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Energy consumption, economic growth and CO_2 emissions: Empirical evidence from India

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ABSTRACT

This paper examines the causal and co-integrating relationship between energy consumption, economic growth and CO_2 emissions in a multivariate framework by including urbanization, trade openness and gross fixed capital formation as other control variables for an emerging economy like India. Using the annual data from 1971 to 2012, the paper applied the Auto Regressive Distributed Lag (ARDL) bounds testing approach to examine the existence of short run and long run relationship; and VECM Granger causality test for checking the direction of causality. Stationary properties of the variables are checked by using DF-GLS, PP and KPSS unit root tests. The bounds test result supports the existence of long run relationship among the variables. The results of ARDL test indicate that energy consumption and urbanization has positive impact on CO_2 emissions while economic growth has positive impact on the energy consumption in the long run. The short run and long run causality results indicate the presence of unidirectional causality from energy consumption and urbanization to air pollution and short run causality from economic growth to energy consumption. The study concludes that for accelerating economic growth, expansion of the industrial output depending on energy consumption is needed, which puts pressure on the environment.

Keywords: Energy consumption, economic growth, CO_2 emissions, ARDL bounds test, VECM, India.

JEL Classification: C32, C33, O13

1. Introduction

Global warming has been considered as one of the most important environmental problems in recent times. The ever increasing amount of carbon dioxide (CO_2), the dominant contributor to the greenhouse effect, seems to be aggravating this problem. Recognizing the importance of taking corrective measures to condense global warming several countries have signed the Kyoto Protocol and agreed to meet the target set under the Kyoto Protocol, particularly to reduce greenhouse gas emissions. The negotiations for the Kyoto Protocol were hard, as various countries had different interests in the international effort for the solution of world temperature increase.

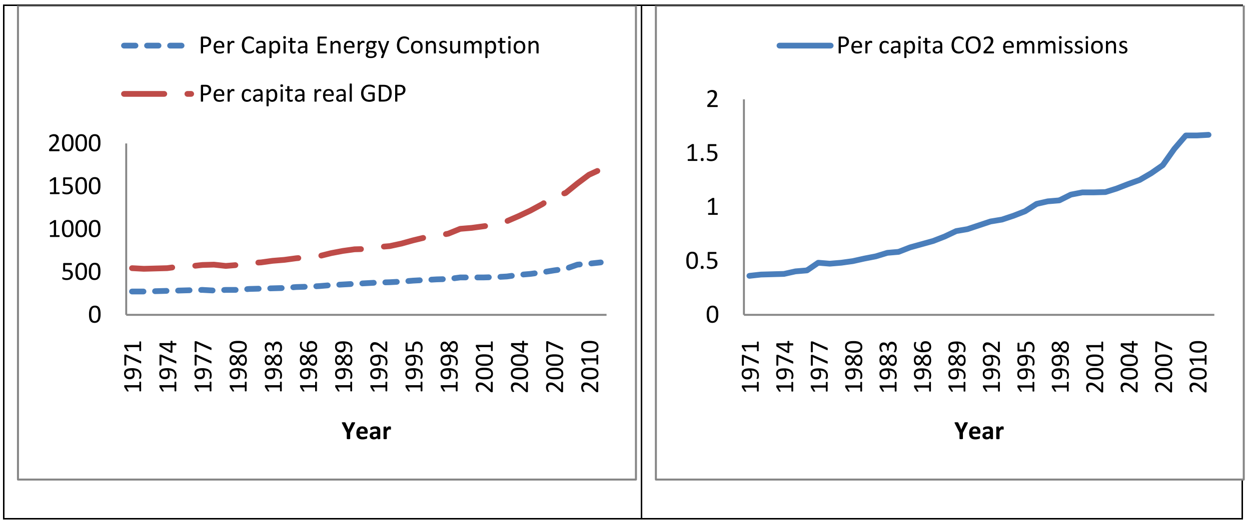
Reflecting a global phenomenon, many countries have struggled to achieve economic growth without concurrently witnessing an increase in CO_2 emissions. However, there has been growing interest over the method of 'low carbon and green growth'. That is, the question of whether it is really possible to achieve sustained economic growth without increasing energy consumption or green house gases has become a topic of special interest. Developing and underdeveloped countries have argued that any restriction on carbon energy would impede economic growth and suggested that developed countries should raise funds to mitigate global warming. This issue is partly related to post-Kyoto negotiations over climate change, and thus, it is important to examine the relationship between the energy consumption, environmental degradation and economic growth through an empirical analysis.

There seems to be basically three research strands in literature on the relationship between energy consumption, economic growth and environmental pollutants. The first strand focuses on the environmental pollutants and economic growth nexus. It is closely related to testing the validity of the so-called environmental Kuznets curve (EKC) hypothesis, which postulates an inverted U-shaped relationship between the level of environmental degradation and income growth (Grossman and Krueger, 1991; Shafik and Bandyopadhyay, 1992; Panayotou, 1997). The second strand concentrates on the link between economic output and energy consumption, since the emissions are mainly caused by burning fossil fuels. Following the seminal study of Kraft and Kraft (1978), an increasing number of studies has assessed the empirical evidence employing Granger causality and cointegration model. The third strand of research addresses a combined approach of those two methods has emerged which is implied to investigate the inter-temporal links in the energy–environment– income nexus in a multivariate setting with income, energy consumption, carbon emissions and some other control variables.

The major users of energy were China and India, who continue to lead the world in relation to economic growth and energy demand growth. Together, China and India accounted for about 10 percent of the world's total energy consumption in 1990 and 20 percent in 2007 (EIA, 2010). China and India's other significant increase include a fast-paced growth in population, rapid economic growth and industrial expansion into other areas of the Asian region.

