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# ENERGY CONSUMPTION AND ECONOMIC GROWTH NEXUS IN THE INDIAN CONTEXT

**Mousumi Bhattacharya*, Sharad Nath Bhattacharya****

**Assistant Professor, Army Institute of Management, Kolkata. Email: mbhattacharya9@gmail.com*
***Faculty in Finance, Rajiv Gandhi Indian Institute of Management, Shillong.*
*Email: sharadbhattacharya@gmail.com*

**Abstract** ***An attempt is made to determine the direction of causality between disaggregated energy consumption (coal consumption, petroleum consumption and electricity consumption) and overall economic growth in India's economy. Methodology adopted includes Johansen co-integration test, Granger causality test in a VECM framework followed by impulse response analysis. The findings show a long term relationship among the variables. Additionally, bidirectional causality between coal consumption and economic growth is observed and a unidirectional causality is observed from petroleum consumption to economic growth. The findings suggest that proper and efficient sectoral allocation policy on energy should be designed coupled with adoption of environmental policies aiming at increasing energy efficiency and the use of renewable energy.***

**Keywords:** *Energy Consumption, Economic Growth, Co-integration, Granger Causality, Impulse Response Analysis.*

## Introduction

The inter-relationship between energy consumption and economic growth has long been an area of interest amongst economists and policy makers. Energy is an important component of the production factor in addition to labour and capital which reveals the importance of energy in recent times. Many earlier studies have focused on the total energy consumption and economic growth with only a few studies focusing on the inter-relationship between disaggregated energy consumption and economic growth in India. In a developing country like India, coal is often treated as black gold keeping in view the significance this element has in the Indian economy. India is the second largest consumer of coal after China and no doubt this increased use of coal will inevitably result in rising global carbon dioxide ($CO_2$) emissions. This heavy dependence on coal affects the energy allied emissions of carbon dioxide which is rising in India. Therefore in order to sustain a phenomenal rate of economic growth proper environmental protection measures are necessitated otherwise growth will be limited. Petroleum is an important component in the country's energy consumption. The importance of petroleum energy can be accredited by the mammoth amount of money spent to import crude oil and it is a known fact that any smooth operation of a business in a country is affected by an increase in petroleum price and LPG shortage. Electricity is required for both commercial and non-commercial uses and plays an important role in the economic development of a country. Not only the use of electricity is associated with improving health and education standards of the poor but also the growth of the service sector (information and communication technologies such as mobile phones, digital video recorders, laptops etc.) over the years is heavily depended on this principal form of energy.

Whether energy consumption is an incentive for economic growth or economic growth is a vehicle for energy consumption is the relevant question for policy makers. If energy causes economic growth then reducing consumption may lead to a decline in income and employment. Masih and Masih (1997) suggested that in the absence of causality from energy for economic growth, energy conservation policies may be initiated that may not have detrimental side effects on growth and employment. An attempt is made here to explore the possible relationships between various forms of energy and economic growth as they have important implications for policy makers.

## Previous Research

The energy crises which affected India in the 1970s and 1980s and the steadily rising energy prices in the recent years have led to increased concern for policy makers and economists on the relationship between energy consumption and economic growth. The empirical research on energy consumption and economic growth were possibly motivated from the seminal paper by Kraft and Kraft (1978) who found evidence in favour of unidirectional causality running from energy consumption to GNP for USA during the period of 1947-1974. Apostolakis (1990) concluded that capital and energy act more as substitutes in the long-run and more as complements in the short-run. Yang (2000) observed causal relationship from economic growth to oil consumption in Taiwan without any feedback relationship. The causal relationship between energy consumption and economic growth in G7 countries and emerging markets was studied by Soytas and Sari (2003) and they observed that causality runs from GDP to energy consumption in Italy and Korea. Stern and Cleveland (2004) suggested that the shifts in the mix of the other inputs, from a more labour-intensive economy to a more capital-intensive economy can affect the relationship between energy and output and thereby, the energy consumption and economic growth. Lee (2005) found evidence to support long-run and short-run causalities run from energy consumption to GDP, but not vice versa whereas Lee (2006) analyzed the cases of 11 major industrialized countries but did not find consistent evidences on the direction of causality. Yoo (2006a) studied the causality relationship between electricity consumption and economic growth in the ASEAN countries. In case of China, the causal relationship between electricity consumption and economic growth was evidenced by Shiu and Lam (2004) whereas Ghosh (2002) provided similar evidence from India. Feedback causality between coal consumption and economic growth was evidenced by Yoo (2006b) in case of South Korea. Narayan and Prasad (2008) provided electricity consumption and real gross domestic product causality for 30 OECD countries whereas Jinke et al. (2008) observed that unidirectional causality running from GDP to coal consumption exists in Japan and China, and no causal relationship between coal consumption and GDP exists in India, South Korea and South Africa while the series are not co-integrated in the USA. Apergis and Payne (2010) examined the relationship between coal consumption and economic growth for 15 emerging market economies using a multivariate panel framework over the period 1980–2006. They suggested the existence of bidirectional causality between coal consumption and economic growth in both the short- and long-run.

