

# Carbon Dioxide Emissions (CO<sub>2</sub>), Energy Consumption and Economic Development of New Industrialized Countries Using Panel Econometric Analysis

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**Abstract:** The present research work started with a simple question: Is there any relationship between carbon dioxide emissions, energy consumption and economic growth of new industrialized countries. The study tries to evaluate the relationship, cause and effect between CO<sub>2</sub> emissions, energy consumption and economic growth. Since the research used panel data, the sophisticated panel data models such as unit root, cointegration, error correction model, granger causality, impulse response function and variance decomposition tests were used over the period of 1960 to 2014. From the result, it is found that there exists long run relationship and causality between energy consumption and economic growth and also found the relationship between carbon dioxide emissions. Hence the study has concluded that, if the country needs to increase their economic growth they are bound to use energy, but at the cost of CO<sub>2</sub> emission. The study also suggested that as per the Kyoto protocol, new industrialized countries need to take necessary steps to reduce CO<sub>2</sub> emissions with an immediate effort.

**Keywords:** CO<sub>2</sub> Emissions, Energy Use, Economic Development, Panel Data Models, Environmental Kuntz Curve

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## 1. Introduction

Industrial revolution led to faster economic growth worldwide but at the cost of environmental degradation. The resources were exploited; energies were consumed relentlessly on the eve of industrialization, unmindful of the imbalances caused in the natural setting of the earth and environment, which resulted in the global warming and climate change. The growth of the countries through industrialization was directly related to consumption of energy, exploitation of natural resources that resulted in environmental degradation through dumping the energy waste. The corrosion of environmental quality all over the countries has reached alarming stage and the long lasting consequences of it not only on the life and health of present generation but for the future generations also has, of late, got greater attention worldwide. The evil effect of global warming and climatic change has made the world conscious about it and all out efforts are made to check the environment not to fall further in its grade to save the world from various

catastrophes. Thus consciences have been built to improve the economic growth without making environmental degradation and it has become a serious topic for the researchers to probe in to it in the recent times.

Earlier research works between economic growths; pollution and energy consumption have highlighted four possible relationships that are growth, conservation, neutrality and feedback hypothesis. The growth hypothesis presupposes energy use plays vital role for economic development both directly and indirectly. If the energy use increases it leads to increase the real GDP so that economy is considered as energy dependent. The conservation hypothesis suggest that energy usage and economic growth may not have any consistent relationship i.e. the policy targeting to reduce energy use and waste may not influence the economic growth. The neutrality hypothesis suggested that if energy use is not substantial it will not have any impact with real GDP. This hypothesis is similar to conservation hypothesis

and the difference is, it will be a small portion of energy consumption policy and also it do not support the causal relationship among energy use and economic development. The feedback hypothesis presumes that energy use and economic development are interrelated and it supports a bidirectional relationship between energy use and growth. In this policy any increase in energy consumption may not badly affect to the economic development [1].

### ***Significance of the Study***

Environmental degradation caused due to high emission of greenhouse gases, most specifically carbon dioxide (CO<sub>2</sub>) emitted by the industrial houses has made it critical and of late the concerns are rising to maintain the social and environmental welfare. The global warming caused due to environmental degradation is expected to lead to sea level rising by 20 ft further by 2020 as per the prediction. In case the global warming increase by 3 to 4 Celsius it will result in unseasonal flood, drought etc., which may affect more than 340 million people. The increasing greenhouse gas emission is threatening the global warming situation continuously. It looks as if the developed countries are developing at the cost of the whole world, more specifically the developing and underdeveloped world. In the Kyoto protocol summit 1997 where the governments of all the countries of the world decided to pay heed to such as alarming situation of greenhouse gases emission and decided that countries around the world should attempt to reduce their greenhouse emission to an extent of 5% by 2008-12 from 1990 level. The greenhouse gas those were considered detrimental to environmental health in the Kyoto protocol summit were carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O) and three fluorinated gases namely sulfur hexafluoride (SF<sub>6</sub>), per fluorocarbons (PFCs) and hydro fluorocarbons (HFCs). In this background it is necessary to study the relationship between carbon dioxide emissions, energy consumption and economic growth especially in new industrialized countries.

Rest of the paper is organized as follows; Section 2 provides an overview of earlier research works relating carbon dioxide emissions, energy use and economic growth. Section 3 discusses materials & methods of panel econometric analysis. Section 4 discusses empirical results of carbon dioxide emissions, energy use and economic growth relationship. Section 5 provides summary and conclusion of the research work.