The following figures present the progress of the three variables, per capita energy consumption, per capita CO_2 emissions and GDP per capita for India during the years 1971 – 2011. From figure 1 (left panel) we can see the existence of an upward trend of per capita energy consumption and GDP per capita during last four decades. Further, it is clear that there is a sharp increase in the GDP per capita from 2001 to 2011. From figure 1 (right panel) we can see that CO_2 emissions have the same trend as that of energy consumption and GDP per capita for India. But we observe an upward trend on CO_2 emission till 2008 after which it remained constant till 2011. From these figures we conclude that energy consumption seems to be the principal source of the CO_2 emissions since the two curves follow the same tendencies during the period. Besides, the trend exhibits a positive correlation between growth and energy consumption and between growth and CO_2 emissions. In this context, the principal objective of the present study is to investigate the dynamic causal relationship between energy consumption, CO_2 emissions and economic growth of India in a multivariate setting using time series data for the period of 1971 - 2012.

Figure 1: Energy Consumption Per capita, CO_2 Emission Per capita, GDP per capita (1971-2011)



Source: World Bank database

2. Literature Review:

The relationship between energy consumption, economic growth, and environmental degradation, has been one of the most extensively investigated issues in the economic literature in the last three decades. However, results from the research have varied considerably. Whether energy consumption stimulates, retards or is neutral to economic growth has motivated interest among economists and policy makers to investigate the direction of causality between energy consumption, environmental pollution and economic variables. The empirical outcomes of the various studies on this subject which differ in terms of the time period covered, country chosen, econometric techniques employed, and the proxy variables used in the estimation, have reported mixed results and supports to present policy recommendation that can be applied across countries. Depending upon the direction of causality; the policy implications can be considered from the point of view of energy conservation, emission reduction and economic performance.

The pioneer study by Kraft and Kraft (1978) found a unidirectional Granger causality running from output to energy consumption for the United States using data for the period 1947–1974. Yang (2000) considers the causal relationship between different types of energy consumption and GDP in Taiwan for the period 1954–1997.Using different types of energy consumption he found a bi-directional causality between energy and GDP. This result contradicts with Cheng and Lai (1997) who found that that there is a unidirectional causal relationship from GDP to energy use in Taiwan. Soytas and Sari (2003) discovered bidirectional causality in Argentina, causality running from GDP to energy consumption in Italy and Korea, and from energy consumption to GDP in Turkey, France, Germany and Japan. Paul and Bhattacharya (2004) found bi-directional causality between energy consumption and economic growth in India. Using cointegration model, Wietze and Van

Montfort (2007) show that energy consumption and GDP are co-integrated in Turkey over the period 1970–2003 and found a unidirectional causality running from GDP to energy consumption indicating that energy saving would not harm economic growth in Turkey.

The earlier studies mostly apply a bivariate model and fail to get consensus results. The bivariate model is criticized in many econometric issues, especially the omitted variables bias. Employing a multivariate model with energy consumption, gross domestic product (GDP), capital, and labor force, (Stern, 1993) found Granger causality running from energy use to GDP for the USA. Following (Stern, 1993), a considerable number of studies has tested the causal relationship between the energy consumption and economic output in a multivariate context. However, the multivariate studies also produced conflicting results.

An assessment of the existing literature indicates that most studies focus on the nexus of output-energy or output-pollution. Only recently, a combined approach of those two methods has emerged which is implied to investigate the inter-temporal links in the energy, environment and income nexus. Appling a multivariate model with income, energy consumption, carbon emissions, gross fixed capital formation, and labor force, Soytas et al. (2007) found no Granger causality between income and carbon emissions, and no Granger causality between energy use and income in the US. But energy consumption causes the carbon emissions in the long run. Using the same approaches and variables, Soytas and Sari (2009) found the same link between income and carbon emissions in Turkey. However, the carbon emissions Granger cause the energy consumption in the long run. The lack of a long run Granger causality between income and carbon emissions provides evidence that both the US and Turkey reduce carbon emissions without forgoing economic growth. Applying the bounds testing to cointegration procedure in a multivariate model with carbon emissions, energy use, income, and foreign trade, (Halicioglu, 2009) found that there is a bi directional Granger causality (both in short and long run) between the carbon emissions and income in Turkey. This result is conflicting with that of Soytas and Sari (2009). Ang (2008) found that output growth Granger causes energy consumption in Malaysia. However, weak evidence of causality running from carbon emissions to income in the long run, but no feedback link is observed. Zhang and Cheng (2009) found unidirectional Granger causality running from economic growth to energy consumption and energy consumption to pollution emissions in the long run, while Ang (2007) found unidirectional Granger causality running from economic growth to energy consumption and pollution emissions in the long-run. Sari and Soytas (2009) provides conflicting results for five OPEC countries - Algeria, Indonesia, Nigeria, Saudi Arabia and Venezuela by incorporating labour and capital in the framework of production function besides energy consumption, CO_2 emissions and economic growth. It is argued that higher economic growth rates pursued by developing countries are achievable only by consumption of a larger quantity of commercial energy, which leads to environmental degradation. There is still dispute on whether energy consumption is a stimulating factor or a result of, economic growth. Further, the increased share of CO_2 in the systems and is a main factor contributing to climate change.