In the Indian context, Cheng (1999) found causality from economic growth to energy consumption both in the short run and long run. Paul and Bhattacharya (2004) applied Engle–Granger co-integration approach combined with the standard Granger causality test on Indian data for the period 1950–1996 and found that bidirectional causality exists between energy consumption and economic growth. Ghosh (2006) using co-integration and error correction modelling approach found the existence of a long-run equilibrium relationship between total petroleum products consumption and economic growth in India for the period of 1970-71 to 2001-02. Payne (2010) provides a good survey of the literature on causal relationship between energy consumption and economic growth and concludes that there is no clear consensus whether a particular country is energy dependent or neutral. The empirical findings on the causal relationship between energy consumption and economic growth are inconclusive and it may be attributed to different structural frameworks and policies followed by different countries under different conditions and time periods, methodological differences and statistical problems of using proxies for energy consumption and growth, shifting energy consumption patterns, etc. (Ferguson et al., 2000; Toman and Jemelkova, 2003; Arbex and Perobelli, 2010; Pradhan, 2010). In order to explore the possibility of further information on the direction of causality we disaggregated energy consumption into three component coal consumption, petroleum consumption and electricity consumption. Our study attempts to revisit the possible long and short run causal relationship between economic growth and coal, electricity and petroleum consumption in Indian context.

## Methods / Theoretical Framework

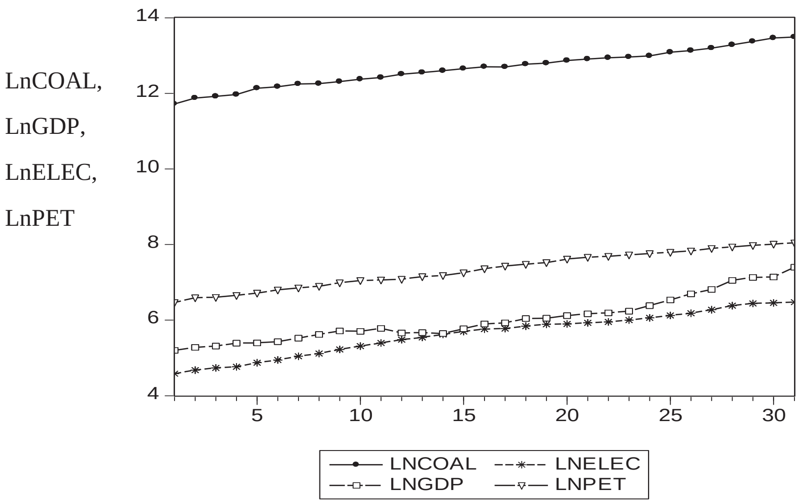
The objective of the study is to examine the causal links between GDP, COAL, PET and ELEC in India over the period 1980 to 2010 in a Vector Autoregressive (VAR) framework. Annual data on gross domestic product is taken as a proxy for economic growth. Energy has been considered at disaggregated level and three most important components of energy consumption in India have been considered which includes total electricity net consumption (ELEC), total coal consumption (COAL), and total petroleum consumption (PET) (including motor gasoline, jet fuel, kerosene, distillate fuel oil, residual fuel oil, liquefied petroleum gas, and other products). GDP data are from the IMF database and all other data are from the U.S. Energy Information Administration. The time period for the study is 1980 to 2010 (Figure1).

