RELATIONSHIP BETWEEN CO$_2$ EMISSIONS AND ECONOMIC GROWTH IN INDIA

Hardeep Kaur  
Senior Research Fellow  
Punjab School of Economics  
GNDU, Amritsar  
E-mail: hardeepkaur_07@yahoo.com

Dr. H.S. Bhalla  
M.Com., M.Phil., Ph.D., CES, PES-I,  
UGC Research Project holders, Head,  
Department of Commerce,  
Govt. College, Ajnala (Amritsar).
ABSTRACT

In the present paper, an attempt is made to examine the causal relationship between consumption and production of various energy variables such as coal, petroleum, electricity and gross domestic product (GDP) with carbon dioxide emissions using Granger Causality Method. Empirical findings reveal that there is a unidirectional causality between various energy variables, economic variables and carbon dioxide emissions. The result reveals that sufficient steps should be required to switch over clean efficient technologies for production of energy.
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Mrs. Hardeep Kaur  
Dr. H.S. Bhatta

Introduction

India is the world’s fifth largest economy. It is expected to be one of the fastest growing countries over the period of 5-10 years. As seen from the experiences of 30-40 years, with the growth of the economy there is a tremendous rise in the utilization of energy resources and greenhouse gas emissions due to structural changes. Commercial energy demand is growing at a high annual rate of over six percent (Shukla 1997). The energy mix of coal, oil, and gas is primarily used due to make easy availability of these resources. However, due to higher availability of coal, the consumption of coal is a dominant factor in India’s energy sector (CMIE, 2005). This has led to a rapidly rising trend of energy emissions. This trend that is likely to continue will enhance India’s share in the global emissions in next few decades. (Fisher-vender et. al, 1997).

Various studies on the changes in the atmosphere have indicated an increase in concentration of atmosphere CO$_2$ carbon dioxide, N$_2$O (Nitrates Oxide) and MH (Methane) by about 31 percent, 17 percent and 15 percent respectively between 1950 to 2000. The mean global temperature increased by 0.6°C ±(0.2%) during the 20$^{th}$ century (Teri, 2000).

India’s emissions may have grown due to rapid industrialization but its per capita CO$_2$ emissions are only 1.1 tonne as against 20.1 tonne for the US, 17.8 tonne for Canada and 11.5 tonne for Russia. Per capita emissions of china, India’s colleague in G77, are 3.7 tonne.

The causal relationship between energy consumption, CO$_2$ emissions and economic growth is a well known subject in these days. There has been a renewed interest in examining the relationship between these variables. The higher economic growth rates pursued by developing countries are achievable
only in association with the consumption of larger quantity of energy which in turn has the impact on carbon dioxide emissions. There is still confusion regarding, it whether energy consumption is a stimulating factor for, or a result of economic growth. However when more energy, particularly oil and coal is used to achieve high economic growth rates, carbon dioxide emissions rise accordingly.

**A Brief Survey of the Literature**

A number of studies have investigated the causal relationship between energy consumption and economic growth. For example Aquel and Butt (2001) studied the causal relationship between energy consumption and economic growth in Pakistan. To investigate the causal relationship among the stated variables they used Granger test and co-integration. Mozumder and Marathe (2007) applied a vector error correction model to explore the dynamic Granger Causality. They studied that per capita GDP granger causes per capita energy consumption in Bangladesh. Masih and Masih (1996) studied temporal causality between energy consumption and income of six Asian economies. Ghali and EI-Sakka (2004) conducted a study on the causality between energy consumption and economic growth in Canada.

**Database and Methodology**

Time series data on various energy variables, carbon dioxide emissions and GDP has been considered for the period 1970-2005 to investigate the casual relationship between energy variables, carbon dioxide emissions and economic growth. The necessary data has been collected from various sources. For example data on GDP and other economic variables were collected from Annual statistics of Indian Economy. Data of various energy sources were collected from Ministry of coal, Ministry of Petroleum and Natural Gas and Central Electricity Authority.

The main purpose of this article is to estimate the relationship between energy consumption, carbon dioxide emissions and economic growth.
Econometric Methodology

The time series data presents a number of methodological problems. It is necessary to that the data should be stationary to estimate the relationship through regression method. The time series ‘stationary’ refers to a condition wherein the series have constant mean and variance. Most of the time series data reflect trend, cycle or seasonality. These patterns must be removed to make the series stationary.