Chebbi and Boujelbene (2008) investigated long and short-run linkages between economic growth, energy consumption and CO_2 emission using Tunisian data over the period 1971-2004. The findings indicate that economic growth, energy consumption and CO_2 emission are related in the long-run. In the short run, results support the argument that economic growth exerts a positive causal influence on energy consumption. Similarly, Boopen and Harris (2012) investigate the relationship among energy consumption, carbon emissions and economic growth for Mauritius using VECM model for the period 1960-2011. The study found that increase in energy consumption causes increase in economic growth, capital accumulation and trade in the long run. Interestingly, the study found that energy consumption has significant impact on CO_2 emission in Mauritius.

Alam et al. (2011) investigated the causality relationships among energy consumption, carbon dioxide (CO_2) emissions and income in India using a dynamic modeling approach. The results provide evidence of the existence of bi-directional Granger causality between energy consumption and CO_2 emissions in the long-run but neither CO_2 emissions nor energy consumption causes movements in real income. Alam et. al. (2012) investigates the existence of dynamic causality between energy consumption, electricity consumption, carbon emissions and economic growth in Bangladesh. The study used the Johansen bi-variate cointegration and auto-regressive distributed lag model to examine the cointegration relationship. The Granger short-run, the long-run causality are tested with VECM framework. The results indicate that uni-directional causality exists from energy consumption to economic growth both in the short and the long-run while a bi-directional long-run causality exists between electricity consumption and economic growth but no causal relationship exists in short-run.

Hossain S (2012) examines the dynamic causal relationship between carbon dioxide emissions, energy consumption, economic growth, foreign trade and urbanization using time series data for the period of 1960-2009 for Japan. Short-run unidirectional causalities are found from energy consumption and trade openness to carbon dioxide emissions, from trade openness to energy consumption, from carbon dioxide emissions to economic growth, and from economic growth to trade openness. Tiwari et al. (2013) investigates the dynamic relationship between coal consumption, economic growth, trade openness and CO_2 emissions for Indian economy. The results confirm the existence of cointegration for long run between coal consumption, economic growth, trade openness and CO_2 emissions. The causality results report the feedback hypothesis between economic growth and CO_2 emissions and same inference is drawn between coal consumption and CO_2 emissions. Hwang and Yoo (2014) conducted similar study for Indonesia using annual data covering the period 1965–2006. The results show that there is a bi-directional causality between energy consumption and CO2 emissions. In addition, the results support the occurrence of unidirectional causality running from economic growth to energy consumption and to CO_2 emissions without any feedback effects.

However, as shown above, few studies have investigated the relationship between energy consumption, economic growth and CO_2 emission by taking oil consumption as the proxy for energy consumption. Specifically, to the best of our knowledge, no empirical study in the context of Indian economy has taken oil consumption as the proxy for energy consumption while investigating the above nexus. Hence, this paper seeks to investigate the nexus between energy consumption, economic growth and CO_2 emission for India by taking oil consumption as the proxy for energy consumption to fill the research gap and enrich the literature.

3. Data Source and Variable Identification:

To conduct our empirical analysis and investigate the relationship between CO_2 emission, energy consumption and economic growth, we have considered following variables for Indian economy;

- CO_2 emission (CE) measured in metric tons per capita
- Energy Consumption (EC) measured in Kt of Oil equivalent per capita
- Per capita real GDP (PGDP) measured at 2005 constant US dollars which is used as the proxy for economic growth.
- Trade openness (TO) measures as a percentage of (exports + imports) to GDP which is used as the proxy of foreign trade.
- Urban Population (URB) measured as the ratio of urban population to the total population in the country over the year which is used as the proxy for urbanization.
- Gross Fixed Capital Formation (GFCF) is measured as 2005 constant US dollar which is used as the proxy for capital stock.

The data are collected from World Bank development indicator (WDI). Data are annual data and cover the period 1971 – 2012 for the Indian economy.

4. Empirical Model and Conceptual Framework

4.1 Empirical Model

In order to find the long-run relationship between CO_2 emissions, energy consumption, economic growth, and few control variables, viz., trade openness, capital stock and urbanization, the following linear logarithmic form is proposed

$$\mathrm{LCE} = \alpha_0 + \alpha_1 \mathrm{LEC} + \alpha_2 \mathrm{LPGDP} + \alpha_3 \mathrm{LTO} + \alpha_4 \mathrm{LURB} + \alpha_5 \mathrm{LGFCF} + \varepsilon_t \quad (1)$$

Where LCE is CO_2 emissions per capita, LEC is energy consumption per capita, LPGDP is per capita real GDP, LTO is trade openness, LURB is urbanization, LGFCF is the capital stock and ε is the random error term. The parameters α_1 α_2 α_3 α_4 and α_5 represent long-run elasticity of carbon dioxide emissions with respect to LEC, LPGDP, LTO, LURB and LGFCF respectively.

4.2. Conceptual Framework:

Oil now constitutes a critical factor in sustaining the well-being of an emerging country as well as the nation's economic growth. Production in industries such as manufacturing, transportation, and electricity generation demands a substantial amount of oil. It emits a high amount of CO_2 and pollutes our environment. It is empirically and theoretically shown that an increase in energy consumption results in greater economic activity. Thus we can expect that energy consumption and high level of economic growth (GDP) to have positive impact on CO_2 emissions at least in the short run. Thus from Equation (1) we have $\alpha_1 > 0$ and $\alpha_2 > 0$. International trade causes the movement of produced goods from one country to another for either consumption or for further processing. More consumption of goods and further processing of goods, which takes place due to greater trade openness, is a source of pollution. This implies that pollution is stimulated from further processing and manufacturing of goods which results from greater trade openness. Thus we can expect that trade openness to have a positive impact on CO_2 emission indicating that $\alpha_3 > 0$ in Equation (1) at least in the short-run. Further, due to increased urbanization, most cities are growing at a faster rate than the national average, as the endurance workers are migrating from rural area to urban area for better jobs, better life, better education, better treatment, etc. Thus urban populations put pressure on urban resources and as a result environment is polluted. Thus we expect that there is a positive impact of urbanization on CO_2 emissions, indicating that $\alpha_4 > 0$ in Equation (1). Finally, an increase in capital formation results in greater economic activity of a country. Thus we can expect that capital stock and high level of economic growth (GDP) to have positive impact on CO_2 emissions. But the expectations of sign of the coefficient of different variables of Equation (1) based on subjective judgment are not always true, in reality. Hence, in the present study, variables such as energy consumption, economic growth, trade openness, capital stock and urbanizations are introduced to determine the level of CO_2 emissions for India.