### Co-integration Test

A prerequisite for co-integration test is to determine if the data series are stationary or integrated. Augmented Dickey Fuller (ADF) (1979) test and Phillips-Perron (PP) (1988) is conducted to examine if the data are stationary. The co-integration technique of Johansen (1988) and Johansen and Juselius (1990) is used to study whether the variables are tied in a long term relationship. The co-integration test of maximum likelihood (based on the Johansen-Juselius Test) has been developed based on a VAR approach initiated by Johansen (1988). According to Johansen (1988), a p-dimensional VAR model, involving up to k-lags, can be specified as below.

$$Z_t = \Pi_1 Z_{t-1} + \Pi_2 Z_{t-2} + \ldots\ldots\ldots \Pi_k Z_{t-k} + \varepsilon_t \qquad (1)$$

**Figure 1: Logarithmic values of COAL, GDP, ELEC and PET**




where $Z_t$ is a ($p \times 1$) vector of p potential endogenous variables and each of the $\Pi_i$ is a ($p \times p$) matrix of parameters and $\varepsilon_t$ is the white noise term. Equation (1) can be formulated in an Error Correction Model (ECM) form as below.

$$\Delta Z_t = \Pi_k Z_{t-k} + \sum_{i=1}^{k-1} \theta_i \Delta Z_{t-i} + \varepsilon_t \quad (2)$$

where the first difference operator is represented by $\Delta$, and $\Pi$ and $\theta$ are p by p matrices of unknown parameters and k is the order of the VAR translated into a lag of k-1 in the ECM and $\varepsilon_t$ is the white noise term. Evidence of the existence of co-integration is the same as evidence of the rank (r) of the $\Pi$ matrix. Johansen and Juselius (1990) have shown that the rank of r of $\Pi$ in equation (2) is equal to the number of co-integrating vectors in the system. When the rank of $\Pi$ is reduced i.e. [$1 \le Rank\Pi \le (p-1)$ ], in this case, even if all the variables are individually I(1), the level-based long-run component would be stationary. In this case, there are (p-1) co-integrating vectors and Vector-Error Correction Model (VECM) methodology to be used. Johansen and Juselius (1990) have developed two Likelihood Ratio Tests. The null hypothesis of 'r' co-integrating vector(s) against the alternative of 'r+1' co-integrating vectors is evaluated in the Maximal Eigenvalue statistic whereas the null hypothesis of, at most, 'r' co-integrating vector(s) against the alternative hypothesis of more than 'r' co-integrating vectors is evaluated in the Likelihood Ratio Test based on the Trace Test. If the two variables are I(1), and co-integrated, the Granger Causality Test will be applied in the framework of the error correction mechanism (ECM).

Table 1: VAR Lag Order Selection Criteria

| Lag | LogL | LR | FPE | AIC | SC | HQIC |
|---|---|---|---|---|---|---|
| 0 | 78.13264 | NA | 4.85e-08 | -5.491307 | -5.299331 | -5.434222 |
| 1 | 234.9195 | 255.5045* | 1.46e-12 | -15.91996 | -14.96008* | -15.63454 |
| 2 | 247.6895 | 17.02676 | 2.02e-12 | -15.68071 | -13.95292 | -15.16695 |
| 3 | 271.3601 | 24.54725 | 1.46e-12 | -16.24890 | -13.75321 | -15.50680 |
| 4 | 300.8213 | 21.82309 | 9.26e-13* | -17.24602* | -13.98243 | -16.27558* |

Source: created by the authors

* indicates lag order selected by the criterion

LR: sequential modified LR test statistic (each test at 5% level)

FPE: Final prediction error

AIC: Akaike information criterion

SC: Schwarz information criterion

HQIC: Hannan-Quinn information criterion

**Table 2: Results from the stationarity tests**

| Country | Variables | ADF | | PP | |
|---|---|---|---|---|---|
| | | Level | First Difference | Level | First Difference |
| India | LnGDP | 2.511 | -3.853*** | 2.511 | -3.853*** |
| | LnCOAL | -1.249 | -6.817*** | -1.249 | -6.817*** |
| | LnPET | -1.827 | -5.947*** | -1.827 | -5.947*** |
| | LnELEC | -1.560 | -3.013** | -1.795 | -3.013** |

Source: created by the authors

(a)The critical values are those of MacKinnon (1991).

