

Dynamics of oil price shocks and emerging stock market volatility: a generalized VAR approach

Emerging
stock market
volatility

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Abstract

Purpose – This study aims to establish the dynamic relationship between international crude oil prices and Indian stock prices represented by the Bombay Stock Exchange (BSE) energy index.

Design/methodology/approach – Using Johansen's cointegration test, vector error correction (VEC) model, impulse response function and variance decomposition test the study tries to ascertain the short-term and long-term dynamic association between the oil price shock and the movement of stock price and Granger causality test is applied to find out the nature of causality.

Findings – Considering vector autoregression estimation, the present study analyzes the relationship between the variables and tries to make a valid conclusion. The result of the co-integration test exhibits the presence of a long-term association between these two macro-economic variables during the period under study. Also, in the short-run VEC Granger causality result reveals that the movement of international crude oil price significantly influences the Indian stock price.

Research limitations/implications – To get a more robust result the study can be further extended by taking a longer time period with data of shorter time-frequency such as daily or weekly and further by using more sophisticated econometric and statistical tools. Further, the study can be extended to firm-level investigation considering the forward trading concentration with the Indian oil basket.

Social implications – In today's globalized era, forecasting of share price movement helps investors in predicting the market and invest accordingly. Through this liquidity of the markets enhance and markets become more active in the global arena.

Originality/value – This study represents fresh findings in the changing time period the linkage between crude oil prices and stock prices which are of value to the academicians, researchers, policymakers, investors, market regulators, etc.

Keywords Crude oil price, Stock market volatility, BSE energy indices, VAR approach

Paper type Research paper

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Introduction

Crude oil is a worldwide required energy product treated as the most essential product to run the different essential activities. The growth of industrial production of any country and its requirement of crude oil is highly and positively interrelated (Mitra, 2018). As per the IMF (2019) report in terms of nominal gross domestic product and purchasing power parity, India is the fifth and third largest nation in the world. It clearly indicates that among the countries of the globe, the economy of India is one of the world's most rapidly growing economies. Besides these, strengthening of the standard of living, increasing population, the advancement of the technological and economic climate of emerging economies like India have been a major factor for the rising demand for crude oil (Rahman, 2020). The persistent increasing demand and dependency of the economy on oil have captured one of the strategic positions in the Global among energy indices. Recently, unexpected and ongoing movements in crude oil prices attract investors, analysts, academicians to forecast the linkage between oil price and stock price. It is very crucial to understand the linkage between oil price and share price for risk managers, policymakers to manage investment and financial decisions.

In emerging countries' economic context, variations in oil prices are likely to have a greater impression on share prices and earnings (Basher and Sadorsky, 2006). Crude oil price affects the earnings of companies may be directly through the cost of raw material or indirectly through overhead cost (Ghosh and Kanjilal, 2016; Sahu, 2016; Maghyereh, 2006). Another way, earnings affect the share values of the companies and share values are straightly related to Sensex and Nifty, which are the representation of the economic conditions. Therefore, crude oil prices are regarded as a chief operator in becoming up and down of the prices of shares.

The oil and natural gas (ONG) industry have a remarkable impact, among all other industrial segments, on the ballooning of a country's economy. The crude oil production of India is not sufficient to meet its internal demand, so India is too dependent on other countries for its own consumption (Sahu *et al.*, 2015). The price of crude oil unlike other commodities, apart from demand and supply condition, in short-term affected by so many other factors such as geopolitical, economic, social and volatility of the capital market (Sharma *et al.*, 2018). Since the past few years, the Government of India has taken effective steps to deregulate the price of crude oil by narrowing the subsidy, which helps the government meaningfully in improving the reserve of foreign exchange. In this scenario, too many ups and down in crude oil prices impact the economy and increases the risk and uncertainty in the minds of investors. Slight fluctuation in crude oil prices hit different sectors of the economy differently (Phan *et al.*, 2015; Bouri *et al.*, 2016). The interrelation of oil prices and share prices has additional properties, as it varies from an oil importer to oil exporter countries (Youssef and Mokni, 2019; Wang and Liu, 2016). Likewise, stock markets in the long and short-term may reply in dissimilar ways to the swing in crude oil prices. Hence, considering the impact of oil price fluctuation on emerging countries' share prices is an area of extensive research as emerging countries continue to grow and prosper their industrial sphere and their capital market is likely to exert greater influence on the economy and over the global economy.