5. Econometric Methodology

5.1 ARDL bounds test

The bounds test approach for cointegration, known as the autoregressive-distributed lag (ARDL) of Pesaran Shin and Smith (2001), has become most popular amongst researchers. The bounds test approach has certain econometric advantages in comparison to other single equation cointegration procedure. They are as follows: 1) endogeneity problems and inability to test hypotheses on the estimated coefficients in the long-run associated with the Engle-Granger method, are avoided; 2 the long-run and short-run parameters of the model in question are estimated simultaneously; 3) the bounds test approach for testing the existence of long-run relationship between the variables in levels is applicable irrespective of whether the underlying time series variables are purely I(0), I(1) or fractionally integrated; 4) the small sample proper- ties of the bounds testing approach are far superior to that of multivariate. In this paper to implement the bounds test for cointegration, the following unrestricted regression equations have been formulated:

$$\Delta LCE = \alpha_0 + \sum_{i=1}^{q} \alpha_{1i}\, \Delta LCE_{t-i} + \sum_{i=0}^{q} \alpha_{2i}\, \Delta LEC_{t-i} + \sum_{i=0}^{q} \alpha_{3i}\, \Delta LPGDP_{t-i} + \sum_{i=0}^{q} \alpha_{4i}\, \Delta LTO_{t-i} + \sum_{i=0}^{q} \alpha_{5i}\, \Delta LURB_{t-i} + \sum_{i=0}^{q} \alpha_{6i}\, \Delta LGFCF_{t-i} + \alpha_7\, LCE_{t-1} + \alpha_8\, LEC_{t-1} + \alpha_9\, LPGDP_{t-1} + \alpha_{10}\, LTO_{t-1} + \alpha_{11}\, LURB_{t-1} + \alpha_{12}\, LGFCF_{t-1} + \varepsilon_{1t} \quad (2)$$

$$\Delta LEC = \alpha_0 + \sum_{i=0}^{q} \alpha_{1i}\, \Delta LCE_{t-i} + \sum_{i=1}^{q} \alpha_{2i}\, \Delta LEC_{t-i} + \sum_{i=0}^{q} \alpha_{3i}\, \Delta LPGDP_{t-i} + \sum_{i=0}^{q} \alpha_{4i}\, \Delta LTO_{t-i} + \sum_{i=0}^{q} \alpha_{5i}\, \Delta LURB_{t-i} + \sum_{i=0}^{q} \alpha_{6i}\, \Delta LGFCF_{t-i} + \alpha_7\, LCE_{t-1} + \alpha_8\, LEC_{t-1} + \alpha_9\, LPGDP_{t-1} + \alpha_{10}\, LTO_{t-1} + \alpha_{11}\, LURB_{t-1} + \alpha_{12}\, LGFCF_{t-1} + \varepsilon_{2t} \quad (3)$$

$$\Delta LPGDP = \alpha_0 + \sum_{i=0}^{q} \alpha_{1i}\, \Delta LCE_{t-i} + \sum_{i=0}^{q} \alpha_{2i}\, \Delta LEC_{t-i} + \sum_{i=1}^{q} \alpha_{3i}\, \Delta LPGDP_{t-i} + \sum_{i=0}^{q} \alpha_{4i}\, \Delta LTO_{t-i} + \sum_{i=0}^{q} \alpha_{5i}\, \Delta LURB_{t-i} + \sum_{i=0}^{q} \alpha_{6i}\, \Delta LGFCF_{t-i} + \alpha_7\, LCE_{t-1} + \alpha_8\, LEC_{t-1} + \alpha_9\, LPGDP_{t-1} + \alpha_{10}\, LTO_{t-1} + \alpha_{11}\, LURB_{t-1} + \alpha_{12}\, LGFCF_{t-1} + \varepsilon_{3t} \quad (4)$$

According to Pesaran, et al.(2001), the joint F-test of the lagged level variables in Equations (2) - (4) are used to test the presence of long-run equilibrium relationship. For instance in Equation (2) the test for cointegration is carried out by testing the null hypothesis of no cointegration is defined by H0: $\alpha_7 = \alpha_8 = \alpha_9 = \alpha_{10} = \alpha_{11} = \alpha_{12} = 0$, using the F-test. The variables are said to be cointegrated if the null hypothesis of no cointegration is rejected; otherwise the variables are not cointegrated. Similarly, procedures can also be carried out for testing the long-run equilibrium relationships for Equations (3) and (4). Two sets of critical values are provided; one which is appropriate where all the series are I(0) and the other is appropriate where all the variables are I(1). According to Pesaran, et al.(2001), if the calculated F-statistic falls above the upper critical value, a conclusive inference can be made regarding cointegration without knowing whether the series are I(0) or I(1). In this case the variables are said to be cointegrated indicating the existence of long-run relationship among the variables. Alternatively if the calculated F-statistic falls below the lower critical value the series are not cointegrated regardless of whether the series are I(0) or I(1). In contrast the inference is inconclusive if the calculated F-statistic falls within lower and upper critical values unless we know whether the series are I(0) or (1). The estimated results are given below in Table 2. The selection of the orders of lags in the ARDL models is very sensitive which is done by using two criteria AIC and SBC.

