Y. (2015) and Sinha (2017)). From Table 3 one can confirm that there is a past shocks in futures market has effects on itself. Similarly, in spot market and in future market there is a price volatility or long-term volatility spillover effects in the spot and future market respectively. There is a strong bidirectional volatility spillover though a bit stronger from spot side (reflected from the absolute value of the coefficients).

Table 3. BEKK GARCH model on spot and futures

Variable	Coefficient	Std Error	T-stat
Mean (Spot)	0.001538642	0.000857044	[1.79529]
Mean (Futures)	0.001564933	0.000866716	[1.80559]
C (One, One)	0.003326689	0.003190518	[1.04268]
C (Two, One)	0.002952545	0.003244131	[0.91012]
C (Two, Two)	-0.000000118	0.000481661	[-2.45731e-04]
A (One, One)	-0.562014661	0.429886931	[-1.30735]
A (One , Two)	-0.713318954	0.449860833	[-1.58564]
A (Two, One)	0.802165807	0.434793754	[1.84493]
A (Two, Two)	0.938864055	0.459330551	[2.04398]*
B (One, One)	3.009607136	0.352987492	[8.52610]*
B (One, Two)	2.114116860	0.333217511	[6.34456]*
B (Two, One)	-2.087543632	0.330468198	[-6.31693]*
B (Two, Two)	-1.160524300	0.310820729	[-3.73374]*

*Significance is less than 5%

For spot and call option pair and there was a shock volatility spillover seen in spot market on its own and it is the same for the call option market. Long-term volatility spillover effect is observed in the spot market on its own. There is no cross-market volatility spillover effects as it is evident from the Table 4 shown below.

Table 4. BEKK GARCH model on spot and call option

Variable	Coefficient	Std Error	T-stat
Mean (Spot)	0.002121767	0.001030064	[2.05984]*
Mean (Call)	-0.020217316	0.013063901	[-1.54757]
C (One, One)	0.004630546	0.003400968	[1.36154]
C (Two, One)	0.010417355	0.191180108	[0.05449]
C (Two, Two)	0.261638368	0.018052479	[14.49321]*
A (One, One)	0.326461553	0.066791236	[4.88779]*
A (One, Two)	-2.249607621	1.195840791	[-1.88119]
A (Two, One)	-0.004516533	0.003275250	[-1.37899]

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A (Two, Two)	0.846282881	0.096496173	[8.77012]*
B (One, One)	0.920274149	0.051544061	[17.85413]*
B (One, Two)	0.097500154	2.031767838	[0.04799]
B (Two, One)	0.007614405	0.004310370	[1.76653]
B (Two, Two)	0.001846477	0.081286250	[0.02272]

*Significance is less than 5%

Same results can be noted when spot and pull option market is observed. The results can be observed in Table 5, which is shown below:

Table 5. BEKK GARCH model on spot and put option

Variable	Coefficient	Std Error	T-stat
Mean (Spot)	0.002106129	0.001075627	[1.95805]
Mean (Put)	0.011196160	0.018832314	[0.59452]
C (One, One)	0.004755576	0.002095110	[2.26985]*
C (Two, One)	0.235082930	0.169080232	[1.39036]
C (Two, Two)	0.245532167	0.176249947	[1.39309]
A (One, One)	0.257358786	0.060992835	[4.21949]*
A (One, Two)	0.365540312	1.277831948	[0.28606]
A (Two, One)	0.000857243	0.002514662	[0.34090]
A (Two, Two)	0.575164975	0.102979419	[5.58524]*
B (One, One)	0.921813208	0.038777474	[23.77187]*
B (One, Two)	-4.250916066	2.446419804	[-1.73761]
B (Two, One)	-0.007038811	0.006001841	[-1.17278]
B (Two, Two)	-0.075702913	0.132830948	[-0.56992]

*Significance is less than 5%

Now we analyse future and call option market. In both the markets shock volatility effects can be noted in their respective markets from the Table 6. Also, one of the things to note is there is a shock volatility spillover effects from futures to call option market but contrary there is no presence of cross-market price volatility spillover effects. There is a long-term price volatility spillover effects from the futures markets to its itself.

Table 6. BEKK GARCH model on futures and call option

Variable	Coefficient	Std Error	T-stat
Mean (Futures)	0.002163829	0.000981109	[2.20549]*
Mean (Call)	-0.018735761	0.012656627	[-1.48031]
C (One, One)	0.004463869	0.003486209	[1.28044]
C (Two, One)	0.064735416	0.213143383	[0.30372]
C (Two, Two)	0.250970665	0.057098433	[4.39540]*
A (One, One)	0.339255143	0.070024453	[4.84481]*
A (One, Two)	-3.044042855	1.201805502	[-2.53289]*
A (Two, One)	-0.004642005	0.003480061	[-1.33389]
A (Two, Two)	0.846943100	0.090603383	[9.34781]*
B (One, One)	0.914131703	0.050843426	[17.97935]*

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B (One, Two)	0.362873140	1.855275812	[0.19559]
B (Two, One)	0.007691639	0.004736477	[1.62392]
B (Two, Two)	0.001134430	0.078980644	[0.01436]

*Significance is less than 5%

At last we discuss the last pair futures and put option market. Here also in the Table 7 we can see that the shock volatility spillover effects on their own market. There is a long-term volatility or price volatility spillover effects from futures on its own market. The results are shown in the table mentioned below:

Table 7. BEKK GARCH model on futures and put option

Variable	Coefficient	Std Error	T-stat
Mean (Futures)	0.002199483	0.001027107	[2.14144]*
Mean (Put)	0.011190530	0.017455105	[0.64110]
C (One, One)	0.005142644	0.002139192	[2.40401]*
C (Two, One)	0.230177978	0.153322211	[1.50127]
C (Two, Two)	0.251051585	0.153859408	[1.63169]
A (One, One)	0.270641436	0.063557085	[4.25824]*
A (One, Two)	0.537738742	1.434618283	[0.37483]
A (Two, One)	0.001044220	0.002575938	[0.40537]
A (Two, Two)	0.580968743	0.095816296	[6.06336]*
B (One, One)	0.913568821	0.039308606	[23.24094]*
B (One, Two)	-3.996022777	2.401650440	[-1.66387]
B (Two, One)	-0.008021858	0.005923610	[-1.35422]
B (Two, Two)	-0.061611797	0.134963125	[-0.45651]

*Significance is less than 5%

5.2 CCC GARCH Estimation Results

Next, we analyze the data using MGARCH CCC model. Some advantage of this model over the previous one is that it has a smaller number of parameters to be determined. Also, this particular model estimates its own ARCH and GARCH effects. This model also estimates the correlation between the markets. CCC-GARCH model is generally used for large number of variables (markets). Unlike the previous model where we implemented it as a bivariate model here, we took all the markets at a time. The results obtained from the implementation is mentioned in Table 8, shown below:

Table 8. CCC GARCH model

Variable	Coefficient	Std Error	T-stat
Mean (Spot)	0.001732101	0.001021015	[1.69645]
Mean (Futures)	0.001672276	0.001028457	[1.62600]
Mean (Call)	-0.028492690	0.013176186	[-2.16244]*
Mean (Put)	0.014195153	0.019932070	[0.71218]
C (One)	0.000014975	0.000015212	[0.98439]
C (Two)	0.000015458	0.000015269	[1.01239]

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C (Three)	0.070112435	0.008455064	[8.29236]*
C (Four)	0.125469954	0.014185505	[8.84494]*
A (One)	0.034562547	0.015152666	[2.28095]*
A (Two)	0.037760488	0.016084209	[2.34767]*
A (Three)	0.790356503	0.181162016	[4.36271]*
A (Four)	0.353059329	0.118214734	[2.98659]*
B (One)	0.928392655	0.044929561	[20.66329]*
B (Two)	0.924255684	0.045847190	[20.15948]*
B (Three)	-0.007189997	0.002289407	[-3.14055]*
B (Four)	-0.014350391	0.024468640	[-0.58648]*
R (Two, One)	0.993499979	0.000655939	[1514.62181]*
R (Three, One)	-0.096654377	0.050724056	[-1.90549]
R (Three, Two)	-0.056313737	0.050997672	[-1.10424]
R (Four, One)	-0.084752376	0.050052984	[-1.69325]
R (Four, Two)	-0.060555827	0.050071757	[-1.20938]
R (Four, Three)	0.014709205	0.050388758	[0.29191]

*Significance is less than 5%

In the Table 8, C (i) represents the estimated constant term for each conditional variance and A (i) and B (i) represents the estimated ARCH and GARCH parameters of market i. And these parameters are highly significant which satisfies the ARCH LM test, i.e. the presence of ARCH effect. R (i, j) represents the corresponding correlations between the pair of four markets. From the Table 8 it is clear that there is a high correlation between spot and futures market and very low correlations between other pairs. Thus, the high conditional correlation between spot and future market confirms the presence of interconnectivity and close proximity between them, which also supports our BEKK GARCH results.

6. Summary and Conclusion

There is no limitation of literature when it comes to volatility spillover effects in various markets from equity market to commodity market. The current study is an extension to the literature by analyzing spot, futures and options market together in Indian context trading in NSE. The sample taken for analysis exists from January 8, 2010 to October 25, 2019. To extract the data from NSE website we observed weekly NIFTY 50 index for the spot market prices. For futures price there are three prices on a particular day (the same month, next month and next to next month), a simple average is taken for analysis. Lastly option prices are extracted using Vega weighted average (Black-Scholes Option Pricing model) method. From the JB test spot and futures market accepts the null hypothesis where as for the options it rejects the null hypothesis. Later the stationarity of the series where checked and all the time-series were found out to be stationary. ARCH effects were reflected in all the series, which means that the presence of volatility clustering in the return data series was confirmed. We selected bivariate BEKK-GARCH (1, 1) as a stochastic model for our estimation of volatility spillover and later applied CCC-GARCH model for testing the conditional correlation or the interconnectivity between the observed markets.

First, we considered spot and future as a pair for BEKK estimation. A strong bidirectional volatility spillover effect was found between the markets albeit a bit stronger from spot side. Also shock volatility spillover effect was reflected in futures

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markets on itself. Then we took spot and call options as a pair and no long-term volatility spillover was found, but there were long term volatility spillover effects in spot market on itself. Shock volatility effects were observed in both markets on themselves. No cross-market volatility spillover effects were found. After that spot and put options were considered as a pair and the same results were reflected as that from spot call option pair. In futures and call options pair there is a unidirectional shock volatility spillover effects from futures to call option market. In both the markets shock volatility effects can be noted in their respective markets and a long-term price volatility spillover effects from the futures markets to its itself. Lastly, for future and put options pair, the results reflect shock volatility spillover effects on their own market. There is a long-term volatility spillover effects from futures on its own market.After the implementation of BEKK-GARCH model we try to fit CCC-GARCH model to find the interconnectivity. The results obtained supports the findings from the BEKK-GARCH. There is a very strong close proximity between spot and future market where as a very weak relation is seen between futures and call options market. This paper is an effort to make an extension to the existing work (Seghal, 2015) by carrying out the analysis using MGARCH model, i.e. CCC model. One of the limitations of this paper is that the data was not a good fit for DCC-GARCH model. The results obtained are very sensitive with respect to the study period. The paper gives a future scope of study; fitting DCC-GARCH for studying the interdependency between these particular markets in Indian context.

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