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The Effect of Crude Oil Price on Economic Growth in India: A VAR Estimation of the Oil Price Volatility and Macroeconomic Performance

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Abstract: *Global as well as national economic growth crucially depends on crude oil and its price volatility invariably has macroeconomic repercussions including stock markets, inflation, interest rate and exchange rate. This paper analyses the effect of global crude oil price on Indian economy in an endogenous framework for 35 long years from 1981 to 2015. The causal long-run relationship between crude oil price and gross domestic product, gross capital formation and real effective exchange rate applying the vector autoregression estimation method. The time series diagnostic tests show no stable long-run relationships and no cointegration between the variables. The VAR estimates reveal that no significant effect of crude oil price on macroeconomic variables in India. Rather the crude oil price is significantly related with the lags of the macroeconomic variables. A significant proportion of variations in crude oil price is due to the shock in gross capital formation, besides its own shock. The crude oil price shock affects the Indian economy mostly in the initial few periods and the crude oil price volatility effect eventually becomes zero over time.*

Keywords: *Oil price, volatility, macroeconomic performance, VAR estimation.*

INTRODUCTION

Energy is an essential input in all production and many consumption activities. There are different sources of energy consumption such as coal, crude oil, natural gas, hydroelectric, solar, wind, and nuclear energy. All over the world, crude oil is the more crucial source of energy among all forms of energy and the world largest commodity market is the crude oil market. Crude oil is one of the highly demanded commodities in the entire world. Hence, any oil price shock is considered to destablise the growth of any economy. Paying for oil prices is the biggest need of every country and changes in oil prices impact substantially the fiscal balance of an economy. It is a well-known fact that crude oil is indispensable in facilitating the development of an economy and it is also evident that how volatile the prices of crude oil and petroleum in the global market are.

India is a rapidly developing economy with a steep rise in industrialisation and oil requirements is ever increasing. With a sharp rise in economic activities, demand of crude oil is many times more than its limited supply. According to the International Energy Agency (IEA) the demand for oil in India is increasing by 2.9 percent per year. In India, in the total energy consumption, crude oil and coal account for about two-thirds of India's energy consumption - coal accounts of 40 percent, crude oil 24 percent, natural gas 6 percent, combustible renewable and waste 27 percent, hydroelectric power 2 percent, nuclear energy and wind energy about 1 percent each, and solar energy has an insignificant share. India had approximately 5.6 billion barrels of proven oil reserves by 2010, the second-largest reserves in the Asia-Pacific region after China. While accounting for more than 11 percent of the regional oil demand in 2012, India also provides 10.8 percent of supply. The western offshore has 43 percent of total 762.74 million tons of crude oil, followed by Assam 23 percent and Gujarat 18 percent.

India is one of the largest crude oil consumers but more than 70 percent of its crude oil requirements comes from imports. With an import of 4.1 million barrels per day (bpd) in 2015, about 4.5 percent of global imports, India is the third largest oil consumer in the world, after the United States (19.39 million bpd) and China (11.96 million bpd). Despite global financial crisis, India's energy demand continues to rise. The fact that crude oil is a non-renewable source of energy and that India is one of the highest energy dependent economy in the world, it is not a cause of surprise how volatile Indian economy is vulnerable to global oil shocks. The changes in price of crude oil has been a major cause for the rise in inflation rate as it greatly affects the prices of essential commodities and adversely affecting the common man.

With such a fundamental and significant dependence of economies on crude oil and its prices, the relationship between crude oil price and economic growth has received a plethora of theoretical and empirical research. Empirical studies analyse the impact of crude oil prices on many macroeconomic variables including economic growth, stock markets, inflation, interest rate and exchange rate (Finn, 2000; Hamilton, 2009). However, most studies focus largely on the US and other developed economies of the world. Studies also relate international crude oil price with other macroeconomic variables like inflation, stock prices, exchange rate and unemployment, and domestic oil prices.

In the Indian context also, studies examine the relationship between global crude oil price and its volatility and economic growth and other macroeconomic indicators of economic performance. However, the existing studies consider only few macroeconomic variables for short time periods. The study aims to contribute to this literature using more macro variables and long time periods. This study analyses the effect of global crude oil price on Indian economy in an endogenous framework for 35 long years from 1981 to 2015. The causal long-run relationship between crude oil price and gross domestic product, gross capital formation and real effective exchange rate applying the vector autoregression estimation method.

REVIEW OF LITERATURE

Abeysinghe (2001) examines the direct and indirect effects of oil price on GDP growth of I2 South East and East Asian economies during the period of l982Q1 to 2000Q4 using a VARX methodology. The estimated results of this exercise show that the transmission effect of oil prices on growth is significant in small open economies, compared to larger economies like the US. The actual working of oil shock depends on how it interacts with consumer and investor confidence just as they have seen during the Asian financial crisis.

Akram (2011) analyse the effect of crude oil price change on the Indian subcontinent (India, Pakistan and Bangladesh) for three decades from I981 to 2010 using a multivariate vector autoregressive analysis. The estimated results show that a decrease in crude oil price significantly affects only India's economic growth. During first year, the impact of crude oil price is significantly negative in all the three countries, negative in second year, smaller than first year for India, larger for Bangladesh and positive for Pakistan.

Arouri *et al.* (2012) examine the relationship between oil prices and stock markets in six Gulf Corporation countries during the period from June l, 2005 to December 31, 2009 using autoregressive distributed lags model. The empirical results show strong causal linkages in the short-run with the impact direction running from oil to stocks, but no long-run links based on standard cointegration analysis. Stock returns are more sensitive to negative than to positive oil shocks.

Baghirov (2014) analyse the direct and indirect effects of an oil price shock on economic growth of Lithuania taking into consideration its trade linkages with seven main trade partners - Russia, Germany, Netherlands, France, Poland, Lithuania and Latvia - for the period 2nd quarter of 1995 to 4^{th} quarter of 2012 using structural VAR model. The empirical results indicate that though the direct effect of oil price shock on real GDP growth of Lithuania is negative, nearly 50 percent of the indirect effects are positive. The positive indirect effects through trade linkages mitigate the negative direct effects of oil price shock both in short and long runs.