Moreover, in the long passage of time, there is huge fluctuation in international benchmark oil baskets (WTI, Brent, Oman- Dubai, etc.) prices due to business cycle, international geopolitical tension, Gulf war, pandemic effect, etc. Besides, in the Indian context, regular policy transformations have been witnessing wide changes over a long period of time along with a major shift in policy by adopting price deregulation policy from price subsidization policy. Therefore, considering all these phenomena the study is carried

out to find the inter-relationship between oil price and share price in line with [Chittedi \(2012\)](#), [Ghosh and Kanjilal \(2016\)](#), [Sriram \(2015\)](#), [Sahu *et al.* \(2015\)](#), [Bhunia \(2013\)](#). Specifically, rather than considering Bombay Stock Exchange (BSE) Sensex or Nifty as a whole this study considers the BSE energy index as the representative of the Indian stock market which has the highest direct linkages with oil price fluctuations to better infer the relationship which will contribute incremental value to the existing set of literature.

Review of literature

Figuring out the linkage between international oil price shocks and the stock price movements has been a major area of theoretical and empirical research. The empirical literature on the dynamic linkages between these two macro-economic variables is evolved with the assumption that the volatility of the stock prices is an indication of the economic condition of a country. However, on that basis, a range of research studies have been undertaken here which are committed to the bondage between oil price and share index.

Recently in the Indian context, [Aggarwal and Manish \(2020\)](#) took other than crude oil prices some other macro-economic variables for their study and finally they come to an end with a positive long-run, as well as the short-run relationship between the stock market returns and oil price. Likewise, [Sahu *et al.* \(2014\)](#) have detected that in the short-run no granger causality exists but in the long-run causality is there from stock indices to oil prices but not the vice-versa. The study finally exhibits that there remains a positive long-run relationship between oil prices and the stock market indices of India. In contrary to the prior results, [Abuolien *et al.* \(2019\)](#), [Fang and You \(2014\)](#), [Papapetrou \(2001\)](#) found a negative relationship between oil price shock and stock price volatility in the context of Jordan, India and Greece, respectively. Similarly, [Mitra \(2018\)](#), [Sriram \(2015\)](#), [Bhunia \(2012\)](#) revealed the long-run cointegrating relationship between indices of BSE and crude oil price. Again, in another study by taking crude oil price, stock index, and some other variables over the period January 1991 to October 2012, [Bhunia \(2013\)](#) observed the long-term relationship among the variables and his study finally concluded by implementing Granger causality that there must be either bidirectional or no causality among the variables.

By implementing the autoregressive distribution lag (ARDL) model, [Chittedi \(2012\)](#) has tried to explore the long-run relationship and finally concludes that volatility in stock prices in India has a remarkable effect on the volatility of oil prices but the reverse is not true. In the context of China, [Cong *et al.* \(2008\)](#) have revealed that the returns on most Chinese share indexes (except some oil companies and manufacturing index) are not significantly influenced by oil price movements. After that in the framework of China, [Du *et al.* \(2010\)](#) observed that although China's economic environment does not impact the international oil price China's economic growth and inflation are influenced by the oil price fluctuation. By considering daily data over the period of 10 years, [Kapusuzoglu \(2011\)](#) has reflected the long-term and short-term relationship among the three indices of the Istanbul Stock Exchange (ISE) and Brent oil price. Through implementing the Johansen cointegration test, they terminated that there remains a long-run relationship between each of three indexes of ISE and global Brent oil price.

Further, [Kilian and Park \(2009\)](#) opine that actual returns of US stock to an oil price shock vary significantly, provided that change in the price of oil in the market is driven by demand or supply shocks. Ultimately, this study summarized that jointly these shocks explain 22% of the long-run variation in US real stock returns. In another study, [Kang *et al.* \(2015\)](#) observe that positive shocks in oil market-specific demand are related to a negative return and a shock in oil supply has a positive effect on the returns of the US share market. By considering eight Asia-Pacific countries, [Li *et al.* \(2013\)](#) have suggested nonlinear long-term

stability between crude oil and stock markets for the eight Asia-Pacific economies. Ultimately, they concluded with the existence of bidirectional short-term Granger causality between global crude oil price and the stock markets of these eight Asia-Pacific countries. Similarly, by taking stock indexes of 22 emerging economies, [Aktham \(2004\)](#) has suggested that stock indices of these economies do not rationally reflect changes in crude oil prices.

[Miller and Ratti \(2009\)](#) for the purpose of their study taken six OECD countries and the two time periods: January 1971 – May 1980 and from February 1988 – September 1999 and at the end exhibits that there exists a negative long-run relationship in both the time periods between world real oil price and real stock market indices of these six countries. Concurrently, [Park and Ratti \(2008\)](#) have tested the effect of global oil price shocks on the share returns of the USA and 13 other European countries and found not for the USA but for many other European countries increased volatility of oil prices decreases stock returns immediately or within one month. Finally, they terminated that there is some affirmation of unsymmetrical effects on stock indices of positive and negative oil price volatility for the USA but there is none for any of the European countries.

