

Chapter 11

Probing Time-Varying Conditional Correlation Between Crude Oil and Sensex



Saif Siddiqui and Arushi Gaur

Abstract Change in oil prices may have a different impact on different countries due to various factors such as their relative position as oil importers or exporters, different tax structures. Oil price affects Indian economy. A small rise in oil price leads to an increase in prices of goods and services. It is also affected by the exchange rate and effects stock market too. Here, we propose to study the co-movement of crude oil prices and volatility spillover affect on stock market and USD–INR rate of exchange. Daily data for the period from June 01, 2014 to August 31, 2016 of BSE S&P Sensex (Sensex), prices of crude oil and USD–INR rate of exchange are taken. We used multivariate GARCH model to identify spillover of volatility. Besides, doing descriptive statistics, Unit Root, Johansen Co-integration and correlation test, we also put Granger causality test. Volatility spillover between exchange rate, Sensex and crude oil prices are found to be significant and bidirectional. Affect of crude oil price movement on Sensex is also significant.

Keywords BEKK · Crude oil · DCC · Exchange rate · Stock market

11.1 Introduction

Oil forces world economies. An oil price change may have a different impact on different countries due to various factors such as their relative position as oil importers or exporters, different tax structures.

In context to Asian countries, oil price is the key factor, which affects the inflation. Due to the rising demand of oil in countries such as China and India, and production cuts by OPEC countries, the oil prices rose significantly from 1999 to mid-2008 from \$25 to \$150 a barrel. On July 2008, it reached its peak of US\$147.27 a barrel. But the financial crises of 2007–2008 affected the oil price

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and underwent a significant decrease after July 11, 2008. In mid of 2014, from a peak of \$115 per barrel in June 2014 oil price started falling because of tremendous increase in production of oil in USA, and diminishing demand in other countries. By February 03, 2016 the price of oil was below \$30 a barrel which is almost a drop 75% since mid-2014. This change affected the world economies to great extent.

It affected the investment in stock markets. Price of oil affects the whole economy, especially in India due to its high use in transportation. A rise in prices of oil results to a rise in inflation. A high inflation is not good for an economy. The value of a free currency such as Rupee is determined by its demand in the currency market.

Keeping in view this important relationship, here, we propose to study the movement of crude oil prices and volatility spillover affect of stock market and Exchange rate.

11.2 Review of Literature

Jones and Kaul (1996) examined the effect of world stock markets to various shocks in oil prices by future and current changes in cash flows and likely returns. They used the data of four countries, i.e. USA (i.e. from 1947 to 1991), Canada (i.e. from 1960 to 1991), Japan (i.e. from 1970 to 1991) and UK (i.e. from 1962 to 1991). They found negative effect of stock prices of these countries to shocks in prices of oil on real cash flows. Sadorsky (2001) applied multifactor market model and estimated returns of Canadian oil and gas stock prices. Data for the period from April 1983 to April 1999 were used. They found that as the gas and oil sector moves pro-cyclical, it is likely to be less risky than the market. Agnolucci (2009) used returns from the generic light sweet crude oil for period from December 12, 1991 to May 02, 2005. The result concluded that GARCH models outperformed the other models used. Soytaş et al. (2009) investigated short- and long-run transmission of information between US dollar–Lira exchange rate, oil prices, Turkish rate of interest and domestic silver and gold spot price. They used data for the period from May 2, 2003 to March 1, 2007. They observed through Granger test that Turkish exchange rate and spot prices of select metals and bond markets would not help to develop a better anticipation of world oil prices in the long run. Kilian and Park (2009), examined the impact of change in prices of oil on stock prices. They used the data from January 1973 to December 2006. They observed that increase in the oil prices due to substantial increase in demand for oil, over concerns of future oil supplies, has a negative impact on stock prices. Narayan and Narayan (2010) studied the period from 2000 to 2008 to analyse the effect of change in prices of oil on stock prices of Vietnam by applying co-integration test. They observed that oil, stock prices and nominal rate of exchange are co-integrated. They also observed that price of oil impact positively the stock prices. Siddiqui and Seth (2011) analysed the data