Stationarity is the first fundamental statistical property tested for in time series analysis, because most statistical models require that the underlying generating processes be stationary.

In simplest terms a time series \( y_t \), is said to be stationary if.

a) \( E(Y_t) = \) constant for all \( t \);

b) \( \text{Var} (y_t) = \) constant for all \( t \); and

c) \( \text{Cov} (y_t, y_{t+k}) = \) constant for all \( t \) and \( k \neq 0 \), or if its mean, its variance and its covariances remain constant over time.

A test for the order of integration is a test for the number of unit root, and it follows the steps described below:

Step 1: Test \( y_t \), to see if it is stationary. If yes then \( y_t \sim I(0) \); if no then \( y_t \sim I(n); n>0 \).

Step 2: Take first difference of \( y_t \) as \( \Delta y_t = y_t - y_{t-1} \), and test \( \Delta y_t \) to see if it is stationary. If yes then \( y_t \sim I (1); \) if no then \( y_t \sim I (n); n>0 \).

Step 3: Take second difference of \( y_t \) as \( \Delta^2 y_t = \Delta y_t - \Delta y_{t-1} \), and test \( \Delta^2 y_t \) to see if it is stationary. If yes then \( y_t \sim I (2); \) if no then \( \Delta^2 y_t = \Delta y_t - \Delta y_{t-1}; n>0 \). Etc…. till we find that it is stationary and then we stop. So, far example if \( \Delta^3 y_t \sim I (0) \), then \( \Delta^2 y_t \sim I (1) \) and \( \Delta y_t \sim I (2) \), and finally \( y_t \sim I (3) \); which means that \( y_t \) needs to be differenced three times in order to become stationary.
As the error term is likely to be white noise, Dickey Fuller extended their test procedure suggesting an augmented version of the test which includes extra lagged terms of the dependant variable in order to eliminate autocorrelation. The lag length on these extra terms is determined by the Akaike Information Criterion (AIC). (E-views, 5)

The three possible forms of the ADF test are given by the following equations:

$$
\Delta y_t = \gamma y_{t-1} + \sum_{i=1}^{p} \beta_i \Delta y_{t-i} + u_t
$$

$$
\Delta y_t = \alpha_0 + \gamma y_{t-1} + \sum_{i=1}^{p} \beta_i \Delta y_{t-i} + u_t
$$

$$
\Delta y_t = \alpha_0 + \gamma y_{t-1} + \alpha_2 t + \sum_{i=1}^{p} \beta_i \Delta y_{t-i} + u_t
$$

The difference between the three regressions again concerns the presence of the deterministic elements $\alpha_0$ and $\alpha_2 t$.

In all cases the test concerns whether $\gamma = 0$. The ADF-test statistic is the ‘t’ statistic for the lagged dependent. IF ADF statistical value is greater in absolute terms than the critical then we reject the null hypothesis of a unit root and conclude that $y_t$ is a stationary process.

**Empirical Findings**

The ADF test has used in present paper to examine unit root in set of population, GDP, various energy indicators and carbon dioxide emissions. In the level from the ADF test supports the hypothesis that all the variables under consideration are non–stationary. However in the first difference all variables become stationery. The results of ADF test is reported as follows:
Table 1
Augmented Dickey Fuller unit root test