## **2. Literature Review**

The present study focuses on three different approaches relating CO<sub>2</sub> emission, consumption of energy and economic development in line with [2] and [3]. The first approach focused on environmental degradation and economic growth by attempting to trace evidence of Environmental Kuznets Curve (EKC) i.e. the hypothesis produce different types of curve in relation between CO<sub>2</sub> emission, energy use and economic growth. [4] tested CO<sub>2</sub>-EKC hypothesis in peak energy countries and found inverted U-shaped curve against per capita GDP. [5] investigated the relationship between

CO<sub>2</sub> emissions, energy consumption, national income and international trade over the period of 1960 to 2005 through time series data of Turkey. Based on the results he found that EKC hypothesis did not hold good. [6] studied EKC hypothesis in Canada using time series data during the period 1948 to 2004 and found no evidence of EKC hypothesis. [7] studied relationship based on EKC hypothesis, between toxin emissions like CO<sub>2</sub>, SO<sub>2</sub> and real GDP for Tunisia during 1961-2004 and found that there is an evidence of EKC hypothesis with SO<sub>2</sub> not CO<sub>2</sub>. The study also found that there is a long run equilibrium relationship between emissions and GDP. [8] investigated relationship of suspended particular matter (spm) i.e. divided solids liquids that may be dispersed through air and sulphur oxide emissions (SO<sub>2</sub>) with per capita national income during 1979-1990 by using quadratic income formula and found no evidence of EKC hypothesis. [9] find out the relationship between per capita CO<sub>2</sub> emission and EKC hypothesis using cubic function of OECD and non-OECD countries with two different data sets i.e. for energy data period was 1960 – 1998, for CO<sub>2</sub> emission data period is 1950 – 1997 and found the evidence of EKC only for OECD countries. [10] studied the EKC hypothesis for 16 industrialized countries during 1960 – 1998 by using cubic function and found that inverted U – shaped EKC relationship. [11] examined the EKC hypothesis of 74 countries between per capita sulphur dioxide emissions with per capita income quadratic function and they found no evidence of EKC hypothesis. [12] examined 100 countries during 1960-1996 and found the application of EKC hypothesis. The other studies also used with larger data sets and found the evidence of EKC hypothesis [13, 14].

The second approach focused on relating energy consumption and economic development. [15] traced the causal relationship between energy use and economic growth on United States economy. The studies like [16, 17, 18] pointed out absence of defined relationship between energy consumption and growth. [19] measured the relationship between energy use and economic growth of 11 major industrialized countries by using econometric tools of panel approach and found that bi-directional relationship exists between energy use and economic growth in case of USA and existence of uni-directional relationship in case of France, Italy and Japan and no relationship for the rest of the countries like UK, Germany and Sweden.

Third approach combined the above two approaches i.e. relationship between carbon dioxide emissions, energy consumption and economic development. [20] linked carbon dioxide emissions, energy usage and economic development of France during the study period 1960 to 2000 by using quadratic econometric model and found that long run relationship exists between CO<sub>2</sub> emission, energy use and economic development. The study also found bi-directional relationship between the variables. [21] studied inter linkages between CO<sub>2</sub> emission, energy use, real GDP and international trade for China for the period 1975 – 2005 and found that long run relationship exists between the variables. The relationship was found to be uni-directional between real

GDP and CO<sub>2</sub> emission. [22] found existence of the relationship between CO<sub>2</sub> emission and real GDP by using cubic function of GDP and suggested the macroeconomic variables like trade, debt to have effect on environment. [23, 24] measured the relationship between SO<sub>2</sub> and NO<sub>2</sub> with macroeconomic variables like per capita GDP, trade intensity and population and found significant relationships between the environment degradation and macroeconomic variables. [25] used quadratic relationship and found a defined relationship between SO<sub>2</sub>, NO<sub>2</sub> and CO<sub>2</sub> on per capita GDP of Turkey. [26] studied the relationship between environmental quality, per capita income and other variables like endowment, income, technology and policy. [27] measured the relationship between international trade and pollution among cross – country by collecting the data of 132 countries over the period 1950 to 1992. Through the study the conclusion arrived was that increased trade intensity leads to higher CO<sub>2</sub> emissions in lower – income countries and similarly it is lower CO<sub>2</sub> emission in higher income countries. [28] studied the relationship between pollution and trade among developed countries by using cubic function and found that trade openness is significantly related to pollution. [29] investigated causal relationship between CO<sub>2</sub> emission, energy consumption, economic development, real investment and employment by using econometric models in India during 1971 - 2006. From the results it was concluded that no relationship exists between the variables and there is a bi-directional relationship between economic development and CO<sub>2</sub> emission. [5] used quadratic function for identifying the relationship between CO<sub>2</sub> emission, per capita energy consumption, per capita income and trade openness and found bi-directional relationship between carbon dioxide emission and income in Turkey. [30] studied the relationship between carbon dioxide emission, per capita energy consumption and economic growth in case of Pakistan using the data from 1971 to 2006 and found that long term relationship exists among the variable with bi-directional relationship between CO<sub>2</sub> emission and energy consumption.

