

10th International Conference on Applied Energy (ICAE2018), 22-25 August 2018, Hong Kong, China

Effect of energy consumption & economic growth on environmental degradation in India: A time series modelling

Krishan K. Pandey\textsuperscript{a*}, Harshil Rastogi\textsuperscript{b}

\textsuperscript{a}\textit{Professor \& Director, Office of Doctoral Studies, O.P. Jindal Global University, Sonipat, Haryana, India}
\textsuperscript{b}\textit{MBA Scholar, Jindal Global Business School, O.P. Jindal Global University, Sonipat, Haryana, India}

Abstract

This study empirically investigates the impact of energy consumption (electricity consumption) and economic growth (in terms of real Gross Domestic Product) on the environmental degradation in form of CO2 emissions. The study aims to identify the interrelationship among the three variables viz. real GDP, electricity consumption & CO2 emissions. The analysis is based on the time series annual data for the period of 1971-2017. We tested the stationarity for the variables by applying Dicky Fuller test and examined the short run & long run causal relationships among electricity consumption, real GDP and CO2 emissions using Johansen Cointegration & Granger Causality approach. The Johansen cointegration test ascertains that some combinations of the two variables are cointegrated which concludes the long-term relationship among the defined variables. The results also indicate for a short run causality from electricity consumption to economic growth and to the CO2 emissions. The results conclude that India should take stringent measures to curb the surging emissions of greenhouse gases in which CO2 has a major portion.

\textcopyright\ 2019 The Authors. Published by Elsevier Ltd.
This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/)
Peer-review under responsibility of the scientific committee of ICAE2018 – The 10th International Conference on Applied Energy.

**Keywords:** CO2 emissions; Energy Consumption in India; environmental degradation; economic growth.

1. Introduction

Climate change has become an absolute environmental challenge in last couple of decades in every continent and all sectors across the world. It occurs due to increase in temperature of atmosphere by burning of fossil fuels and releasing

\textsuperscript{*} Corresponding author. Tel.: +91-8396907453
E-mail address: kkpandey@jgu.edu.in
of greenhouse gases most specifically Carbon-di-oxide. These days, massive quantities of fossil fuels have been used for energy source to power the economy of a country. This scenario significantly contributes to a large percentage of carbon dioxide emissions. By comparing with other economic sectors, it was reported in the literature that the consumption of energy in buildings accounts for about one third of the total consumption and responsible for an equal portion of carbon dioxide emissions in both developed and developing countries. Similarly, an economic growth of a country directly or indirectly affects the CO2 emissions in the environment. There are manifold links between a country’s economic growth and environment. The environment provides resources for the economy and acts a sink for emissions. Aye & Edoja (2017), investigated the effect on economic growth on CO2 emissions and indicated that in the low growth regime, economic growth has negative effect on CO2 emissions but in the high growth regime, a positive effect with the marginal effect being higher prevails [1].

With the advent of various technology encroachments and ever progressing economic growth with the increasing energy consumption per capita, CO2 emissions is a major distress not only for India but for the whole world. Since liberation, sustainable economic growth has been an issue of major concern in India. With progressive economic growth, environmental protection must be considered for a high and sustainable economic growth.