<table>
<thead>
<tr>
<th>Variable</th>
<th>ADF test statistics with trend</th>
<th>ADF test statistics without trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>-5.24</td>
<td>-8.58</td>
</tr>
<tr>
<td>GDP</td>
<td>-7.55</td>
<td>-6.15</td>
</tr>
<tr>
<td>Industry</td>
<td>-5.20</td>
<td>-5.13</td>
</tr>
<tr>
<td>Mining</td>
<td>-5.29</td>
<td>-5.33</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>-5.24</td>
<td>-4.85</td>
</tr>
<tr>
<td>Electricity</td>
<td>-4.75</td>
<td>-4.63</td>
</tr>
<tr>
<td>Services</td>
<td>-8.34</td>
<td>-8.47</td>
</tr>
<tr>
<td>Construction</td>
<td>-4.91</td>
<td>-4.11</td>
</tr>
<tr>
<td>Trade</td>
<td>-4.59</td>
<td>-3.19**</td>
</tr>
<tr>
<td>Finance</td>
<td>-4.94</td>
<td>-4.28</td>
</tr>
<tr>
<td>Community</td>
<td>-4.35</td>
<td>-3.75</td>
</tr>
<tr>
<td>Agriculture</td>
<td>-7.28</td>
<td>-7.41</td>
</tr>
<tr>
<td>Coal production</td>
<td>-4.44</td>
<td>-4.35</td>
</tr>
<tr>
<td>Coal consumption</td>
<td>-5.54</td>
<td>-5.49</td>
</tr>
<tr>
<td>Petroleum production</td>
<td>-4.22</td>
<td>-3.92</td>
</tr>
<tr>
<td>Petroleum consumption</td>
<td>-5.42</td>
<td>-5.43</td>
</tr>
<tr>
<td>Natural gas production</td>
<td>-8.57</td>
<td>-4.68</td>
</tr>
<tr>
<td>Natural gas consumption</td>
<td>-4.81</td>
<td>-4.45</td>
</tr>
<tr>
<td>Electricity production</td>
<td>-5.55</td>
<td>-5.33</td>
</tr>
<tr>
<td>Electricity consumption</td>
<td>-4.39</td>
<td>-4.28</td>
</tr>
<tr>
<td>CO₂</td>
<td>-7.17</td>
<td>-6.80</td>
</tr>
<tr>
<td>Number of vehicles</td>
<td>-4.91</td>
<td>-4.85</td>
</tr>
<tr>
<td>TPEC</td>
<td>-6.41</td>
<td>-5.90</td>
</tr>
</tbody>
</table>

* values are significant at 1% level.
** value is significant at 5% level.

From the table 1 it is clear that all the variables are stationary at first difference, when log values are taken.

In present study, before applying Granger casualty test, data were checked for stationarity by applying Augmented Dicky Fuller Unit root test. In Granger, causality value of F statistics is calculated for all possible direction of causality.
which helps us to decide about the type of causation existing in the given variables. As in table 1 the stationary of data is confirmed to study whether Y cause X or X causes Y, the following equations are considered.

\[
Y_t = \sum_{i=1}^{n} \alpha_i y_{t-i} + u_{1t}
\]

\[
Y_t = \sum_{i=1}^{n} \alpha_i y_{t-i} + \sum_{j=1}^{n} \beta_j x_{t-j} + u_{2t}
\]

\[
X_t = \sum_{i=1}^{n} \lambda_i x_{t-i} + u_{3t}
\]

\[
X_t = \sum_{i=1}^{n} \lambda_i x_{t-i} + \sum_{j=1}^{n} \delta_j y_{t-j} + u_{4t}
\]

### Table 2
Results of Causality

<table>
<thead>
<tr>
<th>Variables</th>
<th>F$_{cal}$</th>
<th>F$_{tab}$</th>
<th>Decision</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC→GDP</td>
<td>4.00</td>
<td>3.30 (5%)</td>
<td>Rejected</td>
</tr>
<tr>
<td>CC→CO$_2$</td>
<td>5.97</td>
<td>5.35 (1%)</td>
<td>Rejected</td>
</tr>
<tr>
<td>CP→CO$_2$</td>
<td>5.01</td>
<td>3.30 (5%)</td>
<td>Rejected</td>
</tr>
<tr>
<td>EC→CO$_2$</td>
<td>13.60</td>
<td>5.35 (1%)</td>
<td>Rejected</td>
</tr>
<tr>
<td>EP→CO$_2$</td>
<td>8.01</td>
<td>5.35 (1%)</td>
<td>Rejected</td>
</tr>
<tr>
<td>Vh.→CO$_2$</td>
<td>5.34</td>
<td>3.30 (5%)</td>
<td>Rejected</td>
</tr>
<tr>
<td>P→TPEC</td>
<td>3.54</td>
<td>3.30 (5%)</td>
<td>Rejected</td>
</tr>
<tr>
<td>I→CO$_2$</td>
<td>0.39</td>
<td>3.30 (5%)</td>
<td>Not Rejected</td>
</tr>
<tr>
<td>Po.→CO$_2$</td>
<td>1.15</td>
<td>3.30 (5%)</td>
<td>Not Rejected</td>
</tr>
<tr>
<td>PC.→CO$_2$</td>
<td>1.19</td>
<td>3.30 (5%)</td>
<td>Not Rejected</td>
</tr>
<tr>
<td>TPEC→CO$_2$</td>
<td>1.30</td>
<td>3.30 (5%)</td>
<td>Not Rejected</td>
</tr>
</tbody>
</table>