(b)*** represent the rejection of the null hypothesis at the 1 % level of significance.

## Granger Causality Test with VECM framework

Granger Causality Test is conducted not only to examine the causal linkages between the variables but also to determine the direction of the impact of each of the variables on the other. The optimal lag length (p) is chosen (which is 4 in the present study) through a combination of information criteria like LR or FPE or AIC or SC or HQIC (Table 1).

Causality is said to exist in at least one direction if the variables contain co-integrating vector and in this case the direction of a causal relationship is detected through VECM. Engel and Granger (1987) have found that, in the presence of co-integration, there always exists a subsequent error-correction representation, captured by the error-correction term (ECT) which captures the long-run adjustment of co-integration variables. Apart from identifying the direction of causality, the incorporation of the error correction term (ECT) in the VECM model helps to analyse the long term relationship between the variables.

$$\Delta LnCOAL_t = \sum_{j=1}^{p\text{-}1} \beta_{11} \Delta LnCOAL_{t\text{-}j} + \sum_{j=1}^{p\text{-}1} \beta_{12} \Delta LnELEC_{t\text{-}j} + \sum_{j=1}^{p\text{-}1} \beta_{13} \Delta LnGDP_{t\text{-}j} + \sum_{j=1}^{p\text{-}1} \beta_{14} \Delta LnPET_{t\text{-}j} + \alpha_1 ECT_{t\text{-}1} + \varepsilon_{1t} \ldots\ldots 3(a)$$

$$\Delta LnELEC_t = \sum_{j=1}^{p\text{-}1} \beta_{21} \Delta LnELEC_{t\text{-}j} + \sum_{j=1}^{p\text{-}1} \beta_{22} \Delta LnCOAL_{t\text{-}j} + \sum_{j=1}^{p\text{-}1} \beta_{23} \Delta LnGDP_{t\text{-}j} + \sum_{j=1}^{p\text{-}1} \beta_{24} \Delta LnPET_{t\text{-}j} + \alpha_2 ECT_{t\text{-}2} + \varepsilon_{2t} \ldots\ldots 3(b)$$

$$\Delta LnGDP_t = \sum_{j=1}^{p\text{-}1} \beta_{31} \Delta LnGDP_{t\text{-}j} + \sum_{j=1}^{p\text{-}1} \beta_{32} \Delta LnCOAL_{t\text{-}j} + \sum_{j=1}^{p\text{-}1} \beta_{33} \Delta LELEC_{t\text{-}j} + \sum_{j=1}^{p\text{-}1} \beta_{34} \Delta LnPET_{t\text{-}j} + \alpha_3 ECT_{t\text{-}3} + \varepsilon_{3t} \ldots\ldots 3(c)$$

$$\Delta LnPET_t = \sum_{j=1}^{p\text{-}1} \beta_{41} \Delta LnPET_{t\text{-}j} + \sum_{j=1}^{p\text{-}1} \beta_{42} \Delta LnCOAL_{t\text{-}j} + \sum_{j=1}^{p\text{-}1} \beta_{43} \Delta LELEC_{t\text{-}j} + \sum_{j=1}^{p\text{-}1} \beta_{44} \Delta LnGDP_{t\text{-}j} + \alpha_4 ECT_{t\text{-}4} + \varepsilon_{4t} \ldots\ldots 3(d)$$

where the first difference operator is represented as $\Delta$ and $\varepsilon_{1t}, \varepsilon_{2t}, \varepsilon_{3t}$, and $\varepsilon_{4t}$ are white noise. The error correction term is denoted by ECT, and the order of the VAR is represented by p, which is translated to lag of p-1 in the ECM. $\alpha_1, \alpha_2, \alpha_3$ and $\alpha_4$ represent the pace of adjustment after the COAL, ELEC, GDP and PET deviate from the long-run equilibrium in period t-1.