On the basis of literature review as well as the knowledge of author no attempt has been made yet to relate carbon dioxide emission, energy consumption and economic growth of newly industrialized countries by employing panel data models. The study also considered the suggestion given by [30] that the future study should focus on industrial sectors rather than other sectors. According to [31] suggested to include the variables like labour, trade openness and capital formation. Taking clue from the above studies the present study has considered all the supported variables. Thus this study tried to fill the gap and made an attempt to relate carbon dioxide emissions, energy consumption, economic growth, labour, trade openness and capital formation for new industrialized countries over the period of 1960 to 2014 by using econometric panel data models.

### 3. Materials & Methods

The main objective of this study is to examine the

relationship between carbon dioxide emissions (CO<sub>2</sub>), energy consumption, economic growth and other variables in case of new industrialized countries. Since the study is able to differentiate three different approach in the field of CO<sub>2</sub> emissions, energy use and economic growth it is appropriate to use all three approaches. So the present study made three sub objectives i.e. 1. To explore the EKC hypothesis for CO<sub>2</sub> emission data over the period of 1960 to 2014 for new industrialized countries. 2. To study the relationship between environmental pollution and economic growth 3. To examine the relationship between CO<sub>2</sub> emissions, energy consumption, economic growth and other variables for new industrialized countries. Variables used in this study are CO<sub>2</sub> emission per capita which is measured in metric tons per capita (CO<sub>2</sub>), per capita GDP is used as proxy for economic position of the country (GDP), energy consumption is measured in kg of oil equivalent per capita (EU), and the other variables like labour (LR), trade openness (TO) capital formation (CF) have been used in natural logarithm form. Capital formation refers to countries net capital stocks such as equipments, buildings and other intermediate goods. A country uses capital stock along with the combination of labour for producing goods and services. This goods and services stimulate economic growth and thus for increasing economic growth there is possibility of increased CO<sub>2</sub> emissions. International trade uses natural resources such as petrol, diesel and gas through that emission of carbon dioxide, thus quite possible that environmental issues can be influenced by trade pattern of the country. Hence the study included the variables like trade openness, labor and capital formation in addition with energy use and GDP. The necessary data has been collected from 10 new industrialized countries such as South Africa, Mexico, Brazil, China, India, Indonesia, Malaysia, Philippines, Thailand and Turkey over the period of 1960 to 2014 from World Bank; World Development Indicators.

This study followed cubic function that was used by [7]. Since the nature of the data in both time series and cross section panel econometric models such as Panel unit root, Panel cointegration, Panel error correction and Panel granger causality were used. The study also used Impulse response as well as Variable decomposition model.

Any econometric analysis of relationship of data requires the investigation of stationarity of data through unit root test. After achieving the stationarity either at level or at first, second difference, the analysis moves to check the cointegration either long run or short run. In the present case after checking the stationarity through panel unit root test, panel cointegration test was employed. Since the cointegration test is aimed at long term relationship, error correction model was used to measure short run relationship between the variables. After the identification of long and short run relationship granger causality test was used. In addition impulse response function and variance decomposition models also were used to check the effect of shocks given to error term on the dependent variables.

## 4. Results & Discussion

### 4.1. EKC Hypothesis

The study followed the basic model used by [7] for checking the EKC hypothesis of New Industrialized countries. For finding out the relationship of EKC hypothesis with CO<sub>2</sub> emissions, the study used the variables like CO<sub>2</sub> emissions, energy use and economic growth. The model applied the following equation.

$$co_{2_{it}} = \delta_0 + \delta_1 eu_{it} + \delta_2 gdp_{it} + \delta_3 gdp_{it}^2 + \delta_4 gdp_{it}^3 + \varepsilon_{it} \quad (1)$$

Where CO<sub>2</sub> - carbon dioxide emissions per capita, EU – measured in kg of oil equivalent per capita and GDP – per capita gross domestic product proxy of economic growth. Where  $\delta_0$  is a constant and  $\delta_1$ ,  $\delta_2$ ,  $\delta_3$ , and  $\delta_4$  are the slope parameters. It is assumed that higher level of energy consumption will result higher economic growth and possibility of high emissions of CO<sub>2</sub> therefore  $\delta_1 > 0$  as per the equation (1). Based on the EKC hypothesis, the greater economic growth will produce more CO<sub>2</sub> emissions. Therefore it is expected that  $\delta_2 > 0$ ,  $\delta_3 < 0$  and  $\delta_4 > 0$ . The

above equation also tries to find out different types of environmental economic relationships.