By distinguishing the companies as oil consumers and oil producers [Phan et al. \(2015\)](#) examine how the movement of global oil price affects share values of oil producers and oil consumers. They concluded with sufficient evidence that the profitability of oil consumers is influenced by a lot of factors except oil price but the profitability of crude oil producers is influenced mainly by oil price changes. Thus, the oil producer sectors' stock index respond earlier to oil price fluctuations in comparison with the oil consumer sectors index. Similarly, by applying Johansen's co-integration test, [Sahu et al. \(2015\)](#) draw that oil price, exchange rate and stock price are cointegrated in the long-run.

Of continent Asia, [Shafi et al. \(2015\)](#) have taken two oil-importing countries i.e. India and Pakistan and ultimately at the end exhibits a negative relationship between the crude oil price and the stock indices [BSE and Karachi Stock Exchange (KSE)] of both the countries. [Sharma et al. \(2018\)](#) have analyzed the relationship between crude oil future prices; nifty and BSE Energy index and find that they are not co-integrated means a long-term relationship among the variables are not exist. By exercising the DCC-FIGARCH model [Youssef and Mokni \(2019\)](#) ascertained the influence of oil price on stock prices of oil-importing and oil-exporting countries. They finally observed that the reaction of stock market returns to oil price changes in oil-importing countries are more noticeable than for oil-exporting countries during the time of turmoil.

By taking data over the period March 1991 to January 2009 and by implementing the extended vector autoregression (VAR) model, [Ghosh and Kanjilal \(2014\)](#) have revealed that variations in oil price meaningfully impact the inflation rate and foreign exchange reserve. Additionally, this study also finds that variations in the oil price are exogenous in regard to the variables of India's macroeconomy and the effects of oil price variations are not symmetric in nature, with positive price shocks having a less pronounced result than negative shocks on inflation. Another remarkable study has been carried on by [Gupta \(2016\)](#) using monthly data of 70 countries for the period 1983 to 2014. The study ultimately found that variation in oil price positively affects firm-level returns and firms which are located in high oil-producing countries are highly sensitive to global oil price shocks. [Gjerde and Sættem \(1999\)](#) have checked the consistency of findings of the small, open Norwegian economy with the major economies. This study terminated that in similarity with US and Japanese stock markets, the Norwegian stock market also reacts to oil price changes and interest rate variation also influences inflation and stock yields but stock price showed a deferred response to fluctuations in domestic real activity.

The above-mentioned studies were conducted in the context of varied economies and legal frameworks and in different time periods. Specifically, it is perceived that most of the studies are in the context of developed countries economy (Park and Ratti, 2008; Kilian and Park, 2009; Papapetrou, 2001) and few studies exist in the context of emerging countries like India (Aggarwal and Manish, 2020; Fang and You, 2014; Sriram, 2015). So, their findings may exhibit heterogeneous and inconsistent results. Therefore, the dynamic relationship between international crude oil price fluctuation and Indian stock price volatility needs to be examined and understood repeatedly over time with changing economic context and international relationship. Moreover, most of the literature focusing on the dynamism between international oil price ripples and overall stock price movement, whereas, the energy produced companies have been directly influenced by the oil price shocks, whether it may be demand shock or supply shock. In this backdrop, ***this empirical study is carried out with the broad objective to establish the dynamic relationship between international crude oil price fluctuation and Indian stock prices represented by BSE Energy Index.***

Data and methodology

Data

To establish the dynamic relationship between international crude oil price and Indian stock price, the study uses secondary data in monthly frequency during the period from September 2005 to March 2020. The study considers a maximum number of data points in the context of the energy index i.e. the BSE had been publishing Energy index data from September 2005. To estimate the dynamics between crude oil price ripples and stock market volatility, the study considers the BSE Energy index as a representative of Indian stock price. Having the 28 companies related to the energy sector this index is directly influenced by the fluctuation of the price of crude oil. Data on share prices have been obtained from the website of BSE and crude oil data has been collected from the database of the Ministry of Petroleum and Natural Gas, Government of India.

Methodology

The study first determines the descriptive statistics to know the basic characteristics of the variables used in the analysis and estimates unit root test to check the stationary property of the data. This would properly assist us in adopting the generalized VAR model accurately.

It is necessary to check the unit root property for investigating the long-run equilibrium relationship under a time series framework. It is also augmented the accuracy and reliability of the model constructed for investigation. This study considers the two most common and popular unit root tests, namely, augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) test, as per the requirement.