For short run behavior of the variables, we use error correction version of ARDL model as following:

$$\Delta LCE_t = \mu + \sum_{i=1}^{q} \alpha_i \, \Delta LCE_{t-i} + \sum_{i=0}^{q} \beta_i \, \Delta LEC_{t-i} + \sum_{i=0}^{q} \theta_i \, \Delta LPGDP_{t-i} + \sum_{i=0}^{q} \sigma_i \, \Delta LTO_{t-i} + \sum_{i=0}^{q} \mu_i \, \Delta LURB_{t-i} + \sum_{i=0}^{q} \phi i \, \Delta LGFCF_{t-i} + \lambda ECM_{t-1} + U_{1t} \quad (5)$$

$$\Delta LEC_t = \mu + \sum_{i=0}^{q} \alpha_i \, \Delta LCE_{t-i} + \sum_{i=1}^{q} \beta_i \, \Delta LEC_{t-i} + \sum_{i=0}^{q} \theta_i \, \Delta LPGDP_{t-i} + \sum_{i=0}^{q} \sigma_i \, \Delta LTO_{t-i} + \sum_{i=0}^{q} \mu_i \, \Delta LURB_{t-i} + \sum_{i=0}^{q} \phi i \, \Delta LGFCF_{t-i} + \lambda ECM_{t-1} + U_{2t} \quad (6)$$

Where $\alpha, \beta, \theta, \mu, \sigma, \phi$ are short run dynamic coefficient to equilibrium and λ is the speed adjustment coefficient. To ascertain the goodness of fit of the ARDL model, diagnostic and stability tests are conducted. The stability test is conducted by employing the cumulative sum of recursive residuals (CUSUM) and the cumulative sum of squares of recursive residuals (CUSUMSQ).

5.2 Granger Causality Test:

The direction of causality between foreign aid, economic growth, private investment, inflation, trade openness and government final consumption expenditure is investigated by applying the VECM Granger causality approach after confirming the presence of cointegration between the above mentioned variables. On the same line Granger and Newbold (1974) argued that vector error correction model (VECM) is more appropriate to examine the causality between the series at I(1). The VECM is restricted form of unrestricted VAR and restriction is levied on the presence of long run relationship between the series. The system of error correction model (ECM) uses all the series endogenously. This system allows the predicted variables to explain itself both by its own lags and lags of forcing variables as well as the lags of the error correction term and by residual term. The augmented form of the Granger causality test involving the error correction term is formulated in a multivariate p^{th} order vector error correction model given as below.

$$\begin{pmatrix} \Delta LCE_t \\ \Delta LEC_t \\ \Delta LPGDP_t \\ \Delta LURB_t \\ \Delta LTO_t \\ \Delta LGFCF_t \end{pmatrix} = \begin{pmatrix} C1 \\ C2 \\ C3 \\ C4 \\ C5 \\ C6 \end{pmatrix} + \sum_{i=1}^{p} \begin{bmatrix} \beta_{11i} & \beta_{12i} & \beta_{13i} & \beta_{14i} & \beta_{15i} & \beta_{16i} \\ \beta_{21i} & \beta_{22i} & \beta_{23i} & \beta_{24i} & \beta_{25i} & \beta_{26i} \\ \beta_{31i} & \beta_{32i} & \beta_{33i} & \beta_{34i} & \beta_{35i} & \beta_{36i} \\ \beta_{41i} & \beta_{42i} & \beta_{43i} & \beta_{44i} & \beta_{45i} & \beta_{46i} \\ \beta_{51i} & \beta_{52i} & \beta_{53i} & \beta_{54i} & \beta_{55i} & \beta_{56i} \\ \beta_{61i} & \beta_{62i} & \beta_{63i} & \beta_{64i} & \beta_{65i} & \beta_{66i} \end{bmatrix} \mathrm{X} \begin{pmatrix} \Delta LCE_{t-i} \\ \Delta LEC_{t-i} \\ \Delta LPGDP_{t-i} \\ \Delta LURB_{t-i} \\ \Delta LTO_{t-i} \\ \Delta LGFCF_{t-i} \end{pmatrix} + \begin{pmatrix} \gamma_1 \\ \gamma_2 \\ \gamma_3 \\ \gamma_4 \\ \gamma_5 \\ \gamma_6 \end{pmatrix} ECM_{t-1} + \begin{pmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \\ \varepsilon_{4t} \\ \varepsilon_{5t} \\ \varepsilon_{6t} \end{pmatrix}$$

(7)

The C's, β's and γ's are the parameters to be estimated. ECM_{t-1} represents the one period lagged error-term derived from the cointegration vector and the ε's are serially independent with mean zero and finite covariance matrix. From the Equation (7) given the use of a VAR structure, all variables are treated as endogenous variables. The F test is applied here to examine the direction of any causal relationship between the variables. The energy consumption (EC) does not Granger cause CO_2 emissions (CE) in the short run, if and only if all the coefficients of $\beta_{12i's}$ are not significantly different from zero in Equation (7). Similarly the CO2 emissions do not Granger cause energy in the short run if and only if all the coefficients $\beta_{21i's}$ are not significantly different from zero in the Equation (7). There are referred to as the short-run Granger causality test. The coefficients on the ECM represent how fast deviations from the long-run equilibrium are eliminated. Another channel of causality can be studied by testing the significance of ECM's. This test is referred to as the long run causality test.