Berna and Berk (2015) investigate the impact of crude oil price variations on the Turkish stock market returns for the period between January 2, I990 and November l, 2011 employing vector autoregression model. using daily observations of Brent crude oil prices and Istanbul Stock Exchange National Index (ISE-100) returns. The paper incorporates a proxy variable for global liquidity conditions, the Chicago Board of Exchange's (CBOE) S&P 500 market volatility index (VIX), in the relationship between oil prices and stock market returns. The variance decomposition test results suggest little empirical evidence that crude oil price shocks have been rationally evaluated the Turkish stock market. Rather it was global liquidity conditions that were found to account for the greatest amount of variation in stock market returns.

In India, Bhattacharyya and Bhattachrya (2001) study the transmission mechanism of an increase in petroleum prices on the prices of other commodities and output for the period April I994 to December 2000 using VAR model. The nature and the extent of 'feedback' in such a transmission mechanism shows evidence of bidirectional causality between oil and non-oil inflation in India. Bhattacharjee (2013) analyse the impact of crude oil price on inflation during the period 2000-2009. The study shows that crude oil price is a significant factor in rising the wholesale price index. Jain (2013) examines the effect of crude oil price on stock prices and inflation in India during 2007-2013. The study finds that there exists a significant positive relationship between crude oil price and inflation and the stock prices are also affected by changes in the crude oil price.

Bhattacharya and Batra (2009) examine the differential impact of international oil prices on domestic inflation and output growth in India for the period 1991-2007 using structural vector autoregressive model under two alternative scenarios. One scenario is, when domestic fuel prices are allowed a formula-based automatic alignment with international oil prices and the second, when as per current policy, fuel prices evolve as a consequence of revisions specified periodically by the government. The differential impact analysis reveals symmetric results implying oil prices do not have an impact on oil consumption in any significant manner in India.

The empirical studies in the Indian context show that crude oil price plays a significant role in the Indian economy, reducing economic growth, rising the wholesale prices, and affecting the stock market and macro variables. The studies also show confiicting directional relationship between oil price and macro variables.

DATA AND METHODOLOGY

This study uses annual time series data for 35 years for India from 1981 to 2015. The data are collected from various secondary sources. The data on

GDP per capita and gross capital formation at constant 2011 in US dollars, used as a proxy for economic growth, are taken from the International Financial Statistics of IMF. The data on crude oil price in India has been taken from the OECD National Accounts. The real effective exchange rate in India has been collected from the World Bank, Eurostat, Bank of International Settlement and OECD. The annual exchange rate has been used to convert crude oil price in terms of Indian rupees.

Stationary Test: The stationarity of time series data is to be checked before using it for analysis. A time series is non-stationary if its first three moments - mean, variance and covariance - are not constant. If time series is not stationary, then it moves away from its mean value, whereas if a series is stationary then it comes back to the mean after fluctuations. In a non-stationary series unit root present while a series where no unit root is present is said to be stationary. The presence of unit root in a series leads to spurious regression. Non-stationary data can be made stationary by differencing it, may be more than once. Therefore, the hypothesis for testing stationarity of a time series is the presence of a unit root. Formal graphical scatter plot of the time series gives an initial idea about the likely nature of time series. Further plots of the autocorrelation and partial autocorrelation functions, the correlogram, to some specified order of lags also reveal the pattern of temporal dependence in the series.

A statistical test of the presence of unit root in a time series is the Dickey-Fuller test. The standard Dickey-Fuller test is carried out by estimating a simple AR (l) process of a time series y_t:

$$y_t = \rho y_{t-1} + \delta x_t + \varepsilon_t \quad (1)$$

where x_t are optional exogenous regressors consisting of constant or a constant and trend, and are parameters to be estimated, ε are assumed to be white noise. Subtracting y_{t-1} from both sides, the differenced equation is:

$$\Delta y_t = \alpha y_{t-1} + \delta x_t + \varepsilon_t \quad (2)$$

where $\alpha = \rho - 1$. Adding p more lagged difference terms, the AR(p) process is given by:

$$\Delta y_t = \alpha y_{t-1} + \delta x_t + \beta_1 \Delta y_{t-1} + \beta_2 \Delta y_{t-2} + \ldots + \beta_p \Delta y_{t-p} + \varepsilon_t \quad (3)$$

where p is the lag order of the autoregressive process and β are coefficients of lagged differenced terms. The null hypothesis and alternative hypothesis of the ADF test are:

H0: $\alpha = 0$, unit root present

H1: $\alpha < 0$, unit root absent

The significance of α is evaluated with the conventional t-test.

Optimal Lag Length: The determination of optimal lag length of variables for further analysis like cointegration test and VAR is based on criteria like likelihood ratio, sequential modi?ed LR, Final Prediction Error (FPE), Akaike information criterion (AIC), Bayesian information criterion (BIC), Schwarz information criterion (SIC) or Hannan-Quinn information criterion (HQ). Generally, the optimal lag length for which the values of most of these lag length criteria are minimised is chosen.

Cointegration Test: When all the variables in the data set are stationary of same order, then the cointegration test is applied to check if there is long-run correlation or equilibrium relationship between the series of variables leading to spurious regression. The series are said to be cointegrated if they have unit root present individually in each of them and their combination has lower order of integration (Engle and Granger, 1987). The cointegration is defined as:

$$\beta y_t = z_t \sim I(d - c) \tag{4}$$

The elements of a n-dimensional vector y are cointegrated of order (d, c) i.e. $y \sim CI(d - c)$ if all elements of y are integrated of order d, I(d) and if there exists at least one non-trivial linear combination z of these variables, which is I(d-c) where $d > c > 0$ holds. The vector ? is the cointegration vector. The cointegration rank r is equal to the number of linearly independent cointegration vectors. If all variables are $I(1)$, it holds that $0 \le r \le k$. For $r = 0$, the elements of vector y are not cointegrated, and the appropriate model is a system of first differences.