## Impulse Response Analysis

Impulse responses are the changes in the future predicted values due to a change in the current period values. Typically in a VAR, the coefficient estimates of the individual equations are of little or no importance. Instead of static interpretation of the effects of changes in any of the variables in the system, Impulse Responses (IR) provide a dynamic response curve that depicts the effects of a change in one of the variables, considering the effects of the other variables in the system. In the present study, the orthogonalized IR analysis is done by changing the order of the equations to see whether any change in the IR function is revealed.

## RESULTS, DISCUSSION AND LIMITATIONS

It is observed from the results of the ADF and PP test that all the four variables LnCOAL, LnELEC, LnGDP and LnPET have the same order of integration, i.e., I(1).

The Johansen Cointegration Test determines the rank (r) of the coefficient matrix of a VAR model of the series with the rank indicating the presence of co-integration as well as the number of co-integrating relationship. The null hypothesis is rejected in the cases of both the Trace statistic and Max-Eigen

**Table 3: Johansen -Juselius Cointegration Test Results**

| H0 | H1 | $\lambda_{trace}$ | $CV_{(trace,5\%)}$ | Prob** |
|---|---|---|---|---|
| $r=0$ | $r \quad 1$ | 107.3152 | 47.85613 | 0.0000** |
| $r \leq 1$ | $r \quad 2$ | 60.74918 | 29.79707 | 0.0000** |
| $r \leq 2$ | $r \quad 3$ | 26.65005 | 15.49471 | 0.0007** |
| $r \leq 3$ | $r \quad 4$ | 0.929058 | 3.841466 | 0.3366 |
| H0 | H1 | $\lambda_{\max}$ | $CV_{(\max,5\%)}$ | Prob** |
| $r=0$ | $r=1$ | 46.56600 | 27.58434 | 0.0001** |
| $r \leq 1$ | $r=2$ | 33.09912 | 21.13162 | 0.0005** |
| $r \leq 2$ | $r=3$ | 25.72100 | 14.26460 | 0.0005** |
| $r \leq 3$ | $r=4$ | 0.929058 | 3.841466 | 0.3366 |

Source: created by the authors

(a) is the number of co-integrating vectors.

(b) Trace test indicates 3 co-integrating equation at the 5% level of significance.

(c) Max-Eigen value test indicates 3 co-integrating equation at the 5% level of significance.

(d)** denotes rejection of the null hypothesis at the 5% level of significance

(e) The critical values (i.e., CVs) are taken from Mackinnon-Haug-Michelis (1999).

value statistic. Table 3 shows that the number of statistically significant co-integration vectors is equal to 3 for the Trace statistic and also for the Max-Eigen value statistic. The results suggest that there is a long-run relationship among the variables considered for the study.

In Table 4, the coefficients of the co-integrating equations are given along with the equation for changes in coal consumption (first column), changes in electricity consumption (second column), changes in gross domestic product (third column), and changes in petroleum consumption (fourth column). Whether the earlier period values affect the recent period values is reflected through the coefficient of the error correction term (ECT). If the coefficient is significant it reveals that there is a role played by past equilibrium errors in determining the recent period outcomes. The short-run dynamics are captured through the individual coefficients of the difference terms. The adjustment coefficient in equation 3(a) is negative and statistically significant at the 1% level of significance, which means that the error term contributes in explaining changes in GDP and a long-term relationship exists between the GDP and coal consumption. The estimates of lagged coefficients in equation 3(a) are negative and statistically significant at the 5% level of significance, implying that higher GDP has a negative impact on coal consumption in the short-run. The adjustment coefficient in equation 3(c) is positive and statistically significant at the 5% level of significance, which means that the error term contributes in explaining changes in coal consumption and petroleum consumption and a long-term relationship exists between the coal and petroleum consumption (independent variables) with GDP. The estimate of the lagged coefficient in equation 3 (c) is negative and statistically significant at the 5% level of significance, implying that higher coal consumption has a negative impact on economic growth in the short-run. The estimate of the lagged coefficient in equation 3 (c) is negative and statistically significant at the 5% level of significance, implying that higher petroleum consumption has a negative impact on GDP in the short-run.