6. Empirical Analysis:

6.1 Stationarity Test Results

To determine the order of integration, this study uses unit root tests advocated by Elliott, et al. (1996), Phillips and Perron (1988) and Kwiatkowski, et al. (1992). The vital results of these tests are reported in Table 1. The results indicate that all series are non-stationary at their level but stationary at their first differences irrespective of using the random walk model with drift or random walk model with slope. In time series econometrics, series integrated of order one are denoted by X_t I (1) and series integrated of order zero by ΔX_t I (0). Here, the order of the integration is one. Note that the same order of integration is a pre-requisite when the Johansen framework is used for testing cointegration and then the causality. Our Johansen cointegration test is complemented by the ARDL bound test. That is why we also check whether any of the variables is I(2) because of the critical values provided by Pesaran et al. (2001) are only for I(0) and I(1). The results confirmed that none of the variables are I (2), therefore, it allows for testing long-run relationship by ARDL method.

Table 1: Unit root Tests (With Trend and Intercept)

Variables	DF-GLS	PP	KPSS
LEC	-0.712	-0.6273	0.1739
LCE	-2.2956	-2.2657	0.1431
LGFCF	-2.5137	-2.5583	0.0943
LPGDP	-0.5105	-0.7867	0.2065
LTO	-1.4523	-1.5821	0.1444
LURB	-1.1320	-1.4220	0.1897
ΔLEC	**-6.2276**	**-6.1139**	**0.0818**
ΔLCE	**-6.4411**	**-6.4232**	**0.0759**
ΔLGFCF	**-6.8739**	**-6.7784**	**0.0574**
ΔLPGDP	**-7.4350**	**-10.0109**	**0.0964**
ΔLTO	**-5.5539**	**-5.4927**	**0.1037**
ΔLURB	**-4.2906**	**-4.2288**	**0.1096**

Note: All the variables are in natural logs, lag lengths are determined via SIC. The null hypothesis of all the test except KPSS are unit root. KPSS test null hypothesis is stationary.

6.2 ARDL Test Results

After determining the order of integration, next we employ ARDL approach to co-integration in order to determine the long run relationship among the variables. The F-Statistics tests the joint Null hypothesis that the coefficients of lagged level variables in equation (2 - 4) are zero. Table 2, reports the result of the calculated F-Statistics. The bound test evidence confirms the long run relationship for equation 2 and 3 with LCE and LEC as the dependent variables. As in these cases, the calculated F statistics greater than the critical values of the upper level of the bound at 1% level of significance for both the models.

Table 2: ARDL bounds testing procedure, tests of long run procedure

Test Equation	Lags		
	1	2	3
F (LCE | LEC, LPGDP, LURB, LTO, LGFCF)	**5.6810***	3.651	2.542
F (LEC | LCE, LPGDP, LURB, LTO, LGFCF)	**4.9759***	3.4523	3.004
F (LPGDP | LEC, LURB, LTO, LGFCF)	3.6021	3.090	2.604

The next step is to estimate the long run and short run coefficients of ARDL model. The estimated long run coefficient of ARDL approach for the equation with LCE as the dependent variable (Model A) and LEC as the dependent variable (Model B) are presented in Table 3.

From the estimated results in Table 3 (model A) it has been found that for a 100% increase in the energy consumption leads to 118% increase in carbon dioxide emissions in the long run which is statistically significant at any significance level. The elasticity of carbon dioxide emissions with respect to urbanization is 0.9162, suggesting that for increasing 100% urbanization the carbon dioxide is increased by 91% and the contribution of urbanization in India is also significant at 1% level. Further, per capita GDP influences the carbon emission negatively and significant at 1% in the long run. The long run elasticity of carbon emission with respect to capital stock is 0.63 and the coefficient is significant at 1% level. This implies that heavy investment in India resulted in high carbon dioxide emissions over the years. But in case of foreign trade, the relationship is insignificant with respect to carbon dioxide emission. From model B results, it is found that the long run elasticity of energy consumption in India with respect to economic growth is 0.46, suggesting that for increasing 100% growth the energy consumption increases by 46% and the contribution is significant at 1%. However, other variables fail to influence significantly the energy consumption level in India.

Table 3: Estimated Long Run Coefficients using ARDL Approach

Model A: Dependent variable: LCE

Regressor	**Coefficients**	**T-Statistics (Probabilities)**
LEC	1.1829	3.536 (0.000)***
LPGDP	-0.9162	-3.1663 (0.004)***
LURB	0.9196	4.8530 (0.000)***
LTO	0.1199	1.212 (0.206)
LGFCF	0.6315	3.506 (0.001)***
CONS	-3.9171	-6.4528 (0.000)
Robustness Indicators		
R^2	0.9977	Serial Correlation, F = 2.6552[.114]
Adjusted R^2	0.9971	Heteroscedasticity, F=2.0129[.164]
F Statistics	1477.1	Ramsey Test F=.076745[.701]
D.W. Stat	2.1834	

Model B: Dependent variable: LEC

Regressor	**Coefficients**	**T-Statistics (Probabilities)**
LCE	0.2075	1.8284 (0.077)
LPGDP	0.4576	4.7710 (0.000)***
LURB	-0.2451	-1.3505 (0.186)
LTO	-0.03295	-0.5831 (0.564)
LGFCF	0.1563	0.8889 (0.419)
CONS	1.3937	4.1163 (0.000)
Robustness Indicators		
R^2	0.9972	Serial Correlation, F = 0.4532[.506]
Adjusted R^2	0.9966	Heteroscedasticity, F=0.2276[.636]
F Statistics	1916.1	Ramsey Test F=.064843[.801]
D.W. Stat	2.2037	

Note: Figures in parentheses are estimated t-values. *, ** and *** indicate significant at 10, 5 and 1 percent level of significance, respectively.