The Johansen test tests the cointegrating relationships between several non-stationary time series data. It allows for more than one cointegrating relationship. The autoregression of AR (p) process of the vector y can be specified as:

$$\Delta y_t = \Psi y_{t-1} + \Sigma_{i=1}^{p-1} \Lambda_i \, \Delta y_{t-i} + \delta x_t + \varepsilon_t \tag{5}$$

where $$\Psi = \Sigma_{i=1}^{p} \beta_i - I \quad and \quad \Lambda_i = -\Sigma_{j=i+1}^{p} \beta_j \tag{6}$$

The Johansen test procedure uses two tests to determine the number of cointegrating vectors: the maximum eigen value test and trace test. The maximum eigen value statistics tests the null hypothesis of r cointegrating relations against the alternative of $r + 1$ cointegrating relations for $r = 0, 1, 2 \ldots n - 1$. This test statistics are computed as:

$$LR_{max}\,(r \mid r + 1) = -\,T \ln\,(1 - \lambda_{r+1}) = LR_{tr}\,(r \mid k) - LR_{tr}\,(r + 1 \mid k) \tag{7}$$

The Trace statistic investigate the null hypothesis of *r* cointegrating relations against the alternative of *n* cointegrating relations, where n is the number of variables in the system for $r = 0, 1, 2, \ldots, n-1$. The trace statistic for the null hypothesis of r cointegrating relations is computed as:

$$LR_{tr}\,(r \mid k) = -\,T\,\Sigma_{i=r+1}^{n} \ln(1-\lambda_i) \tag{8}$$

In both cases, T is the sample size and λ_i is the i-th largest eigen value of the Ψ. If the variables are cointegrated i.e. there is a long run relationship, the Vector Error Correction Model (VECM), and if the variables are not cointegrated, the Vector Autoregression Model (VAR) is applied in the estimation.

Causality Test: When the variables are cointegrated i.e. if there is a long run relationship between the variables, then the nature of relationship i.e. direction of causality need to be tested. Whether there exists unidirectional causality i.e. *x* affects *y* or *y* affects x or bidirectional causality i.e. both influencing each other is to be identified. As Granger (1987) suggests that a variable *x* is said to cause another variable *y* if past values of *x* help predict the current level of *y* given all other appropriate information. Similarly, if *y* in fact causes *x*, then given the past history of *y*, it is unlikely that information on *x* will help predict *y*. The Granger causality approach allows determining the direction of the short-run relations between the variables. Given the two series yt and xt, both are regressed on their own lags:

$$y_t = \alpha_0 + \Sigma_{i=1}^{p}\, \alpha_i y_{t-1} + \Sigma_{j=1}^{p}\, \alpha_j\, x_{t-1} + u_{1t} \tag{9}$$

$$x_t = \gamma_0 + \Sigma_{i=1}^{p}\, \gamma_i y_{t-1} + \Sigma_{j=1}^{p}\, \gamma_j\, x_{t-1} + u_{2t} \tag{10}$$

where *p* is the number of lags that adequately models the dynamics and the error terms are white noise.

The null hypothesis for this test is that the variables do not Granger causes each other i.e. unidirectional causal relationship and the alternative hypothesis is that they Granger causes each other i.e. bidirectional causal relationship between *y* and *x*. If the sets of *x* and *y* coefficients are not statistically significant in both the regressions, then the test suggests independence of the variables. Conversely, unidirectional causality from x to y is indicated if the estimated coefficients on the lagged x are statistically different from zero as a group i.e. $\Sigma\alpha_i \neq 0$ and the set of estimated coefficients on the lagged *y* is not statistically different from zero i.e. $\Sigma\alpha_j = 0$. On the other hand, unidirectional causality from *y* to *x* exists if the set of lagged *x* coefficients is not statistically different from zero i.e. $\Sigma\gamma_i = 0$ and the set of the lagged *y* coefficients is statistically different from zero i.e. $\Sigma\gamma_j \neq 0$.

Vector Auto Regression (VAR) Model

The VAR approach sidesteps the need for structural modeling by treating every endogenous variable in the system as a function of the lagged values of all of the endogenous variables in the system. If the series are integrated of order one i.e. I(I), the VAR model can be specified as:

$$\begin{aligned} GDP_t &= a_{10} + a_{11}\, COP_{t-1} + a_{12}\, GDP_{t-1} + a_{13}\, GCF_{t-1} + a_{14}\, REER_{t-1} + \varepsilon_{1t} \\ COP_t &= a_{20} + a_{21}\, COP_{t-1} + a_{22}\, GDP_{t-1} + a_{23}\, GCF_{t-1} + a_{24}\, REER_{t-1} + \varepsilon_{2t} \\ GCF_t &= a_{30} + a_{31}\, COP_{t-1} + a_{32}\, GDP_{t-1} + a_{33}\, GCF_{t-1} + a_{34}\, REER_{t-1} + \varepsilon_{3t} \\ REER &= a_{40} + a_{41}\, COP_{t-1} + a_{42}\, GDP_{t-1} + a_{43}\, GCF_{t-1} + a_{44}\, REER_{t-1} + \varepsilon_{4t} \end{aligned} \quad (11)$$

where the errors are white noise. The VAR model in terms of matrix notation is stated as:

$$\begin{bmatrix} COP_t \\ GCF_t \\ GDP_t \\ REER_t \end{bmatrix} = \begin{bmatrix} a_{10} \\ a_{20} \\ a_{30} \\ a_{40} \end{bmatrix} + \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ a_{31} & a_{32} & a_{33} & a_{34} \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix} \begin{bmatrix} COP_{t-1} \\ GCF_{t-1} \\ GDP_{t-1} \\ REER_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \\ \varepsilon_{4t} \end{bmatrix} \quad (12)$$

The estimation is by OLS as the lagged values of the variables are exogenous and the coef?cients are the marginal effects.