India is the sixth largest economy of the world with a nominal GDP of US $ 2.45 (International Monetary Fund. Retrieved 1st October 2017) and currently India surpassed China in world’s fastest growing economy. According to BP statistical (2017), India’s energy consumption grows by 5.4 % in 2016 as it remained the third largest energy consumer in the world. India has 2088 MtCO2 CO2 emissions from fuel consumption, making it third largest country of the world as a CO2 emitter (Global Energy Statistical Yearbook 2017). Witnessing such a quantum of growth, there arises a need of intensified study to establish a relationship of GDP and energy consumption with CO2 emissions [2]. As per Maenhout et.al (2017), India’s CO2 emissions continued to increase to 2.5 Gton CO2 in 2016, 4.7% more than in 2015. This annual increase is a little below the average annual increase of 7.5% per year for the period 2006–2012 [3]. India is the next largest emitting country after China, the United States and the EU28. However, India’s per capita emissions of 1.9-ton CO2/cap/year are more than four times lower than the average per capita emissions of China and the EU28, eight times lower than the average per capita emissions of the United States and lower even than average per capita emissions in many developing countries. India’s emissions are not yet decoupled from GDP growth. The major contribution to India’s growing emissions is the 5.7%/year increase in Total Primary Energy Supply (TPES), 57% of which is supplied by coal. Annual coal consumption increased with 3.6% whereas annual oil consumption increased by 8.6% (with a 29.4 % share of TPES), according to BP (2017).

Hence therefore this paper aims to establish a relationship between energy consumption of India, economic growth in terms of real Gross Domestic Product (GDP) and combined effect on degradation of environment in terms of CO2 emissions using annual historical data for the years 1971-2017.

2. Literature Review

There is a wide variety of hypothetical and experimental studies finding the interrelationship of energy consumption, economic growth and environmental degradation in terms of CO2 emissions in both developed and developing countries. Different empirical studies have targeted on different countries, time periods and have analysed different proxy variables for macroeconomic and energy indicators & their combined effect on environmental degradation. Literature also reveals some eminent work done in relation to the effect of energy consumption & economic growth on environmental degradation. Some of the earlier studies conducted on this topic used Granger Causality, Unit root and co-integration test to establish the relationship among the three variables i.e. Energy consumption, real GDP and CO2 emissions.

Nain et.al.(2017) examines the short run and long run causal relationships among the three variables by using aggregate and disaggregate (sectoral) energy consumption measures using the annual data from 1971 to 2011. It includes Toda-Yamamoto causality test and reveal that the long run and short run causal relationship among the variables is not uniform across sectors. Also, the weights of evidences from the study indicates that there exists a short run causality from electricity consumption to economic growth and to the CO2 emissions [4].

Tiwari (2011) revisits the evidence from India’s energy consumption, CO2 emissions and economic growth and examines causality in both static and dynamic frameworks among the three variables with the time series data for the period of 1971-2007. The study uses IRFs and VDs whose results indicate that CO2 emissions has positive impact on energy use and capital but negative impact on population and GDP. It implies that in the framework of production functions, energy use in the production process substitute labour and capital. It claims that as energy consumption
(EC) generates GDP, therefore, reduction in EC has a negative impact on economic growth and Indian economy may confine to developing economy [5].

Ghosh (2009) establishes the presence of Granger Causality running from real GDP and electricity supply to employment without any feedback and the author uses supply of electricity instead of electricity consumption [6].

Paul & Bhattacharya (2004) examines the different direction of causal relation between energy consumption and economic growth in India. Applying Engle–Granger co-integration approach combined with the standard Granger causality test on Indian data for the period 1950–1996, the study finds a bi-directional causality between energy consumption and economic growth. It also applies Johansen multivariate co-integration technique on the different set of variables [7].

Nain & Ahmad (2012) Examines the relationship between electricity consumption and economic growth in India at aggregated and disaggregated level using annual data of 1970-2010. The study suggests that there is a long-term relationship and economic growth at aggregated level. In agriculture, commercial and industrial sectors the ARDL test exhibit a long-term relationship except for the domestic sector at disaggregated level [8]. According to MSPI (2015) CO2 is the most vital anthropogenic Green House Gas (GHG) that constitutes 70% of total emissions [9]. The analysis of time series data of CO2 emissions conducted by Enerdata (2018) infers that India’s contribution to the world in 2016 is 6.64% as compared to USA contribution of 16.25% and China’s contribution of 27.95% [10]. As per Indian Central Pollution Control Board, there is no set defined standard for CO2 emissions in thermal power plants. The government of India recommends some levels but don’t obligate them on coal fired power plants [11].