The autoregressive model is most sensitive to the appropriate lag length and obviously, it is a decisive factor. Therefore, the appropriate lag length needs to be determined prior to estimation. Further, to ascertain the long-run relationship between oil price fluctuation and volatility in stock price, the study uses the VAR-based approach of cointegration test. The test suggested by Johansen (1988) is based on the following vector autoregressive model-

$$Y_t = \mu + A_1 Y_{t-1} + A_2 Y_{t-2} + A_3 Y_{t-3} + \dots + A_p Y_{t-p} + u_t$$

Where Y_t is a vector containing n variables, all of which are integrated of order one and the time period is denoted by t . μ is an $(n \times 1)$ vector of constants, A_p is an $(n \times n)$ matrix of coefficient where p is the maximum lag included in the model and u_t is an $(n \times 1)$ vector of

error terms. This can be written in the form of the error correction framework. The previous VAR can be written as-

$$\Delta Y_t = \mu + \prod Y_{t-p} + \Gamma_1 \Delta Y_{t-1} + \Gamma_2 \Delta Y_{t-2} + \dots + \Gamma_{p-1} \Delta Y_{t-p+1} + u_t$$

Where $\Gamma_i = -\sum_{j=i+1}^p A_j$ represents the dynamics of the model in the short-run and $\prod = \sum_{i=1}^p A_i - I$ represents the long-run relationship among the variables included in the vector Y_t and I is the identity vector.

The nature of the relationship between international crude price and the Indian energy stock index in the short-run can be explored by considering the vector error correction mechanism (VECM). The VECM is basically a restricted VAR having co-integration restriction and specifically modeled for non-stationary series that should be co-integrated. Further, the error correction term (ECT) of the model exhibits the speed at which it adjusts the previous period disequilibrium to pull back the long-run equilibrium relationship. More precisely, in a two-variable setting where X and Y are integrated of order one or $I(1)$, the vector error correction (VEC) model can be formulated as

$$\begin{aligned} \Delta X_t &= \delta_i + \sum_{i=1}^p \alpha_i \Delta X_{t-i} + \sum_{i=1}^p \beta_i \Delta Y_{t-i} + \gamma_1 \hat{\varepsilon}_{1t-1} + u_{1t} \\ \Delta Y_t &= \lambda_i + \sum_{i=1}^p d_i \Delta X_{t-i} + \sum_{i=1}^p c_i \Delta Y_{t-i} + \gamma_2 \hat{\varepsilon}_{2t-1} + u_{2t} \end{aligned}$$

where $\hat{\varepsilon}_{1t-1}$ and $\hat{\varepsilon}_{2t-1}$ are the error correction terms obtained from the long-run model, which can be interpreted as the deviation of X and Y from their long-run equilibrium values, respectively. β_i measures the short-run impact of changes in Y on X , d_i measures the short-run impact of changes in X on Y and u_{it} is the standard error term.

In the generalized VAR model, [Granger \(1969\)](#) test for investigating short-run causality is applicable if there is no co-integration among the variables. On the contrary, if there exist significant co-integrating vectors then Engle and Granger test (1987) under an error correction framework should be applied. The present study adopts the Engle and Granger test (1987) based on VECM having the existence of co-integration. Under VECM the long-run causality is tested through its error correction term, whereas Block Exogeneity Wald Test is applied for gauging the short-run causality.

For a more comprehensive estimation of the relationship between the variables, this study applies the variance decomposition test (VDT) and impulse response analysis (IRF). The VDT is used to determine the degree of endogeneity or exogeneity of the variables used in the model. Again, IRF is used to forecast the responses of a variable for future periods having an impulse is put to the VAR system. Therefore, by using the IRF and VDT the study confirms the degree, direction and time length for the variables are responded to.

Analysis and findings

The descriptive statistics of the variables are calculated and presented in the first phase of the study. The summary statistics such as central tendency, dispersion and normality provide a historical background for the nature and behavior of the data used in the study. From the summary statistics presented in [Table 1](#), it is observed that both the variables i.e.

Statistics	Oil price	BSE_Energy
Mean	67.85406	2,739.536
Median	65.54000	2,546.350
Maximum	133.9300	5,280.380
Minimum	23.57000	953.9000
Standard deviation	22.46325	960.3988
Skewness	0.295953	0.757217
Kurtosis	2.598426	3.096254
Jarque-Bera test statistics	3.730528	16.79106
Probability	0.154855	0.000226

Table 1.
Descriptive statistics

Source: Authors calculation

oil price and BSE Energy index considered in the study are not stable at all during the study period.

During the study period, both the variables are found to be very high and significant variability from their mean. In respect of oil price, the maximum value of \$133.93 per barrel and minimum value of \$23.57 per barrel is found with an average of \$67.85 per barrel, which justifies its instability during the study period. The high value of standard deviation (22.46) also confirms the instability in this regard. During the study period, the BSE Energy indices also have very high and significant variability from their mean. The high difference between the maximum index (5,280.38) and minimum index (953.9) reveals that the Energy stock indices are also highly unstable during this period. However, values of the data series lie within $\bar{X} \pm 3\sigma$, where, \bar{X} and σ represent mean and standard deviation, respectively.

Findings from the long-run analysis

The study applies Johansen's co-integration test, after the fulfillment of the preconditions of applying the test, to determine the long-run comovement between the variables.