Impulse Response and Variance Decomposition: The VAR results are augmented by the impulse response function (IRF) and the forecast error variance decomposition (FEVD). The IRF shows the persistence of the impact of a unit shock or innovation in one variable on other variables in the system and FEVD shows the proportion of forecast error variance in one variable elucidated by innovations or shocks in itself and that of other variables in the system. The impulse responses give the direction of the movement of each endogenous variable in the system with respect to the shock in each other variables including the variable itself. The variance decomposition shows the dynamic linkage between all variables of the system decomposing the variation in an endogenous variable into the component shocks to the VAR. It gives the percentage change of the forecast error variance in one variable with innovation in that variable and shocks to other variables. As n increases, the variance decompositions should converge.

Empirical Analysis

The Table 1 presents the descriptive statistics of the variables used to study the relationship between crude oil price, gross domestic product, gross capital formation and real effective exchange rate. The variables are transformed into natural log values in order to eliminate the impact of heteroskedasticity in the data sets.

Table 1
Descriptive Statistics of the Variables

Variable	*Description*	*Mean*	*Std. dev.*
ln(COP)	Spot price of oil by Texas Intermediate / Brent Blend (US dollars per barrel)	3.894	0.531
ln(GCF)	Outlays on additions to the fixed assets of the economy plus net changes in the level of inventories (at constant 2010 US dollars)	7.626	0.845
ln(GDP)	Gross domestic product per capita (at constant 2005 US dollars)	6.628	0.445
ln(REER)	Weighted average of exchange rate of Indian rupee to US dollar, adjusted for the effects of inflation (US dollars)	4.693	0.245

Stationarity Test: The correlogram and ADF test to test the stationarity of variables are used. The graphical plots in Figure 1 shows upward trend

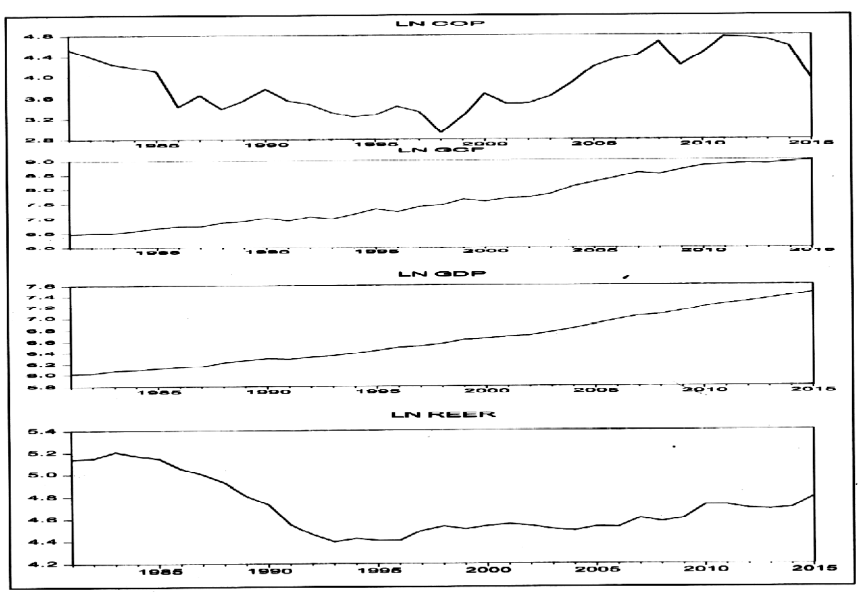

Figure 1: Graphical Plots of COP, GCF, GDP and REER

of all variables indicating that the mean is varying over time, implying that the time series are not stationary at levels.

Correlogram: The correlogram of the first differenced series are shown in Figure 2. The dotted lines in the plots of the autocorrelations and partial autocorrelation are the approximate two standard error bounds. The solid vertical line in autocorrelation column represents the zero axis, the observations above the line are positive and below the line are negative values. The rule of thumb is to compute autocorrelation and partial autocorrelation up to one-third to one-quarter the length of time series. As the time frame of this is study the 35 years, by rule lags 10-13 will do. The autocorrelation coefficient starts at small values and decline quickly showing that each series has become stationary after the difference.

LN_COP at 1st Difference

Sample: 1981 2015
Included observations: 34

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.02...	-0.02...	0.0168	0.897
		2	-0.06...	-0.06...	0.1743	0.917
		3	0.118	0.116	0.7241	0.868
		4	-0.05...	-0.05...	0.8302	0.934
		5	0.094	0.109	1.2000	0.945
		6	0.190	0.177	2.7790	0.836
		7	-0.04...	-0.01...	2.8714	0.897
		8	0.006	0.005	2.8728	0.942
		9	-0.11...	-0.15...	3.5109	0.941
		10	-0.11...	-0.11...	4.1629	0.940

LN_GCF at 1st Difference

Sample: 1981 2015
Included observations: 34

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.29...	-0.29...	3.1726	0.075
		2	0.241	0.169	5.3850	0.068
		3	-0.05...	0.059	5.5050	0.138
		4	-0.06...	-0.11...	5.6740	0.225
		5	0.174	0.147	6.9576	0.224
		6	-0.11...	0.004	7.5059	0.277
		7	0.094	-0.00...	7.9104	0.341
		8	-0.24...	-0.22...	10.633	0.223
		9	0.102	0.011	11.146	0.266
		10	-0.01...	0.098	11.151	0.346

LN_GDP 1st Difference

Sample: 1981 2015
Included observations: 34

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.251	0.251	2.3417	0.126
		2	0.152	0.094	3.2197	0.200
		3	0.045	-0.01...	3.3001	0.348
		4	0.207	0.200	5.0455	0.283
		5	0.185	0.104	6.4930	0.261
		6	0.150	0.049	7.4725	0.279
		7	0.194	0.146	9.1871	0.239
		8	0.035	-0.08...	9.2452	0.322
		9	0.107	0.051	9.8009	0.367
		10	0.110	0.058	10.413	0.405