Shearer (2017) discusses about Paris climate agreement in which world’s countries decided to limit the increase of global mean temperature to well below 2°C and make efforts to limit temperature increase to 1.5°C above pre-industrial level. This aims to frame a country level emission pledge known as Nationally Determined Contributions (NDC’s) [12]. According to its NDC, India didn’t pledge any specific reduction of its greenhouse gas emissions, instead pledged to lessen its emissions per unit GDP by 33-35% from 2005 levels by 2030 and increase its share of non-fossil-based generation capacity to 40% of installed electric power generation by 2030 [13].

We are confining our literature review only on the studies done in the perspective of India and above are the explanations and key highlights discussed in the studies done related to our topic. The last study conducted by Nain et.al. (2017) is for the period of 1971 to 2011 [4]. Since then energy consumption of India has surged from 803 TW-h in 2011 to 1065 TW-h in 2016 i.e. it jumped to 33 % approx. Taking in consideration, the present study examines the interrelation among the energy consumption, economic growth in terms of Gross Domestic Product (GDP) and environmental degradation in terms of CO2 emissions using the data both at aggregated and disaggregated level with stretched time series in the Indian framework.

3. Theory & Hypothesis

This study aims to analyse to study the interrelationship among the three variables which are well defined in the coming section.

Variable 1: Economic Growth: can be defined as the increase in the capacity of an economy to produce goods & services which is compared over a period. We are taking real Gross Domestic Product (GDP) as a measure of economic growth. India’s real GDP growth rate is 7.2% for the Q3 2017-18. The Reserve Bank of India quoted that "On the whole, GDP growth is projected to strengthen from 6.6 per cent in 2017-18 to 7.4 per cent in 2018-19 in the range of 7.3-7.4 per cent in H1 and 7.3-7.6 per cent in H2 with risks evenly balanced” [14] [15].

Variable 2: Energy Consumption: can be defined as consumption of energy in the form of electrical power for industrial and domestic purposes. As per BP energy outlook (2018) India’s energy consumption would grow by 4.2% p.a. which is faster that all major economies in the world and India will overtake China as the largest growth market by the late 2020’s [16]. BP statistical (2017) highlights that India’s primary energy consumption rose by 5.4% in 2016 as it remained the third largest consumer in the world. India remained the second largest coal consumer in the world for the second consecutive year having 11% share in global coal consumption in 2016 [2].

Variable 3: CO2 emissions: can be defined as the gaseous pollutants in the form of CO2 which are emitted by industries specifically by the thermal power plants which are a major source of electrical energy production leading to consumption. India there has 65.76% growth in the previous decade in CO2 emissions [2].
**Null Hypotheses**: There is no causal interrelationship among the three variables defined.

**Alternate Hypotheses**: There exists a causal interrelationship among the variables defined.

Earlier work & literature in this field has clearly shown and concluded with some positive relationships among the variables. Nain et al. concludes that there exists a short run causality from electricity consumption to economic growth and to the CO2 emissions [4]. Yang & Zhao (2014) examined the relationship between economic growth, CO2 emissions and energy consumption in India using Granger Causality test and directed acyclic graphs and find unidirectional causality from energy consumption to economic growth and CO2 emissions [17].

4. **Data Collection**

Our study uses secondary data collected from various reliable government sources which has been aggregated and analyzed further sections. We are not using primary sources for our data collection as these sources which involves surveys, interviews will not solve our purpose of collecting a substantial amount of data as time series. So, we will use only secondary data collection techniques which involves collecting information from a diverse source of documents or electronically stored information. With reference to our study which is contextual to India we are using secondary sources viz. Central Statistical Organization (CSO), Ministry of Statistics & Program Implementation (MOSPI), Central Electricity Authority (CEA), Central Pollution Control Board (CPCB), World Bank, Government of India, BP Statistical Review Reports, BP energy Outlook, Emissions Database for Global Atmospheric Research (EDGAR). This study has been proposed to extract and analyze interrelationship among the energy consumption, economic growth & CO2 emissions. We will use econometric methodology like Correlation, Regression, time series modelling, Granger Causality method to compute the interrelationship among the variables. Our data sample includes annual data on real GDP, total electricity consumption (in GWh) and CO2 emissions from electricity production for the period of 1971-2017.