The above results indicate a bidirectional causality running between coal consumption and economic growth not only in the short run but also in the long run. A unidirectional causality is observed form petroleum consumption to economic growth both in the short run and long run.

The shock to any one of the four variables considered in the study affects all other variables in the system. The shocks

Table 4: Vector Error Correction Estimates

| | | | | |
|---|---|---|---|---|
| Co-integrating Eq: | CointEq1 | | | |
| LnCOAL(-1) | 1.000000 | | | |
| LnELEC(-1) | -0.446854 | | | |
| | (0.05774) | | | |
| | [-7.73903] | | | |
| LnGDP(-1) | -0.269429 | | | |
| | (0.04754) | | | |
| | [-5.66695] | | | |
| LnPET(-1) | -0.128951 | | | |
| | (0.09794) | | | |
| | [-1.31662] | | | |
| C | -7.583768 | | | |
| Error Correction: | D(LnCOAL) | D(LnELEC) | D(LnGDP) | D(LnPET) |
| CointEq1 | -1.274973 | -0.180699 | 1.731698 | 0.215956 |
| | (0.24512) | (0.29488) | (0.76041) | (0.26480) |
| | [-5.2014]*** | [-0.61279] | [ 2.27731]** | [ 0.81553] |
| D(LnCOAL(-1)) | 0.319232 | -0.392404 | -1.144377 | -0.108105 |
| | (0.20233) | (0.24341) | (0.62768) | (0.21858) |
| | [ 1.57778] | [-1.61214] | [-1.82319]** | [-0.49458] |
| D(LnCOAL(-2)) | 0.508341 | 0.251921 | -0.942070 | 0.232690 |
| | (0.21417) | (0.25765) | (0.66440) | (0.23137) |
| | [ 2.37355] | [ 0.97777] | [-1.41792] | [ 1.00571] |
| D(LnCOAL(-3)) | 0.356530 | 0.239531 | 0.822215 | -0.192934 |
| | (0.16356) | (0.19676) | (0.50740) | (0.17669) |
| | [ 2.17984] | [ 1.21736] | [ 1.62045] | [-1.09191] |
| D(LnELEC(-1)) | -0.307817 | 0.818789 | 0.094498 | 0.254419 |
| | (0.24068) | (0.28954) | (0.74665) | (0.26001) |
| | [-1.27895] | [ 2.82790] | [ 0.12656] | [ 0.97850] |
| D(LnELEC(-2)) | -0.080406 | -0.283916 | 0.847220 | -0.227766 |
| | (0.31388) | (0.37761) | (0.97374) | (0.33909) |
| | [-0.25617] | [-0.75189] | [ 0.87007] | [-0.67170] |
| D(LnELEC(-3)) | -0.283465 | 0.024065 | -0.987062 | 0.189990 |
| | (0.26416) | (0.31779) | (0.81950) | (0.28538) |
| | [-1.07306] | [ 0.07573] | [-1.20446] | [ 0.66574] |
| D(LnGDP(-1)) | -0.121610 | -0.039999 | 0.291827 | 0.034788 |
| | (0.08199) | (0.09864) | (0.25436) | (0.08858) |
| | [-1.48320] | [-0.40551] | [ 1.14730] | [ 0.39274] |
| D(LnGDP(-2)) | -0.173709 | -0.084301 | 0.579875 | 0.133343 |
| | (0.08342) | (0.10036) | (0.25879) | (0.09012) |
| | [-2.08233]** | [-0.84002] | [ 2.24070] | [ 1.47961] |
| D(LnGDP(-3)) | -0.203579 | 0.047027 | 0.644210 | -0.159574 |
| | (0.09146) | (0.11003) | (0.28375) | (0.09881) |
| | [-2.22577]** | [ 0.42739] | [ 2.27038] | [-1.61496] |
| D(LnPET(-1)) | -0.132469 | -0.100407 | -0.740192 | 0.385774 |
| | (0.20460) | (0.24614) | (0.63472) | (0.22103) |
| | [-0.64746] | [-0.40793] | [-1.16617] | [ 1.74533] |
| D(LnPET(-2)) | -0.273478 | -0.159347 | -0.222721 | -0.414428 |
| | (0.19805) | (0.23826) | (0.61440) | (0.21395) |
| | [-1.38086] | [-0.66881] | [-0.36250] | [-1.93699] |
| D(LnPET(-3)) | -0.114643 | -0.005012 | -1.396705 | 0.395206 |
| | (0.20375) | (0.24511) | (0.63207) | (0.22011) |
| | [-0.56268] | [-0.02045] | [-2.20974]** | [ 1.79551] |
| | | | | |