The error correction mechanism (ECM) is employed to check the short run relationship among the variables. The results are presented in Table 4 for the estimated equation 5 and 6. Model A results show that the coefficient of ECM (-1) is significant at 1% level which indicate that the speed of adjustment for short run to reach long run is significant. Further, the error correction term is -0.3917 with expected sign, suggesting that when the per capita carbon dioxide emissions is above or below its equilibrium level, it adjusts by almost 39% per year. The full convergence process takes about 2 and half year. The environmental quality is not found to be good in respect of energy consumption and urbanization in India, because the long run elasticity of CO_2 emission with respect to energy consumption (1.18) is higher than short run elasticity of (0.71) and long run elasticity with respect to urbanization (0.91) higher than that for the short run (0.36). This means that over time higher energy consumption and urban growth in India give rise to more CO_2 emissions and the environment will pollute more. For model B, the coefficient of ECM (-1) is significant at 5% level which indicate that the speed of adjustment for short run to reach long run is good. Further, the error correction term is -0.32 with expected sign, suggesting that when the per capita energy consumption is above or below its equilibrium level, it adjusts by almost 32% per year. The diagnostic test for serial correlation, hetereoscedasticity, functional misspecification and non-normal errors are conducted. The rest results indicate that there is no evidence of serial correlation, hetereoscedasticity, functional misspecification and non-normal errors.

Table 4: Error Correction representation for the selected ARDL Model

Model A : dependent variable is LCE

Regressor	Coefficients	T-Statistics (Probabilities)
ΔLEC	0.7102	2.9112 (0.006)***
ΔLPGDP	-0.06294	-0.3471 (0.736)
ΔLURB	0.3602	2.9675 (0.006)***
ΔLTO	-0.0683	-1.1109 (0.275)
ΔLGFCF	0.0317	0.3417 (0.001)
ΔCONS	-1.5345	-3.7100 (0.001)
ECM (-1)	-0.3917	-4.4774 (0.000)***
Robustness Indicators		
R^2	0.5271	RSS : 0.00345
Adjusted R^2	0.3857	S.E.R. : 0.0107
D.W. Stat	1.8451	

Model B : dependent variable is LE C

Regressor	Coefficients	T-Statistics (Probabilities)
ΔLCE	0.0672	1.2253 (0.229)
ΔLPGDP	0.1482	2.1048 (0.050)**
ΔLURB	-0.0794	-1.3224 (0.195)
ΔLTO	-0.1067	-0.5655 (0.576)
ΔLGFCF	0.0506	1.1310 (0.266)
ΔCONS	0.4514	1.5454 (0.132)
ECM (-1)	-0.3238	-2.0904 (0.044)**
Robustness Indicators		
R^2	0.4749	RSS : 0.0011
Adjusted R^2	0.3795	S.E.R. : 0.0059
D.W. Stat	2.2037	

Note: Figures in parentheses are estimated t-values. *, ** and *** indicate significant at 10, 5 and 1 percent level of significance, respectively.

6.4 Granger Causality Test:

The panel short run and long run Granger causality results are reported below in Table 5. The reported values in parentheses are the p-values of the test. The findings indicate that short-run unidirectional causality running from energy consumption, economic growth and trade openness and urbanization to carbon dioxide emissions in India and bi-directional short-run causal relationship between energy consumption and economic growth in India. It has been found that the error correction terms are statistically significant for the specification with LCE as the dependent variables which indicate that there exists a long-run relationship among the variables in the form of Equation (1).

Table 5: VECM Granger Causality Test Results

	Sources of Causation(F values)						*ECM (t Value)*
	ΔLCE	ΔLEC	ΔLPRGDP	ΔLTO	Δ LURB	ΔGFCF	
ΔLCE	--	5.5741*	5.8536*	5.1838*	2.5612**	1.3456	-3.2132*
ΔLEC	1.8041	--	2.6781*	2.0628	1.9518	0.4567	1.8927
ΔLPRGDP	0.1743	3.8291*	--	0.3516	0.12407	2.5678	0.4536
ΔLTO	2.4494	0.5428	2.7474	--	0.5219	0.4567	1.0213
ΔLURB	0.5882	0.5705	0.6452	0.8673	--	1.4567	-1.0667
ΔGFCF	0.5677	0.4567	1.6789	0.5678	1.0234	--	-1.5689

6.5 CUSUM and CUSUMSQ Tests:

Finally the stability of the long-run parameters together with the short-run movements for the equations has been examined using cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests proposed. The related graphs of these tests are presented below in Figures 2 and 3. From Figures 2 and 3 it can be seen that the CUSUM and CUSUMSQ tests results are within the critical bounds implying that all coefficients in the error correction model are stable. Therefore the preferred CO_2 emissions model and energy consumption model can be used for policy decision making purpose, such that the impact of policy changes considering the explanatory variables of CO_2emissions and energy consumption equation will not cause major distortion in the level of CO_2 emissions, since the parameters in this equation seem to follow a stable pattern during the estimation period.