5. **Empirical Methodology**

Here we are analysing the effect of economic growth & electricity consumption on the CO2 emissions with a time series data for the period of 1971-2017. This can be investigated only by applying causation, so we must test our data for stationarity for causal analysis. The commonly used methodologies for conducting cointegration test and causality are residual test of co-integration [18], [19]. Granger (1981) pointed that time-series analysts have a rather different approach to the analysis of economic data than does the remainder of the econometric profession [20]. A fundamental requirement to implement these tests is that the variables should be integrated of order one and of equal order. In this study, an autoregressive distributed lag (ARDL) approach has been used to analyse the presence of long-run relationship among economic growth, electricity consumption and CO2 emissions at both aggregate and disaggregate (sectoral) levels [21].

Based on the availability of data, our sample includes annual data on real GDP, total electricity consumption (in GWh), consumption of electricity at the sector level, namely, agriculture, commercial, domestic and industry (in GWh), CO2 emissions from electricity and heat production (million tons) collected from the Reserve Bank of India, Central Statistical Organization (CSO), Ministry of Statistics and Programme Implementation (MOSPI), Government of India, and World Bank for the period 1971–2017. To compare the results of literature and because of the global importance of this issue, we have used CO2 emissions in absolute value instead of per capita. All the variables are converted into the natural logarithm to analyse them on a constant scale. Descriptive statistics of total electricity consumption, real GDP, CO2 emissions, and electricity consumption in agriculture, industrial, commercial, domestic and railways & traction consumption denoted by LNTec, LNGDP, LNCO2, LNAC, LNIC, LNCC, LDNC and LNTR respectively, are presented in Table given below.

<table>
<thead>
<tr>
<th>Mean</th>
<th>Std Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO2 emissions in MtCO2</td>
<td>GDP (Billions)</td>
</tr>
<tr>
<td>941.507</td>
<td>661.673</td>
</tr>
<tr>
<td>98.706</td>
<td>101.567</td>
</tr>
</tbody>
</table>

**Table 1**
concludes a long run relationship among the defined variables at aggregated and disaggregated (sectoral) level.

indicates that economic growth and electricity consumption for different sectors viz. industrial, agricultural, domestic, presence of at least one vector of cointegration exists among the cointegrated variables. Further analysis of results exists at least one vector of cointegration. It has been observed that CO2 emissions and electricity consumption for commercial & industrial sectors; but for domestic electricity consumption there exists a unidirectional causality with economic growth  and environmental sustainability. Hence, India should  frame policies which aggrava tes the presence of at least one vector of cointegration exists among Electricity consumption, Economic growth and CO2 emissions. The tests were performed on the annual data for the period of 1971-2017.

The results of the cointegration test indicates that economic growth and CO2 emissions are cointegrated and there exists at least one vector of cointegration. It has been observed that CO2 emissions and electricity consumption for different sectors viz. industrial, agricultural, domestic, commercial & traction and railways, are also cointegrated and presence of at least one vector of cointegration exists among the cointegrated variables. Further analysis of results indicates that economic growth and electricity consumption for different sectors viz. industrial, agricultural, domestic, commercial & traction and railways, are also cointegrated and presence of at least one vector of cointegration exists among the cointegrated variables. Also, the total electricity consumption and CO2 emissions are cointegrated which concludes a long run relationship among the defined variables at aggregated and disaggregated (sectoral) level.