Results of unit root test. The study applies ADF and PP tests for determining the stationarity property of the variables. The unit test results reported in the tables (Tables 2 and 3) advocate that oil price and BSE Energy indices are non-stationary in level due to acceptance of the null hypothesis of having unit root. However, from the results of the ADF test and PP test of oil price and BSE Energy index, in its first difference, for the two models Intercept and Trend and Intercept, shows that oil price and BSE Energy index are stationary at their first difference i.e. the variables are integrated of order one I(1).

Selection of optimum lag length. As mentioned earlier the VAR model is sensitive enough with the appropriate lag length, so the study needs to determine the appropriate lag before going to analyze further through VAR. Notably, the Akaike Information Criteria (AIC),

Variables	Level		First difference		Result
	Intercept	Trend and intercept	Intercept	Trend and intercept	
Oil price	-2.599017 (0.0953)	-2.958509 (0.1474)	-8.266023 (0.0000)	-8.263741 (0.0000)	I(1)
BSE_Energy	-1.333955 (0.6131)	-2.211946 (0.4794)	-13.05550 (0.0000)	-13.01594 (0.0000)	I(1)

Notes: I(1): Stationary after first difference; 0 MacKinnon (1996) one-sided p-values

Source: Authors calculation

Table 2.
Results of the ADF
unit root test

XIMB

Schwarz Information Criteria (SIC), as well as the Hannan-Quinn Information Criteria (HQC) are suggesting the same optimum lag and it is two having the lowest values for each of the three selection criteria (Table 4).

Results of the Johansen cointegration test. As oil price and BSE Energy index have fulfilled all preconditions including unit root property, the study precedes Johansen cointegration test to know whether these variables have a long-term common stochastic trend.

The calculated values of Trace Statistics (Table 5) and Maximum Eigen Statistics (Table 6) of the Johansens Cointegration test, when the null hypothesis is $r = 0$ (i.e. no cointegration), are 18.28 and 17.96, respectively. Here, both are rejected at a 5% level of significance. This indicates the existence of a cointegrating vector between oil price and the BSE Energy index. So, Johansen's cointegration test result depicts that international crude price and BSE Energy index are cointegrated and there exists a long-run co-integrating relationship. The long-run cointegrating equations are-

Table 3.
Results of PP unit root test

Variables	Level		First difference		Result
	Intercept	Trend and intercept	Intercept	Trend and intercept	
Oil price	-2.246228 (0.1910)	-2.554856 (0.3017)	-8.266023 (0.0000)	-8.263741 (0.0000)	I(1)
BSE_Energy	-1.333955 (0.6131)	-2.201612 (0.4851)	-13.06242 (0.0000)	-13.02234 (0.0000)	I(1)

Notes: I(1): Stationary after first difference; () MacKinnon (1996) one-sided p -values
Source: Authors calculation

Table 4.
VAR lag order selection criteria

Lag length	AIC	SIC	HQC
0	25.25053	25.28997	25.26655
1	20.00431	20.12263	20.05237
2	19.80821*	20.00541*	19.88831*
3	19.82656	20.10265	19.93871
4	19.84150	20.19647	19.98569
5	19.88247	20.31632	20.05869
6	19.92142	20.43415	20.12969
7	19.91314	20.50475	20.15345
8	19.93331	20.60380	20.20566

Note: * Indicates optimum lag order selected by the criterion
Source: Authors calculation

Table 5.
Results of Johansen cointegration test (trace statistics)

H_0	H_1	Trace statistics	5% critical value	Probability*
$r = 0$	$r = 1$	18.28000	15.49471	0.0185
$r \leq 1$	$r = 2$	0.317736	3.841466	0.5730

Note: *MacKinnon-Haug-Michelis (1999) p -values
Source: Authors calculation

$$\text{BSE_Energy} = 7244.216 - 64.53337 \text{ Oil Price}_{[t=4.15587]} + \mu_t$$

$$\text{Oil Price} = 112.2553 - 0.015496 \text{ BSE_Energy}_{[t=2.13803]} + \mu_t$$

From the cointegrating equations stated above, the study infers that there is a significantly negative relationship between the BSE Energy index and Oil Price i.e. they move in the opposite direction, as the t -values associated with the coefficient in each cointegrating equation is significant at the 5% level of significance.

Findings from the short-run analysis

Having established that both, international crude price and Indian energy stock index, are co-integrated, the study proceeds further for VECM to identify the dynamism between the variables in a comprehensive way.