Source: Author’s calculations

**Coal consumption and GDP**

Table 2 gives the results in case of coal consumption (CC) and Gross Domestic Product (GDP at factor cost). It indicates that coal consumption (CC)
causes gross domestic product (GDP at factor cost) means (CC→GDP) in case of double lag. There is unidirectional causality between the coal consumption (CC) and GDP of India. In case of CC→GDP, calculated value of F statistics is found to be significant at 5 percent level.

**Coal consumption and carbon dioxide emissions**

Table 2 gives the results of coal consumption (CC) and total carbon dioxide emissions (CO₂). It indicates that coal consumption (CC) causes total carbon dioxide emissions (CO₂) i.e. (CC→CO₂) in case of double lag. In case of CC→CO₂ there exists a unidirectional causality between these and calculated value of F statistics is to be found significant at 1 percent level in case of double lag.

**Coal production and carbon dioxide emissions**

Table 2 indicates the results of coal production (CP) and total carbon dioxide emissions (CO₂). The result indicates that coal production (CP) causes total carbon dioxide emissions (CO₂) i.e. (CP→CO₂). The calculated value of F statistics is found to be significant at 5 percent level in case of double lag.

**Electricity consumption and carbon dioxide emissions**

Table 2 gives the results of electricity consumption (EC) and total carbon dioxide emissions (CO₂). The results indicate that electricity consumption (EC) causes total carbon dioxide emissions (CO₂) i.e. (EC→CO₂). Hence, it is found that F statistics is significant at 1 percent level.

**Electricity production and carbon dioxide emissions**

Table 2 gives the results of electricity production (EP) and total carbon dioxide emissions (CO₂). The results indicate that electricity production (EP) causes total carbon dioxide emissions (CO₂) i.e. (EP→CO₂). Hence it is found that F statistics is significant at 1 percent level.
Number of vehicles and carbon dioxide emissions

The results of number of vehicles (Vh.) and total carbon dioxide emissions (CO\textsubscript{2}) are given in table 2. These results indicate that number of vehicles causes the carbon dioxide emissions i.e. (Vh. \(\rightarrow\)CO\textsubscript{2}). The calculated value of F statistics in case of Vh. \(\rightarrow\)CO\textsubscript{2}, is found to be significant at 5 percent level.

Population and total primary energy consumption

Table 2 gives the results in case of population (P) and total primary energy consumption (TPEC). It indicates that population (P) causes total primary energy consumption (TPEC) i.e. (P \(\rightarrow\)TPEC) in case of double lag. The calculated value of F statistic is found to be significant at 5 percent level in case of double lag.

Industry and carbon dioxide emission

The results of industry (I) and total carbon dioxide emissions (CO\textsubscript{2}) are given in table 2. These results indicate that industry is not the causation of carbon dioxide emissions. As clear from the table that the values are not significant at 1%, 5%, 10% level of significance.

Population and CO\textsubscript{2} emission

The table 2 reveals that F statistics is not significant at various levels of significance therefore, the null hypothesis, population does not granger cause CO\textsubscript{2} is not rejected.

Petroleum Consumption and CO\textsubscript{2} emission

The table 2 reveals that F statistics is not significant at various levels of significance therefore, the null hypothesis, petroleum consumption does not granger cause CO\textsubscript{2} is not rejected.
Total primary energy consumption and carbon dioxide emissions

The table 2 reveals that F statistics is not significant at various levels of significance therefore, the null hypothesis, total primary energy consumption does not granger cause CO$_2$ is not rejected.

Summary and Conclusion

Empirical findings reveals that there is a unidirectional causality between coal production and coal consumption with carbon dioxide emissions, electricity production and consumption with carbon dioxide emissions. Number of vehicles and carbon dioxide emissions and population and total primary energy consumption. The results reveals that the technological transformation in Indian energy system is the requirement now a days. The government should take sufficient steps to switching to gas to low emissions and to fulfill peak load requirement. There is a need of beginning improvement in efficiency of lighting and cooking equipments. In case of industry the CO$_2$ emissions can be reduced through waste recycling and other energy efficiency improvements.
REFERENCES