LN_REER 1st Difference

Sample: 1981 2015
Included observations: 34

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.471	0.471	8.2111	0.004
		2	0.355	0.171	13.028	0.001
		3	0.308	0.118	16.778	0.001
		4	0.215	0.001	18.658	0.001
		5	0.162	0.003	19.767	0.001
		6	-0.10...	-0.30...	20.219	0.003
		7	-0.09...	-0.03...	20.646	0.004
		8	-0.13...	-0.05...	21.436	0.006
		9	-0.11...	0.063	22.068	0.009
		10	-0.01...	0.159	22.081	0.015

Figure 2: Correlogram of COP, GCF, GDP and REER at First Difference

Augmented Dickey-Fuller Test: As per the ADF unit root test results presented in Table 2, the null hypothesis of presence of unit root cannot be rejected for all variables at levels i.e. all variables are non-stationary at levels. At first difference, the ADF test results show no unit root present i.e. all variables are stationary at first difference. Since the variables are stationary at first difference, the variables are integrated of order 1 i.e. I(l).

Table 2
Augmented Dickey-Fuller Unit Root Test

Variable	*At levels*		*At first difference*		*Order of integration*
	t-value	*Critical value*	*t-value*	*Critical value*	
ln(COP)	-1.725	-3.639	-5.230*	-3.646	I(1)
ln(GCF)	0.295	-3.639	-7.550*	-3.646	I(1)
ln(GDP)	-3.387	-3.639	-4.386*	-3.646	I(1)
ln(REER)	-1.997	-3.646	-3.951*	-3.646	I(1)

Note: * significant at 1 percent level.

VAR Lag Length: The lag order selection criteria presented in Table 3 suggests the optimal lag length of 1 for the VAR model on the basis of various selection criteria.

Table 3
Optimal Lag Length Criteria

Lag	*lnL*	*LR*	*FBF*	*AIC*	*SIC*	*HQ*
0	17.522	-	5.05e-06	-0.845	-0.662	-0.784
1	187.561	286.94*	3.36e-010*	-10.473*	-9.556	-10.169*
2	199.352	16.950	4.60e-010	-10.209	-8.561	-9.663
3	210.114	12.779	7.32e-10	-9.882	-7.500	-9.093

Note: * significant at 5 percent level.

Johansen Cointegration Test: The Johansen cointegration test to find the endogeneity among the pairs of variables are presented in Table 4 from which the appropriate model to be used, VECM or VAR, is identified. Both Trace statistics and Max-eigen value statistics indicate no cointegrating equation at 5 percent level and therefore the VAR model is estimated.

Granger Causality Test: The Granger causality test results presented in Table 5 show unidirectional causation between all variables. The lnGCF Granger cause lnCOP at 5 percent level of significance. Similarly, lnCOP

Table 4
Johansen Cointegration Test

Hypothesised no. of CE(s)	*Eigen value*	*Trace statistics*	*Max eigen statistics*
None	0.409	36.594 (0.367)	17.386 (0.547)
At most 1	0.322	19.208 (0.478)	12.828 (0.468)
At most 2	0.176	6.380 (0.650)	6.375 (0.566)
At most 3	0.0001	0.004 (0.949)	5.841 (0.949)

Granger cause lnREER at 5 percent level of significance and that lnGDP Granger cause lnCOP at 10 percent level of significance.

Table 5
Granger Causality Test

Lags 1	*F-statistics*	*Probability*	*Causation*
lnGCF does not Granger cause lnCOP	4.344	0.045	1 way causation at 5 percent level
lnCOP does not Granger cause lnGCF	0.789	0.381	
lnGDP does not Granger cause lnCOP	3.066	0.089	1 way causation at 10 percent level
lnCOP does not Granger cause lnGDP	0.723	0.402	
lnREER does not Granger cause lnCOP	0.915	0.346	1 way causation at 5 percent level
lnCOP does not Granger cause lnREER	6.690	0.014	

VAR Estimates: The estimating VAR equations are specified as:

$$\begin{aligned}
lnCOP_t &= a_{10} + a_{11}\, lnCOP_{t-1} + a_{12}\, lnGCF_{t-1} + a_{13}\, lnGDP_{t-1} + a_{14}\, lnREER_{t-1} + \varepsilon_{1t} \\
lnGCF_t &= a_{20} + a_{21}\, lnCOP_{t-1} + a_{22}\, lnGCF_{t-1} + a_{23}\, lnGDP_{t-1} + a_{24}\, lnREER_{t-1} + \varepsilon_{2t} \\
lnGDP_t &= a_{30} + a_{31}\, lnCOP_{t-1} + a_{32}\, lnGCF_{t-1} + a_{33}\, lnGDP_{t-1} + a_{34}\, lnREER_{t-1} + \varepsilon_{3t} \\
lnREER &= a_{40} + a_{41}\, lnCOP_{t-1} + a_{42}\, lnGCF_{t-1} + a_{43}\, lnGDP_{t-1} + a_{44}\, lnREER_{t-1} + \varepsilon_{4t}
\end{aligned} \quad (13)$$

The 4 variable VAR system expresses every endogenous variable as a function of the lagged values of all of the endogenous variables in the system VAR and uses first difference as all the variables are stationary at first difference with the lag length of 1. The VAR estimates of crude oil price, presented in Table 6, shows the coefficients of COP(-1), GCF(-1) and GDP(-1) are significant at 1 percent level. For GCF, GDP and REER, the coefficients of their own lags only are significant at 1 significant level. The elasticity of crude oil price with respect to previous year price is about half a point, 0.56

dollar increase in current year crude oil price, while the effect of an increase in the lagged gross capital formation and gross domestic product on current year crude oil price is an increase of 1.63 dollars and decreases of 2.70 dollars respectively. Though the effect of REER(-1) on COP is positive, it is not statistically significant. The elasticity of GCF with its own lag GCF(-1) is about 0.78, the effect of lagged GDP(-1) on current GDP is 0.95, while an increase in the previous year exchange rate REER(-1) increases current exchange rate to 0.89 dollars. Over all, the VAR estimates suggest that the effect of crude oil price on the macro variables of India are insignificant.