from January 2010 to December 2014 and studied the relationship of the stock price of NSE and world oil prices. They used VAR model. Result confirmed no integration between variables. Basher et al. (2012) proposed and examined structural VAR model to investigate the dynamic relationship of the variables. They studied a period from January 1988 to December 2008 of stock prices, oil production, interest rates, oil price and global real economic activity. It was also observed that prices of oil respond positively to a positive shock to emerging stock market. Ji and Fan (2012) examined the impact of change in crude oil prices on other different markets during 2008 financial crises. They used bivariate EGARCH model to examine volatility spillover. They observed major effect of volatility spillover of crude oil on non-energy commodity market. Batac and Tatlonghar (2013) examined the effect of change in Peso–Dollar exchange rate, money supply on Philippine stock market and price of crude oil. Quarterly data were used from 1992 to 2010. Autoregressive Distributed Lag, Granger causality Test and Johansen Co-integration Test were applied. The results proved a long-run relationship of PESI with other variables. It further provides the existence of a unidirectional causality flowing from the Peso–Dollar rates to Philippine stock market. Creti et al. (2013) investigated the linkages among stock prices and price return of 25 commodities for the period, i.e. from January 2001 to November 2011. They applied GARCH (DCC) model. It was experienced that stock market was highly volatile during crises of 2007–2008. A correlation between stock and commodity market was also observed. Pal et al. (2014) evolved multifractal de-trended cross-correlation analysis. They used the data of gold, Crude oil, Brent crude oil and foreign exchange for the period from January 3, 1995 to August 2013. They found uncorrelated behaviour between oil prices and gold implied that they both are largely dependent on themselves. Siddiqui and Siddiqui (2015) examined the leverage and volatility effect of spot and future indices. GARCH family models were used such as GARCH (1, 1), EGARCH and CGARCH on Indian Multi-Commodity Exchange from November 2005 to March 2015. High persistence of volatility was observed among indices while leverage effect was found in Agricultural spot, Energy Spot and Metal future. Singhal and Ghosh (2016) investigated co-movements of oil and Indian stock market at both sector and aggregate levels. They used the data of Brent crude, BSE Sensex and indices of Automotive, Financial, Energy, Gas, Oil, Industrial and Power from Bombay Stock Exchange (BSE) for the period from January 1, 2006 to February 2015. VAR-DCC-GARCH model was used to study volatility spillover. At aggregate, volatility spillover from oil market to stock market is not significant, but it is at sector level.

11.3 Objectives

Objectives in this chapter are as follows:

1. To ascertain co-integration among price of crude oil, Sensex and exchange rate of USD and INR
2. To assess causality between price of crude oil, Sensex and exchange rate of USD and INR
3. To estimate volatility spillover in price of crude oil, Sensex and exchange rate of USD and INR.

11.4 Hypotheses

In order to meet the objectives, following null hypotheses are proposed:

- H_{01} There is no co-integration among price of crude oil, Sensex and exchange rate of USD and INR
- H_{02} There is no causality between price of crude oil, Sensex and exchange rate of USD and INR
- H_{03} There is no volatility spillover in price of crude oil, Sensex and exchange rate of USD and INR.

11.5 Research Methodology

Research methodology of the study is as follows:

We have taken daily data for the period from June 01, 2014 to August 31, 2016 of USD–INR exchange rate, crude oil prices and Indian BSE S&P Sensex (Sensex). This data were taken from Yahoo Finance. We have also taken historical crude oil prices from Investing.com and exchange rate from the official Website of RBI. We used DCC and BEKK-MGARCH model to forecast volatility spillover, descriptive statistics, Unit Root and co-integration tests. We used Granger causality test for short-term causality.

11.5.1 *Descriptive Statistics*

With the help of descriptive statistic, we are describing the various features of crude oil price, Sensex and USD–INR exchange rate. Following Table shows the result of descriptive statistics of the variables under study (Table 11.1).

Table 11.1 Descriptive statistics

| | Sensex | Crude oil | USD–INR |
|-------------|------------|-------------|-----------|
| Mean | 0.000234 | –0.001480 | 0.000228 |
| Median | 0.000258 | –0.002290 | 8.77E-05 |
| Std. Dev. | 0.009581 | 0.029798 | 0.003452 |
| Skewness | –0.661160 | –0.610070 | 0.181870 |
| Jarque-Bera | 286.596900 | 2261.178000 | 13.063080 |
| Probability | 0.000000 | 0.000000 | 0.001457 |

Table 11.2 Phillips Perron (PP test)

| | At level | | At first difference | |
|-----------|---------------------|--------|---------------------|---------|
| | <i>t</i> -Statistic | Prob.* | <i>t</i> -Statistic | Prob.** |
| Sensex | –2.1704 | 0.2176 | –21.0998 | 0.0000 |
| USD–INR | –1.4944 | 0.5359 | –22.2617 | 0.0000 |
| Crude Oil | –2.2251 | 0.1977 | –24.9290 | 0.0000 |

* figure is insignificant at 5% level

** figure is significant at 5% level

USD–INR exchange rate is least volatile as its standard deviation is least with 0.3452% however crude oil price is examined to be highest volatile as its standard deviation is 2.9798%. Here Sensex and prices of crude oil are negatively skewed, whereas USD–INR exchange rate is positively skewed. Here in all cases, hypothesis of normality is rejected.