Result of the vector error correction model. In Table 7, the study presents the results of the VECM which depicts the t -values associated with the coefficients of both the lag values of the Oil Price are positive and statistically significant when BSE Energy is used as a dependent variable, which indicates that the Oil Price has a significant and positive impact on the Energy stock prices in the Indian Stock Market. Besides, the short-run dynamic results considering BSE Energy as an independent variable also confirms that BSE Energy is impacted positively by Oil price only in the first lag. The results of VECM also pointed out that both the BSE Energy index and the international Crude Price per barrel corrects the previous periods' disequilibrium significantly and in the right direction having significant and expected negative t -values (-3.75466 and -2.59997, respectively). The coefficients of error correction term (ECT) -0.037981 are significant at the 1% level when the BSE Energy index is considered as the dependent variable. Further, the coefficient of ECT is also significant at the 1% level considering Oil Price is a dependent variable. These values

Table 6.
Results of Johansen
cointegration test
(maximum Eigen
statistics)

H_0	H_1	Maximum Eigen statistics	5% critical value	Probability*
$r = 0$	$r = 1$	17.96226	14.26460	0.0124
$r \leq 1$	$r = 2$	0.001996	3.841466	0.5730

Note: * MacKinnon-Haug-Michelis (1999) p -values

Source: Authors calculation

Table 7.
Results of the VEC
model

Independent variables	Dependent variables	
	BSE_Energy	Oil price
ECT (-1)	-0.037981*** [-3.75466]	-0.00793*** [-2.59997]
D(BSE_Energy (-1))	-0.101757 [-1.28673]	0.005151** [2.16047]
D(BSE_Energy (-2))	-0.105690 [-1.31278]	-0.001389 [-0.57222]
D(oil price (-1))	4.420256* [1.64119]	0.373086*** [4.59493]
D(oil price (-2))	4.903409* [1.82352]	0.088186 [1.08786]
C	26.60736* [1.72106]	-0.085305 [-0.18303]

Notes: *** Significant at 1% level; ** Significant at 5% level; * Significant at 10% level; [] t -values

Source: Authors calculation

indicate the rates at which they correct the disequilibrium of the previous period. Thus, the speed of adjustment is almost 38% and 0.8% per month toward the long-run equilibrium.

As the diagnostic tests, the study estimates the serial correlation, normality and the heteroscedasticity test to ensure the correct model specifications and robust results. The diagnostic tests result is presented in Table 8.

The result of the serial correlation test of VECM residuals shows that they are not serially correlated, as the null hypothesis of “no serial correlation” in the residuals is not being rejected. Again, the result is shown in Table 8 (last column) indicates no heteroscedasticity problem in the concerned model because the underlying null hypothesis of “no heteroscedasticity” is not rejected. But, somehow at odd, the result of the Jarque-Bere test advocates the model residual is found to be non-normal. Though the errors do not follow a normal distribution but looking at the theoretical consistency and aptness of the concerned model, it is logical to ignore this issue as the analysis considers a lengthy data series. Besides, the normality problem does not always signify the non-viability of the model used and there may some other factors which significantly influence the pattern of the relationship (Geamanu, 2014). A bunch of other unobserved determinants may influence the oil price and energy stock price relationship.

The cumulative sum of recursive residuals (CUSUM) test is estimated to test the stability of the estimated coefficients. The results of the CUSUM test depicted in Figure 1 suggest that at a 5% level of significance the parameters of the model are stable over the period of the study. So, this part of the investigation ensures the acceptability of the model and the robustness of the results.

VEC residual of	Serial correlation (A)	Normality (B)	Heteroscedasticity (C)
Oil price and BSE_Energy	2.082386 (0.1184)	30.32244 (0.000000)	1.410049 (0.1669)

Table 8.
Diagnostic tests results

Notes: (A) On the basis of Lagrange multiplier test; (B) using Jarque-Bera normality test; (C) applying white Heteroscedasticity test; () probability values

Source: Authors calculation

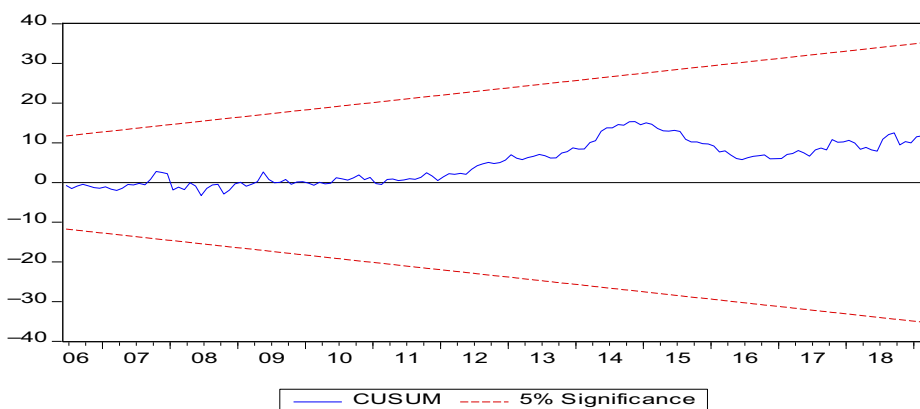


Figure 1.
Plot of cumulative sum of recursive residuals

Source: Prepared by Authors

Findings from the causality test

As the variables are cointegrated, the standard Granger test is misspecified and the error correction mechanism suggested by Engle and Granger (1987) is estimated to establish the long-run and the short-run causal relationship between the variables. The result of the long-run and the short-run causality tests under the VECM framework are reported below:

Long-run causality. The *t*-values associated with the error correction terms of VECM, reported in Table 7 indicate the existence of significant bi-directional long-run causality. The coefficients of the error correction term -0.037981 and -0.00793 are statistically significant at the 1% level which indicates that fluctuation in international oil price influences the BSE Energy indices and conversely, BSE Energy indices Shocks cause oil price fluctuations in long-run.