Table 6
VAR Estimates of COP, GCF, GDP and REER

Variable	*lnCOP*	*lnGCF*	*lnGDP*	*lnREER*
$lnCOP_{t-1}$	0.561* (0.140)	0.007 (0.060)	-0.009 (0.012)	0.050 (0.036)
$lnGCF_{t-1}$	1.639* (0.494)	0.781* (0.211)	0.041 (0.044)	-0.131 (0.129)
$lnGDP_{t-1}$	-2.704* (0.937)	0.409 (0.399)	0.952*** (0.084)	0.258 (0,244)
$lnREER_{t-1}$	0.363 (0.285)	-0.077 (0.122)	0.001 (0.026)	0.894*** (0.074)
Constant	5.409*** (3.033)	-0.633 (1.293)	0.067 (0.272)	-0.418 (0.788)
R-square	0.849	0.989	0.998	0.951

Note: standard errors in parentheses. *, **, *** significant at 1, 5, 10 percent levels.

Stability of VAR Model: The stability of the VAR model has been tested using the inverse roots of AR polynomial graph. The VAR model is stationary if all roots of the characteristic AR polynomial have absolute value less than one and lies outside the unit circle. There should be (number of variables)*(number of model lags) roots visible on the graph. Therefore, in the inverse roots of AR polynomial all the roots should lie inside the unit root circle. The points in Figure 3 are the inverse roots of the VAR model and all roots are inside the unit circle, suggesting that the model does not suffer from the problem of autocorrelation or heteroskedasticity. Therefore, the VAR model is stable and stationary and has finite and time invariant mean and variance.

Impulse Response: The dynamic causality analysis is analysed through impulse response functions (IRF) and are shown in Figure 4 for the period of l0 years. The IRF shows that for a one standard deviation shock given to COP, the own response (DlnCOP) is initially positive and then decreases up to period two and then becomes zero for following periods. The response of GCF to a one standard deviation innovation in COP is positive and then decreases, becomes zero in first period and declines gradually, then becomes

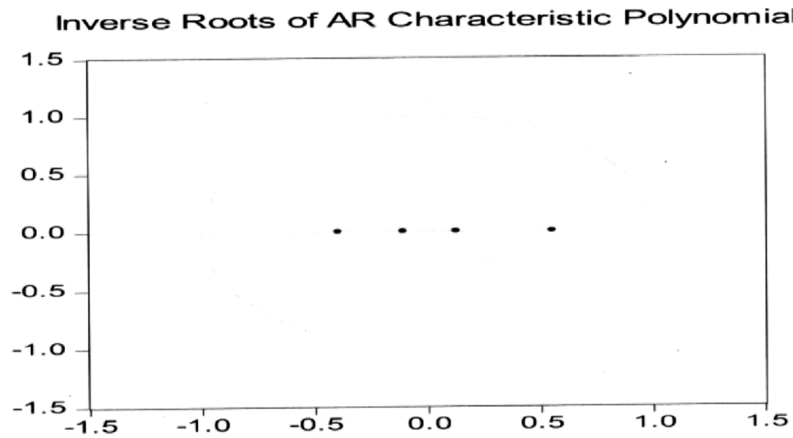

Figure 3: Inverse Root of AR Characteristic Polynomial

negative and then increases, becomes zero and remains same over the period. The response of GDP to shocks in COP is positive and becomes zero and declines to negative and remain zero for the following period. The response of REER to one standard deviation shock to COP is negative and decreases till second period then gradually increases and remains constant over rest of the period. The response of COP to one a one standard deviation shock to GCF is positive and increasing till third period and then gradually declines to zero and remain constant for rest of the period. The response GCF to its own shock is highly positive initially and steeply decreases to zero in second period and then becomes negative and again increases and becomes positive in fourth period then again becomes zero and remains constant for rest of the period. The response of GDP to its own innovation is positive and declining and becomes zero and remains constant after fourth period. The response of REER to its own a one standard deviation shock is highly positive and decreases gradually and fall to zero only over long period.

Variance Decomposition: The Table 7 and Figure 5 present the decomposition of forecast error variance of the VAR variables, indicating the amount of information each variable contributes to the other variables in the autoregression. In the first period, the entire variation in crude oil price is due to its own shock and the effects of innovations in other variables to oil price changes are zero. In the second period. nearly 81 percent variation of crude oil price is due to shock in own price fluctuations, 17 percent due to innovations gross capital formation, 1.3 percent fiuctuation in crude oil price is due to the impulse of gross domestic product, and only less than half a percent effect of shocks in REER on fiuctuations in crude oil price.