11.5.2 Unit Root

This test is applied for examining the stationarity or non-stationarity of the variables of time series. Table 11.2 shows the result of Unit Root Test.

In Table 11.2, null hypothesis cannot be rejected at level but rejected at first difference, which means that Sensex, USD–INR exchange rate and price of crude oil are non-stationary at levels but after first difference they become stationary.

11.5.3 Johansen Co-integration Test

Further to check the non-existence and existence of co-integration, we applied Johansen Co-integration test. The following Table 11.3 presents the result of the Test.

Here trace statistics is the decisive statistics, beginning with null hypothesis having no co-integrating equation ($r = 0$), proving that there is no co-integration. The trace test statistic (26.38743) is lesser than its critical value, and the value of probability is 0.1175. Therefore, there is no co-integration.

Table 11.3 Johansen Co-integration test

| Hypothesized | | | 0.05 | |
|--------------|-------------|-----------------|----------------|--------|
| No. of CE(s) | Eigen value | Trace statistic | Critical value | Prob. |
| None | 0.025598 | 26.38743 | 29.79707 | 0.1175 |
| At most 1 | 0.012121 | 12.59219 | 15.49471 | 0.1306 |
| At most 2 | 0.011408 | 6.104177 | 8.841466 | 0.1350 |

Table 11.4 Granger causality tests

| Null hypothesis: | Obs. | F-Statistic | Prob. |
|--|------|-------------|--------|
| USD/INR does not Granger Cause Crude oil | 534 | 0.29539 | 0.7444 |
| Crude oil does not Granger Cause USD/INR | | 1.68694 | 0.1861 |
| Sensex does not Granger Cause Crude oil | | 0.62775 | 0.5342 |
| Crude oil does not Granger Cause Sensex | | 2.51155 | 0.0821 |
| Sensex does not Granger Cause USD/INR | | 0.11321 | 0.8930 |
| USD/INR does not Granger Cause Sensex | | 0.18331 | 0.8326 |

11.5.4 Granger Causality Tests

The Granger causality test is put in Table 11.4, and this test indicates in which direction causality exists between the understudy variables.

The results of the above Table indicate that null hypothesis is rejected in all cases and causality is non-existence between crude oil price, Sensex and USD–INR exchange rate.

11.5.5 DCC-GARCH

The Dynamic Conditional Correlation GARCH belongs to the class “Models of conditional variances and correlations” which was introduced by Engle and Sheppard (2001). In Sensex, USD–INR exchange rate and crude oil prices, the value of probability of ARCH coefficient is not significant; this means there is no short-run volatility among the variables, whereas the probability of GARCH coefficient is significant, which indicates long-run volatility is there among the variables. As per Table 11.5, it is seen that DCC (A) and DCC (B) are not significant. It implies that there is no spillover effect among the variables.

Table 11.5 DCC-GARCH

| Variable | Coefficient | Std. error | T-Stat | Significance |
|------------------|-------------|------------|-----------|--------------|
| Mean (crude oil) | -2.34E-03 | 1.05E-03 | -2.21973 | 0.0264370 |
| Mean (Sensex) | 1.41E-04 | 5.36E-04 | 0.26389 | 0.7918609 |
| Mean (USD/INR) | 2.40E-04 | 1.26E-04 | 1.90696 | 0.0565259 |
| C(1) | 4.33E-04 | 2.48E-05 | 17.48173 | 0.0000000 |
| C(2) | 4.59E-06 | 1.88E-06 | 24.38043 | 0.0000000 |
| C(3) | 5.17E-06 | 8.98E-07 | 5.76158 | 0.0000000 |
| A(1) | **0.0880 | 0.0352 | 2.49662 | 0.0125385 |
| A(2) | **0.0509 | 0.0218 | 2.33223 | 0.0196888 |
| A(3) | 0.1095 | 0.0597 | 1.83584 | 0.0663819 |
| B(1) | **0.4477 | 0.0153 | 29.34182 | 0.0000000 |
| B(2) | **0.4588 | 0.019 | 24.11362 | 0.0000000 |
| B(3) | **0.4391 | 0.0385 | 11.39303 | 0.0000000 |
| DCC(A) | -1.22E-08 | 0.0821 | -1.48E-07 | 0.9999999 |
| DCC(B) | 0.1971 | 0.2958 | 0.66621 | 0.5052747 |

**Shows significant at 5%

11.5.6 BEKK-GARCH

It refers to a specific parameterization of multivariate GARCH model. This model examines the long-run and short-run volatility spillover among the variables. In case if diagonal coefficient, the value of probability of ARCH coefficient of crude oil price, Sensex and USD–INR exchange rate (A (1,1), A(2,2), A(3,3)) is less than 5% which means that in short-run past innovation have significant impact on current volatility. Similarly, the probability of GARCH coefficient of crude oil price, Sensex and USD–INR exchange rate B(1,1), B(2,2), B(3,3) is less than 5% which means that in long run also, and past innovations have a significant impact on current volatility.