| | | | | |
|---|---|---|---|---|
| C | 0.094326 | 0.041603 | 0.171030 | 0.021129 |
| | (0.02774) | (0.03338) | (0.08607) | (0.02997) |
| | [ 3.39999] | [ 1.24653] | [ 1.98721] | [ 0.70497] |
| R-squared | 0.793338 | 0.581775 | 0.626627 | 0.501504 |
| Adj. R-squared | 0.586676 | 0.163549 | 0.253254 | 0.003007 |
| F-statistic | 3.838816 | 1.391055 | 1.678285 | 1.006033 |

Source: created by the authors

Standard errors are in ( ) and t-statistics are in [ ]

***, ** and * denotes significance at 1% , 5% and 10% at level of significance.

**Figure 2(a): IR of D(LnGDP) to One-standard deviation shocks in other variables**

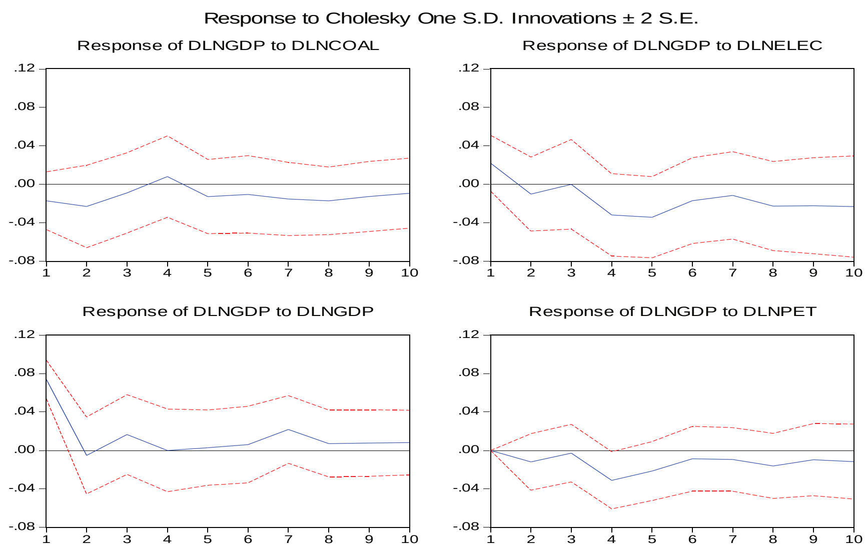
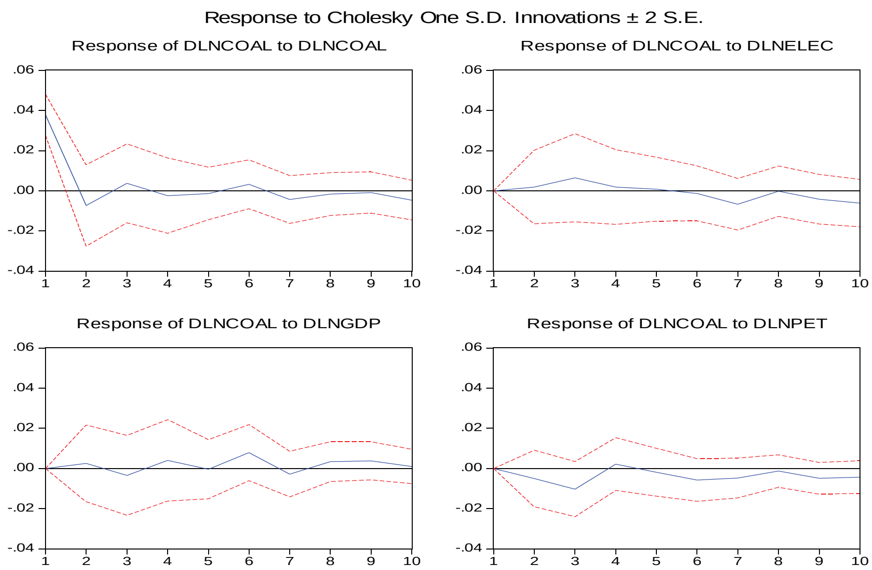