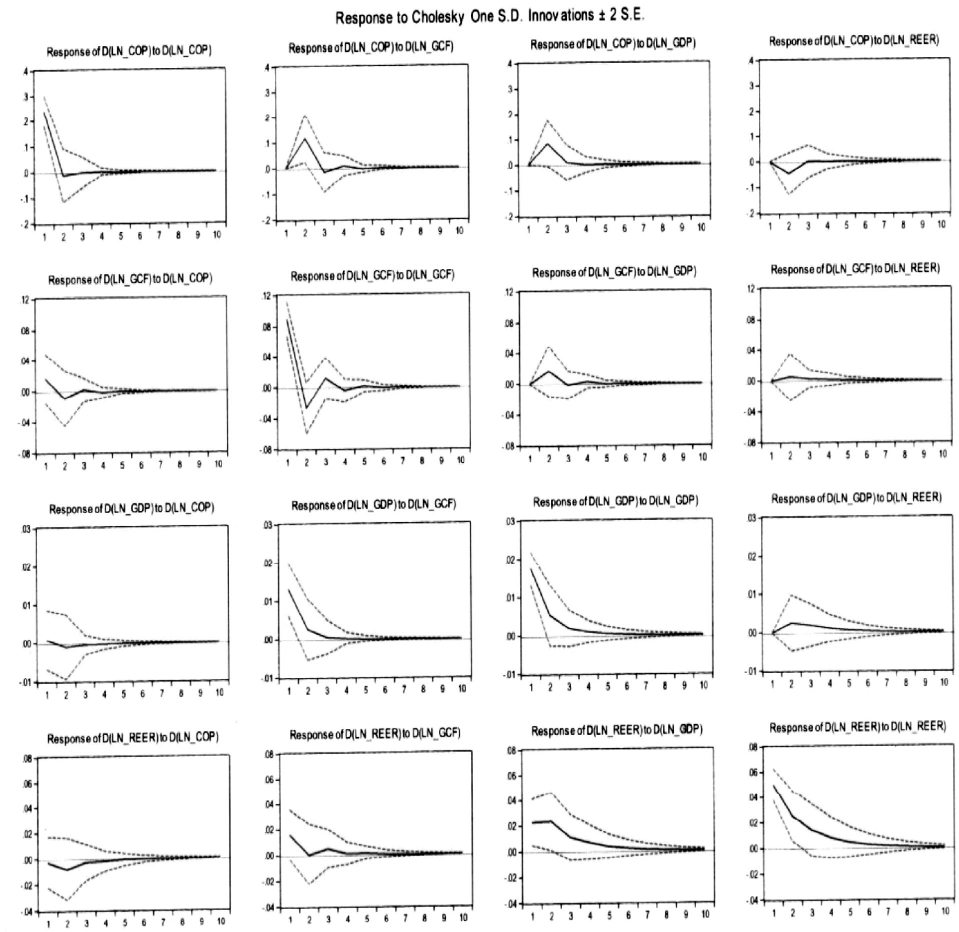

Figure 4: Impulse Response Functions of COP, GCF, GDP and REER

Over the years the effect of own shocks on crude oil price variations declines to 42 percent while the effect of shocks to GCF and GDP increases significantly to 51 and 4.3 percent respectively. Among all variables, shock in GCF causes more fiuctuations in crude oil price after own shock.

The proportion of fiuctuations in GCF due to own shock is 98 percent in the first year and the shocks COP contribute only about 2 percent while the contribution of shocks to other two variables is nothing. Throughout the 10 years period, the variations in gross capital formation is influenced largely by its own innovation and the contribution of innovations in other variables is only meagre. The own shock or innovation in GDP accounts for 57 percent variation of fiuctuation in GDP in the first period itself, while another significant 43 percent variation is due to innovation in GCF. The contribution of COP to GDP fluctuation is a minor 0.1 percent while the cause due to shocks in REER is nil. sizable shock to COP can cause 0.13185 percent fiuctuation in GDP. By 10th year, the contribution of own shock to GDP variation declines to 38 percent and the proportion of GDP variation due to GCF increases to 58.5 percent. Among all variables shock in GCF causes more fiuctuations in GDP after own shock.

The proportion of REER fiuctuations due to own shock account for 83 percent, while shock in GDP can cause 9.79 percent variation of fiuctuation in REER in the first year itself. The shock of GCF can cause 5.7 percent shock and that to COP can cause about 1 percent fiuctuation in REER. However, by 10th year, the contribution of own shock in REER declines to 64 percent, and the proportion of variance of REER for innovations in other variables increases significantly. The contribution of shocks to GDP is about

Table 7
Variance Decomposition of COP, GCF, GDP and REER

Period	*Std. error*	*DlnCOP*	*DlnGCF*	*DlnGDP*	*DlnREER*
Variance decomposition of DlnCOP					
1	0.218	100.000	0.0000	0.000	0.000
2	0.292	81.012	17.256	1.319	0.414
3	0.350	66.406	13.590	2.371	0.632
6	0.446	49.334	46.312	3.726	0.628
10	0.487	43.821	51.355	4.269	0.555
Variance decomposition of DlnGCF					
1	0.093	1.895	98.141	0.000	0.000
2	0.121	1.890	97.851	0.150	0.110
3	0.139	1.731	97.542	0.420	0.307
6	0.171	1.216	95.878	1.730	1.175
10	0.196	1.500	91.576	4.379	2.545
Variance decomposition of DlnGDP					
1	0.020	0.130	42.639	57.230	0.000
2	0.029	0.536	49.795	49.668	0.008
3	0.037	0.878	53.571	45.548	0.003
6	0.055	1.680	57.753	40.464	0.103
10	0.074	2.665	58.504	38.389	0.452
Variance decomposition of DlnREER					
1	0.057	0.957	5.774	9.796	83.474
2	0.077	3.853	3.312	11.785	81.051
3	0.092	6.555	2.454	12.482	78.509
6	0.123	12.268	3.447	11.959	72.326
10	0.150	15.898	8.845	10.409	64.848