The results of Granger Causality analyse the unidirectional and bidirectional causality among the defined variables. The results reveal that there exists a bidirectional causality running from economic growth (in terms of GDP) and CO2 emissions. The electricity consumption in traction and railways Granger causes CO2 emissions and therefore asserts a unidirectional causality. The results also indicate that there exists a bidirectional granger causality between electricity consumption in agricultural, commercial & industrial sectors and CO2 emissions. There also exists a bidirectional causality running from economic growth and electricity consumption in agricultural, traction & railways and industrial sectors; but for domestic electricity consumption there exists a unidirectional causality with economic growth i.e. economic growth granger causes domestic consumption. Also, the economic growth granger causes commercial consumption and holds a unidirectional causality. There also exists a bidirectional causality running from total electricity consumption and CO2 emissions.

Therefore, the study concludes that India should not frame exclusive energy policy for the reductions in CO2 emissions; Instead, India should frame policies considering sustainable economic development. India should adopt different policy options for different sectors on a priority basis. India should discover substitutable sources of energy by making huge investment in R & D and through international associations. India should prioritize & incentivize the private researchers to perform R & D in the sectors of pure and effective energies so that better prospects can be unveiled (because of lack of firm governmental policies) and there will not be any trouble in sustaining its high economic growth and environmental sustainability. Hence, India should frame policies which aggravates the sustainable development & also by taking in account of specific carbon emission-related issues on a sectoral basis in place of an aggregated policy for the whole economy.

6. Conclusion & Policy Implications

This study applies ADF test, Cointegration test and finally Granger Causality test to examine the interrelationship among Electricity consumption, Economic growth and CO2 emissions. The tests were performed on the annual data for the period of 1971-2017.

The results of the cointegration test indicates that economic growth and CO2 emissions are cointegrated and there exists at least one vector of cointegration. It has been observed that CO2 emissions and electricity consumption for different sectors viz. industrial, agricultural, domestic, commercial & traction and railways, are also cointegrated and presence of at least one vector of cointegration exists among the cointegrated variables. Further analysis of results indicates that economic growth and electricity consumption for different sectors viz. industrial, agricultural, domestic, commercial & traction and railways, are also cointegrated and presence of at least one vector of cointegration exists among the cointegrated variables. Also, the total electricity consumption and CO2 emissions are cointegrated which concludes a long run relationship among the defined variables at aggregated and disaggregated (sectoral) level.

The results of Granger Causality analyse the unidirectional and bidirectional causality among the defined variables. The results reveal that there exists a bidirectional causality running from economic growth (in terms of GDP) and CO2 emissions. The electricity consumption in traction and railways Granger causes CO2 emissions and therefore asserts a unidirectional causality. The results also indicate that there exists a bidirectional granger causality between electricity consumption in agricultural, commercial & industrial sectors and CO2 emissions. There also exists a bidirectional causality running from economic growth and electricity consumption in agricultural, traction & railways and industrial sectors; but for domestic electricity consumption there exists a unidirectional causality with economic growth i.e. economic growth granger causes domestic consumption. Also, the economic growth granger causes commercial consumption and holds a unidirectional causality. There also exists a bidirectional causality running from total electricity consumption and CO2 emissions.
economic growth and environmental sustainability. Hence, India should frame policies which aggravate
indicates that economic growth and electricity consumption for different sectors viz. industrial, agricultural, domestic, commercial & traction and railways, are also cointegrated and
exists at least one vector of cointegration. It has been observed that CO2 emissions and electricity consumption for
The results of the cointegration test indicates that economic growth and CO2 emissions are cointegrated and there
exists a unidirectional causality. The results also indicate that there exists a bidirectional Granger causality between
CO2 emissions. The electricity consumption in traction and railways Granger causes CO2 emissions and therefore
private researchers to perform R & D in the sectors of pure and effective energies so that better prospects can be

Consequence & Policy Implications

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Conclusion & Policy Implications

References