Short-run causality. The results of the short-run causality test between the variables based on the VEC Granger Causality test are reported in Table 9.

According to the obtained results, it can be documented that there also exists a unidirectional short-run causal relationship between oil price and BSE Energy index and the direction shows from oil price to BSE Energy index but not the vice-versa.

Results of variance decomposition test and impulse response function analysis

Finally, the study estimates the VDT and IRF under the VECM framework to determine the dynamic relationship between the international crude price fluctuation and the movement of the Indian energy index. Table 10 indicates that international oil price is strongly exogenous because almost 96% of its variance is explained by its own innovation even after 24 months i.e. two years and in this way, innovation in the international oil price itself remains the main driver behind its ripples, while the explanatory power of BSE Energy index is found insignificant. A very small portion, nearly 4%, of the forecast error variance of international oil price is explained by the BSE Energy index at the end of said time horizon in the future. The results also depict that in the very short period or initially the BSE Energy index behaves as strongly exogenous, but it gradually loses the explanatory power to forecast its own error variance and becomes strongly endogenous at the end of the 2nd year. Where, a significant portion, i.e. more than 46% forecast error variance of the BSE Energy index is explained by the international oil price.

The results of the impulse response analysis for a time horizon of 24 months to a one standard deviation shock in BSE Energy index and Oil price are shown in Figure 2. The responses generated from a positive shock of BSE Energy index to Oil price are initially positive for a very small period of time and after that, it shows a consistent and negative in the future periods. However, the responses in the reverse case i.e. for a positive shock of Oil price to BSE Energy index are found to be the same as in the previous results, but here almost nine months it affects positively and thereafter these remain negative for the rest of time horizon.

Dependent variables	Independent variables	Chi-square value	Probability value	Implication
BSE_Energy	Oil price	8.651258	0.0132	Causality exists
Oil price	BSE_Energy	5.325092	0.0698	No causality

Source: Authors calculation

Table 9.
Result of VEC
Granger causality/
block exogeneity
wald test

Variables	Period	Percentage of forecast error variance explained by innovation in:	
		BSE_Energy	Oil price
BSE_Energy	1	100.0000	0.000000
	3	98.99788	1.002122
	6	98.95095	1.049055
	9	94.13499	5.865012
	12	84.24080	15.75920
	15	73.84445	26.15555
	18	65.23620	34.76380
	21	58.63380	41.36620
	24	53.62835	46.37165
Oil price	1	2.340716	97.65928
	3	4.923344	95.07666
	6	3.785380	96.21462
	9	3.027289	96.97271
	12	2.791908	97.20809
	15	2.956510	97.04349
	18	3.346642	96.65336
	21	3.835771	96.16423
	24	4.353888	95.64611

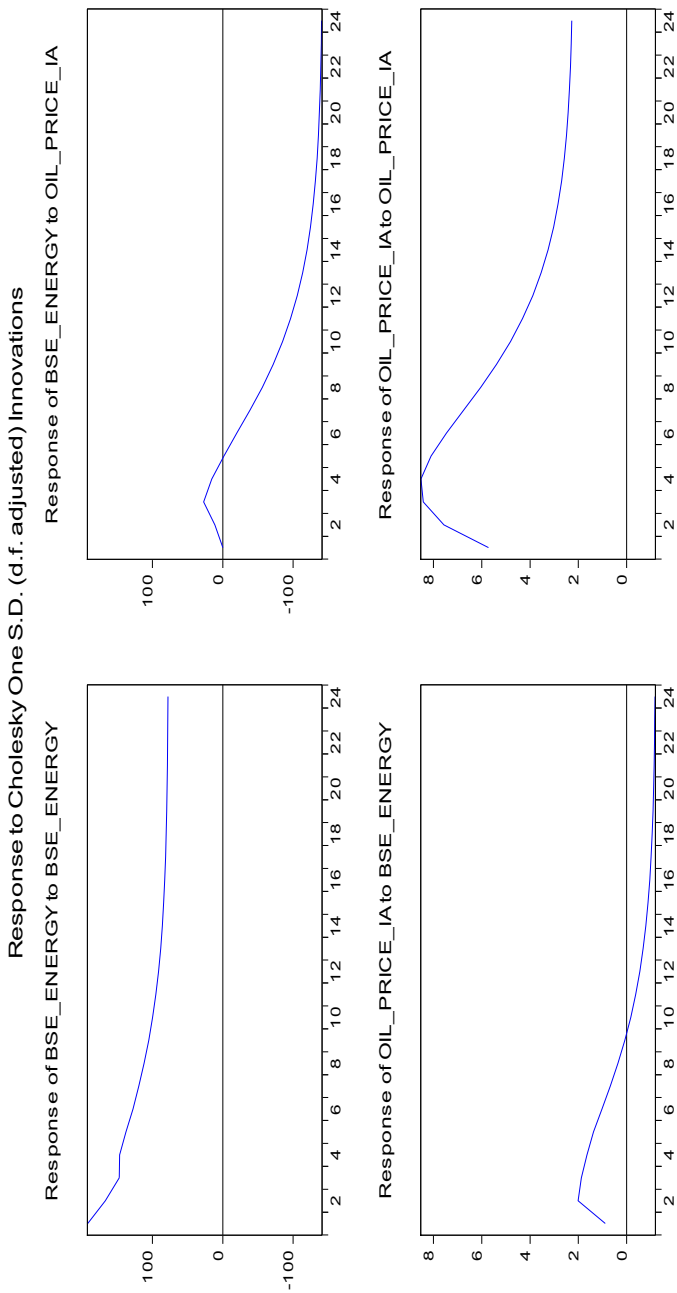
Table 10.
Result of variance decomposition analysis