**Figure 2(b): IR of D(LnCOAL) to One-standard deviation shocks in other variables**



are orthogonalized by using the Choleski decomposition method. The VAR is estimated at the first difference of the variables and the optimum, lag length is chosen to be 3 (minimum of LR or FPE or AIC or SC or HQIC). Thus, IR functions are computed to give an indication of the system's dynamic behaviour. The IR estimates only for the variables that appear to significantly Granger cause other variables (based on Causality Test) are reported. Each of the variables in the study is taken in the natural logarithmic form. The IR function for the VAR system is calculated in the following order – COAL, ELEC, GDP and PET. The IR function only for COAL and GDP are reported in Figure 2(a) and Figure 2(b).

The response of GDP to a unit shock in coal consumption is negative in the first four quarters. The initial response of GDP to a unit shock in petroleum consumption is negative in the first quarter, falls further in the second quarter and remains negative in the third quarter. The initial response of coal consumption to a unit shock in GDP is positive in the first two quarters but falls in the third quarter and becomes negative. The results of the impulse response functions are consistent with the t-statistics for differences of the variables in estimated coefficients.

## Conclusions

The study has investigated the causality between economic growth and disaggregated energy consumption (coal, petroleum and electricity) in the Indian economy for the period 1980 to 2010. The stationarity test showed that all the variables are integrated of order one and the co-integration test confirms the presence of the long run relationship between economic growth and energy variables. Feedback causality running between coal consumption and economic growth is observed in case of India.

The direction of causality from coal consumption to economic growth indicates that a change in coal consumption directly affects economic growth and consumption of coal remains a critical factor in sustaining the nation's economic growth and well being. The direction of causality from economic growth to coal consumption indicates that continuous economic growth has resulted in an incessant rise in coal consumption which is actually driven by GDP. Feedback causality is observed in case of India which indicates that while energy conservation policies may retard economic growth but at the same time fluctuations in economic growth may hamper the consumption of coal i.e. coal consumption and economic growth mutually influence each other. Measures should be taken to conserve coal and overcome the constraints on coal consumption so that growth is not adversely affected. It also supports the argument that an increase in real income also causes an increase in coal consumption. There is also need to explore new sources of coal that must be clean, safe and cheaper in the country. Here, petroleum consumption seems to be an important principal factor in the short run as well as in the long run for the Indian economy. The enormous use of petroleum in the industrial and transportation sector has directly pushed the economy. The production process in manufacturing, construction, electricity generation and transportation demand a substantial amount of petroleum. Increased consumption of petroleum also affects employment. So, in any industrialized country like India petroleum is an important ingredient of economic development. No causality is observed from electricity consumption to economic growth which shows that electricity consumption being a highly qualitative energy source as compared to the other forms of energy consumption may contribute towards economic growth of the country in the future. Efforts should be taken to exploit the renewable sources of energy, which can be used for the purpose of consumption because this could economise the use of natural resources in the economy. Otherwise with continued economic growth, demand for coal and petroleum consumption would increase resulting in the increase of prices of these forms of energy which in turn would lead to macroeconomic imbalances. Keeping in view that these two forms of energy contribute to economic growth proper sectoral efficient allocation policy on energy should be designed because the industrial sector consumes a lot of these forms of energy. Irrespective of the direction of causality found, India should adopt environmental policies aimed at decreasing coal intensity and in turn increasing energy efficiency and the use of renewable energy. Countries should adopt such policies and legislation that would not only limit the growth of coal use but also put a hold to the global warming.

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