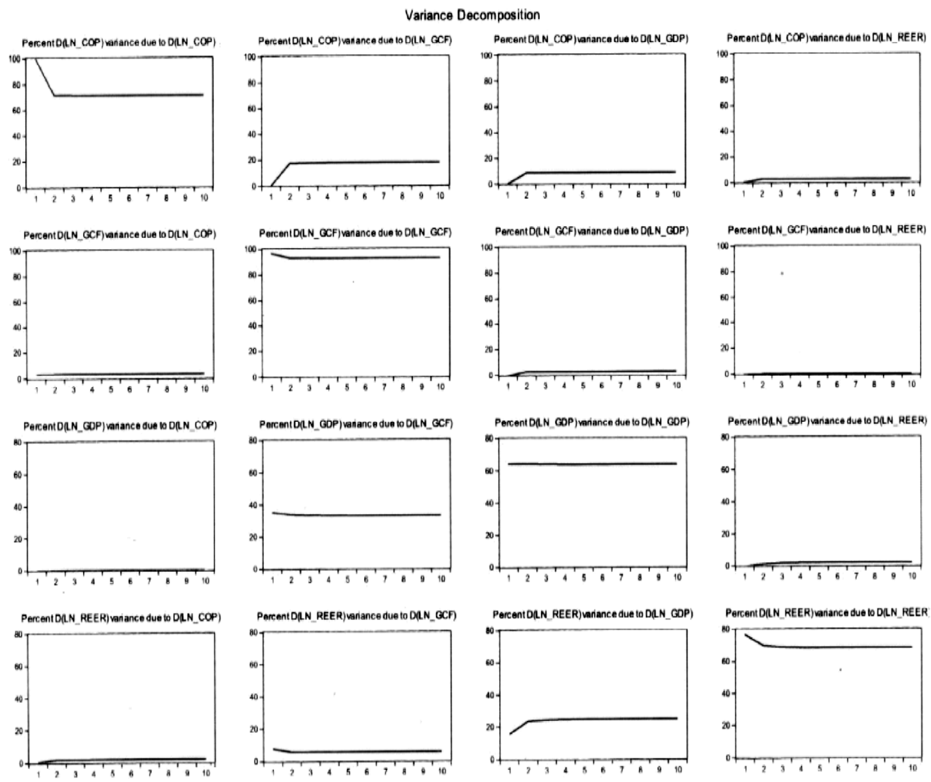

Figure 5: Variance Decomposition of COP, GCF, GDP and REER

10 percent, COP is 16 percent and GCF is nearly 9 percent to the fluctuations in REER in the last year. From the variance decomposition, it is clear that fiuctuations in crude oil price is to a significant extent due to shock in gross capital formation after its own shock and variations in real effective exchange rate to a significant size is due to shock in crude oil price.

CONCLUSION

Any industrialised and manufacturing economy depends on oil for its energy needs. Any fluctuations in oil prices is bound to affect the economy, especially the macro variables such as GDP, exchange rate, inflation, investment and stock prices. As a growing economy, India's energy demand for industrial, commercial and service sectors are largely dependent on imported crude oil. Therefore, the country is very vulnerable to changes in the international crude oil price. The increase in world price of crude oil is transmitted into the domestic economy of India through increases in domestic prices of petroleum products, and the consequent rise in prices of commodities in the country. This study aimed at an examination of the causal relationship between crude oil price and gross domestic product, gross capital formation and exchange rate in India in an endogenous system. Using annual time series data for India for 35 years from 1981 to 2015 derived from secondary sources, the study applies vector autoregression (VAR) estimation, after subjecting the data series to the usual time series tests and checks.

The ADF unit root test reveals that the variables at levels are not stationary and after taking first difference the stationary of variables are achieved. The Johansen cointegration test shows no cointegration between the variables suggesting that there exist no stable long-run relationships among them. The direction of causality is detected using the Granger causality test. Since there is no cointegration among the variables, the VAR is used to analyse the short-run causality with a lag length of 1. The IRF and variance decomposition are used to find the dynamic causality among the variables.

The VAR estimates suggest that there is on significant effect of crude oil price on macroeconomic variables in India. Rather, the crude oil price is significantly related with the lags of other macro variables. For other variables, only their own lags significantly affect their current level. The impulse response estimates show that shocks to each of the variables have impact mostly during the initial few periods and the responses eventually becomes zero over long periods. The variance decompositions reveal that a significant proportion of variations in crude oil price is also due to shock in gross capital formation after its own shock, and innovations in crude oil price causes fluctuations in real effective exchange rate to some extent.

REFERENCES

Abeysinghe, T. (2001). "Estimation of Direct and Indirect Impact of Oil Price on Growth", *Economic Letters*, 73, 2, 147- 153.

Akram, M. (2011). *Do Crude Oil Price Change Affect Economic Growth of India, Bangladesh and Pakistan? A Multivariate Time Series Analysis*, Economics Thesis, Dalarna University, Sweden.

Arouri, M.El-H., J. Jouini, N.T. Le and D.K. Nguyen (2012). "On the Relationship between World Oil Prices and GCC Stock Markets", *Journal of Quantitative Economics*, 10, 1, 98-120.

Baghirov, A. (2014). *Direct and Indirect Effects of Oil Price Shocks on Economic Growth: Case of Lithuania*, Unpublished Thesis, ISM University of Management and Economics, Vilnius, Lithuania.

Berna, A. and I. Berk (2015). "Crude Oil Price Shocks and Stock Returns: Evidence from Turkish Stock Market under Global Liquidity Conditions", *International Journal of Energy Economics and Policy*, 5, 1, 54-68.

Bhattacharjee, P. (20I3). *A study of the Impact of Crude Oil Price on Indian Economy*, Unpublished Doctoral Thesis, D.Y. Patil University, Mumbai.

Bhattacharya, B.B. and A. Batra (2009). "Fuel Pricing Policy Reform in India: Implications and Way Forward", *Economic and Political Weekly*, 44, 29, 77-86.

Bhattacharyya, K. and I. Bhattachrya (2001). "Impact of Increase in Oil Prices on Infiation and Output in India", *Economic and Political Weekly*, 36, 51, 4735-4741.

Engel, R.F. and C.W.J. Granger (1987). "Co-Integration and Error Correction: Representation, Estimation, and Testing", *Econometrica*, 55, 2, 251-276.

Finn, M.G. (2000). "Perfect Competition and the Effects of Energy Price Increases on Economic Activity", *Journal of Money, Credit, and Banking*, 32, 3, 400-416.

Hamilton, J.D. (2009). "Understanding Crude Oil Prices", *Energy Journal*, 30, 2, 179-206.

Jain, H. (2013). "Macro-Economic Impact of Crude Oil Prices on Economy: An Empirical Study of Indian Economy from 1992-2011", *International Journal of Management and Social Sciences Research*, 2, 5, 11-14.

Jain, K. (20I3). "Oil Price Volatility and Its Impact on the Selected Economic Indicators in India", *International Journal of Management and Social Sciences Research*, 2, 11, 26-31.