Source: Authors calculation

Summary and conclusion

The study investigates the cointegrating relationship between crude oil price and Indian stock prices in the form of the BSE Energy index using a time-varying parameter model with vector autoregressive specification during the period September 2005 to March 2020. This present study in the long-term exhibits the presence of a cointegrating association between the two variables. From the cointegrating equation and the forecast results, backed by the impulse response it is clear that in the long-run BSE Energy stock indices are affected negatively through the global oil price changes. According to the theoretical proposition, an increase in the oil price, directly and indirectly, influence various macro-economic factors of India, as well as its stock market. Being the oil importer country, the rise in crude oil price may have an adverse impact on the economy through an increase in the volume of fiscal deficit, fan the cost-push inflation and degrade the Indian currency and many other phenomenons. Besides these factors, a hike in the international crude price leads to an increase in the government subsidy burden due to the price goes up of imported items. However, persisted inflation lessens the value of the Indian rupee by enhancing the trade deficit and thereby increases the cost of imported oil prices (Ghosh and Kanjilal, 2016). Also, in the long-run due to the deregulation of the price of crude oil products, mainly petrol and diesel, by the government (which accounts for 52% of petroleum products consumption in the year 2017–2018) Indian firms are directly exposed to the International oil price fluctuation. In this way, in the long-run, the international crude price fluctuations impacted the Indian Energy stock prices.

However, in the short-run, the study surprisingly finds that the increase of the international oil prices causes the rise of BSE Energy indices but the reverse is not true i.e. Indian stock indices do not exert any impact on the global oil prices it means oil price acts exogenously. This result is supported by the Granger causality, VECM results and even



Source: Prepared by Authors

Emerging stock market volatility

Figure 2. Impulse responses of BSE_Energy and oil price to one standard deviation shocks in the variables

variance decomposition results. Besides this, the short-run dynamics between oil price and BSE Energy does not match with the empirical findings of the long-run. This is most likely due to the fact that fluctuations in the oil price encourage speculations, which may cause share prices to rise. Another way, the higher crude oil prices are driven by the global business cycle expansion, it also stimulates the stock returns to move in the same direction. Furthermore, the impact of the rise in international crude oil prices does not get directly transmitted to the stock prices by showing an adverse effect on the profitability of energy traded firms in India in the very short period, as the Indian subsidize oil price policy makes these firms comparatively competent (internationally).

Hence, the originality of the study lies in the reverse relationship that we find in the short-run and long-run due to the policy of price subsidization and further deregulation of the oil market by the government. It is an important factor to determine the relationship between oil price and stock price, so policymakers, market regulators, oil marketing companies especially private sector companies are directed to take decisions considering the frequently changing policy matters. Finally, in this regard, the investors are also advised to give perusal attention to international crude oil price ripples before investing BSE Energy indices underlying securities. The government should introspect on double-edged sword crisis from a deeper perspective to decide whether the policymakers deregulate the oil prices and substantially reduce the fiscal deficit or griping the inflationary situation through strictly regulating oil prices.

Finally, while considering the Indian oil basket and BSE energy stock basket there is no denying the fact that each stock at the individual level will be able to translate the changes to forward prices and conversely, benchmark oil price fluctuation will derive energy stocks with different margins. Therefore, this macro-level study can be extended to firm-level investigation further in the future considering the forward trading concentration with the Indian oil basket.

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