Figure 2: Stability test for CO_2 emission equation

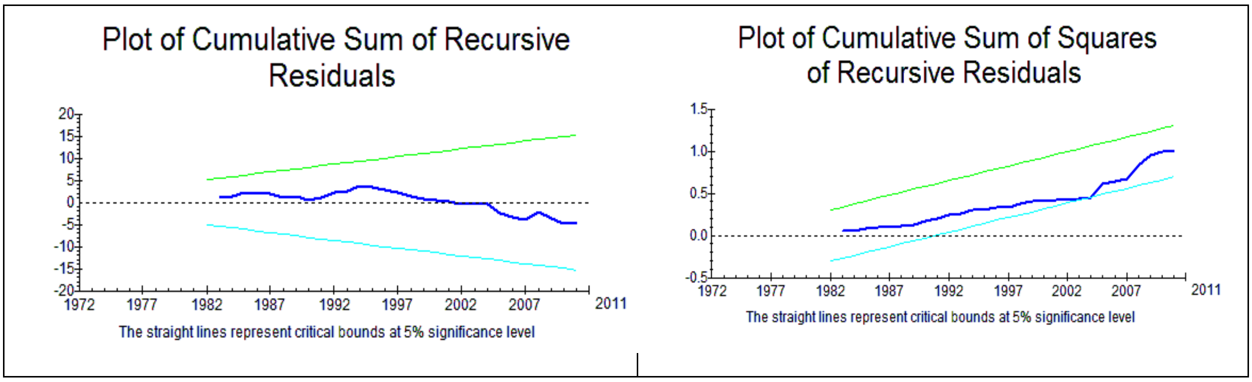
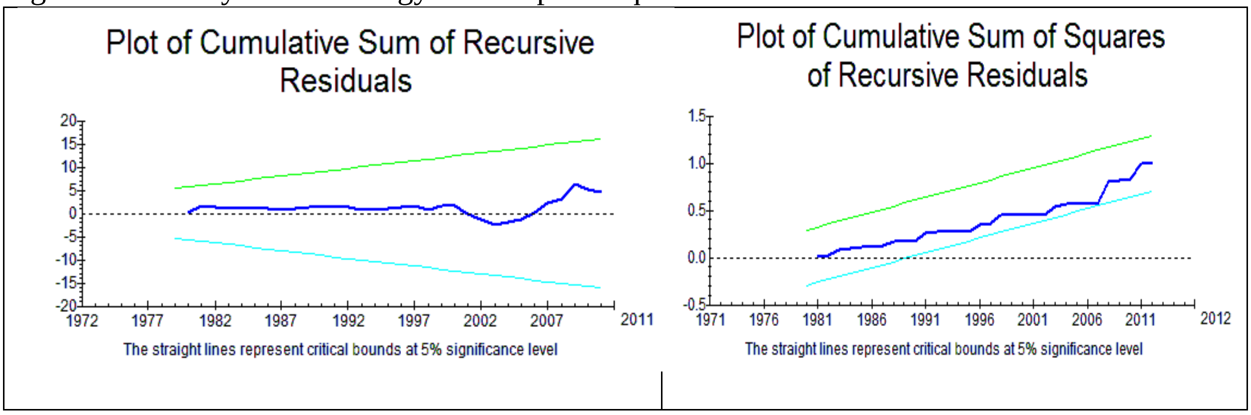


Figure 3: Stability test for energy consumption equation



7. Conclusions and Policy Implications

This paper made an attempt to investigate empirically the dynamic causal relationships between CO_2 emissions, energy consumption and economic growth and few control variables such as foreign trade, urbanization and gross fixed capital formation by using the cointegration and causality analysis in India. The estimated results from bounds test confirmed that CO_2 emissions, energy consumption, economic growth and the control variables are cointegrated. The ARDL test coefficient results of the long-run elasticity of CO_2 emissions with respect to energy consumption is higher than short run elasticity and CO_2 emissions with respect to urbanization is higher than short run elasticity. This indicates that the environmental quality was not found to be good in relation to energy consumption and urbanization in India. This means that over time higher energy consumption in India might give rise to more CO_2 emissions as a result the environment will be expected to be polluted more. The variable energy consumption and urbanization had positive impact while economic growth had negative impact on CO_2 emissions in the long-run.

The Granger causality test results supported the existence of unidirectional short-run causal relationship from energy consumption, trade openness, economic growth and urbanization to CO_2 emissions and bi-directional causal relationship between energy consumption and economic growth in India. It was found that the error correction terms in VECM are statistically significant when CO_2 emissions was taken as the dependent variable but insignificant when economic growth and energy consumption was considered as the dependent variables. This indicates the existence of a long-run relationship among the variables with CO_2 as dependent variable. Further, it was found that the long-run as well as short-run energy consumption has significant positive impact on carbon dioxide emissions. This implies that for expansion of the industrial output, more of energy is consumed, which puts pressure on the environment due to more emissions. Thus it is very essential to apply some sort of pollution control action with respect of energy consumption in India.

From the analytical results, the following points may be suggested for implementation to control CO_2 emissions. India needs to embrace more energy conservation policies in order to reduce carbon dioxide emissions and they should consider strict environmental and energy policies. The research and investment in clean energy should be an integral part of the process of controlling the CO_2 emissions and have to find alternative sources of energy to attain sustainable economic growth. Nuclear power plant may be an option for environmental friendly source of energy since its emission of CO_2 is less than many other sources, and according to the study of Sudtasan and Suriya (2014) indicates that nuclear power plant can be included in combination of energy sources to generate electricity with low pollution measured by the emission of CO_2. Moreover, nuclear power plant is also efficient in terms of cost-benefit analysis over other sources of energy regarding to Sudtasan and Suriya (2012). Thus implementing the environmental and energy policies and also reconsidering the strict energy policies can control CO_2 emissions in India.

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