In case of off-diagonal coefficient, A(1,3) is significant which means that in short-run crude oil price has significant cross-volatility spillover impact on USD–INR exchange rate (Table 11.6).

Similarly, the value of probability of B(2,3) and B(3,2) is also less than 5% (0.00350484, 0.00008323) which means that in long run, Sensex has a significant cross-volatility spillover impact on USD/INR rate, whereas USD–INR rate has also a significant cross-volatility spillover on Sensex in long term.

Table 11.6 BEKK-GARCH

| Variable | Coefficients | Std. error | T-Stats | Significance |
|-----------------|---------------|------------|----------|--------------|
| Mean(crude oil) | -0.002093900 | 0.000952 | -2.19855 | 0.02790993 |
| Mean (Sensex) | 0.000325657 | 0.000411 | 0.79207 | 0.42831858 |
| Mean(USD/INR) | 0.000107644 | 0.000138 | 0.78104 | 0.43477928 |
| C(1,1) | -0.007076520 | 0.001299 | -0.54470 | 0.58596091 |
| C(2,1) | 0.000088145 | 0.003670 | 0.02402 | 0.98083706 |
| C(2,2) | 0.003862646 | 0.001950 | 1.98094 | 0.04759750 |
| C(3,1) | -0.000955900 | 0.000541 | -1.76624 | 0.07735486 |
| C(3,2) | 0.001196517 | 0.000335 | 3.56268 | 0.00035709 |
| C(3,3) | 0.000000710 | 0.002057 | 3.47E-05 | 0.99997233 |
| A(1,1) | **0.308831306 | 0.041504 | 7.44103 | 0.00000000 |
| A(1,2) | -0.03153994 | 0.020023 | -1.57515 | 0.11522243 |
| A(1,3) | **0.014124721 | 0.006840 | 2.06496 | 0.03892705 |
| A(2,1) | -.14355853 | 0.109012 | -1.31691 | 0.18786950 |
| A(2,2) | **-.20988059 | 0.053590 | -3.91638 | 0.00008989 |
| A(2,3) | 0.00454839 | 0.023030 | 0.19750 | 0.84343487 |
| A(3,1) | -0.41866025 | 0.286322 | -1.46220 | 0.14368648 |
| A(3,2) | -0.25792515 | 0.145146 | -1.77700 | 0.07556817 |
| A(3,3) | **0.356774853 | 0.070364 | 5.07044 | 0.00000004 |
| B(1,1) | **0.950092035 | 0.010707 | 88.7363 | 0.00000000 |
| B(1,2) | -0.00183477 | 0.008657 | -0.21194 | 0.83215415 |
| B(1,3) | -0.00199419 | 0.003276 | -0.60868 | 0.54273600 |
| B(2,1) | 0.05781600 | 0.071571 | 0.80781 | 0.41919000 |
| B(2,2) | **0.8532064 | 0.103430 | 8.24913 | 0.00000000 |
| B(2,3) | **-.101981 | 0.034929 | -2.91960 | 0.00350484 |
| B(3,1) | -0.239900 | 0.208600 | -1.15040 | 0.24997900 |
| B(3,2) | **0.558260384 | 0.141874 | 3.93490 | 0.00008323 |
| B(3,3) | **0.77623576 | 0.069478 | 11.17230 | 0.00000000 |

**Shows significance at 5%

11.6 Conclusion

The key findings of the study are that USD–INR exchange rate is least volatile in comparison with other indices as the standard deviation is least, whereas crude oil price is considered to be highest volatile. The results of co-integration and Granger causality show that in all cases long-term co-movement and short-term causality do not exist between Sensex, price of crude oil and USD–INR exchange rate. There is no multivariate dynamic correlation among the variables as per Multivariate DCC Model. In long run, Sensex has a significant cross-volatility spillover impact on USD/INR exchange rate as well as on the other hand USD/INR exchange rate has also a cross-volatility spillover impact on Sensex in long run.

This study is helpful to all institutional investors, corporate executives, practitioners and portfolio managers may draw an important conclusion from the result of this study while operating in stock markets.

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