If  $\delta_2 > 0$ ,  $\delta_3 < 0$ ,  $\delta_4 > 0$ , it produces a N – shape curve

If  $\delta_2 < 0$ ,  $\delta_3 > 0$ ,  $\delta_4 < 0$ , it produces inverted N – shape curve

If  $\delta_2 < 0$ ,  $\delta_3 > 0$ ,  $\delta_4 = 0$ , it produces an U – shape curve

If  $\delta_2 > 0$ ,  $\delta_3 < 0$ ,  $\delta_4 = 0$ , it produces an inverted U – shape curve

N – Shape relationship indicate with income level of country is increasing gradually, the environmental quality declines initially and improves later and goes weak subsequently. For inverted N - shape relationships as countries' income levels improves gradually, environmental quality first improves and subsequently decline and at last improves. Similarly for U – shape relationship for countries income in lower levels the environmental quality will improve as income rises, when the income level is high, environmental quality decline as income rises. For inverted U – shape relationship when income at lower level, environmental quality declines as income rises, whereas when income levels are high the environmental quality improves as income rises.

Table 1. Results of EKC hypothesis.

Variables	Co – eff	SE	P – value
Δ EU	0.0102 **	0.0032	0.0018
Δ GDP	-1.6205 ***	0.2009	0.0000
Δ GDP2	0.3800 ***	7.0659	0.0000
Δ GDP3	-0.0188 ***	0.0035	0.0000
C	0.0062 **	0.0033	0.0627

From the results of EKC hypothesis it was found that EU > 0 (0.0102 > 0), indicating high energy usage lead to increase the country's economic growth as well as high level of carbon dioxide emissions among new industrialized countries. It was also observed that the present study supports inverted N – shaped EKC hypothesis i.e.  $\delta_2 < 0$ ,  $\delta_3 > 0$ ,  $\delta_4 < 0$  (-1.625 < 0, 0.3800 > 0, -0.0188 < 0). The result thus indicated that for new industrialized countries with income level increasing gradually, the environmental quality first improves and subsequently further decline and at later stage improves. Hence the environmental quality of these countries will have ups and downs all the time. Thus it can be concluded that these countries can produce more CO<sub>2</sub> emissions at some point of time so that the environmental degradation will be high. So these countries should take necessary steps to reduce the level of carbon dioxide emissions.

### 4.2. Panel Unit Root Test

Any economic data series analysis requires application of the unit root test to transform non stationarity data to stationarity to avoid spurious or misleading result in

regression modelling. By differencing or detrending the data series the panel unit root test is preferred for non stationarity economic data series. The standard panel unit root tests follows the model as

$$y_{it} = \rho y_{it-1} + \delta_0 + \delta_1 t + n_i + v_i + \varepsilon_{it} \quad (2)$$

From the model testing the coefficient of  $\rho$  is equal to one. Where  $i = 1, 2, \dots, N$  represent the N individual items included in the panel. As the data is balanced panel having same number of years and countries the study adopts common as well as unit specific trends are measured for models advocated by LLC & Breitung as well as IPS test where individual unit root test statistics are averaged. All three above tests follow Augmented Dickey Fuller (ADF) principle i.e. stationarity or presence of unit root as null hypothesis and non stationarity or absence of unit root as alternative hypothesis. But Hadri adopts KPSS test for checking unit root with reverse hypothesis that is absence of unit root or stationarity as null hypothesis and presence of unit root and non stationarity as alternative hypothesis.

Table 2. Panel Unit root results.

Series	CO <sub>2</sub>	EU	GDP	GDP <sup>2</sup>	GDP <sup>3</sup>	LR	TO	CF
Levels								
Levin, Lin, and Chu	-0.8600 (0.1949)	-0.1371 (0.4455)	-0.8135 (0.2079)	-0.1967 (0.4220)	0.5783 (0.7185)	0.7830 (0.7832)	-0.8721 (0.1916)	-0.0250 (0.5100)
Breitung	0.0392 (0.5157)	-1.2216 (0.1109)	0.4294 (0.6662)	0.6910 (0.7552)	2.5930 (0.9939)	-3.2585 (0.1786)	0.7300 (0.7673)	-1.1286 (0.1295)
Im, Pesaran and Shin	-0.3883 (0.3489)	0.6131 (0.7301)	0.5973 (0.7249)	0.8586 (0.8047)	1.2886 (0.9012)	0.3923 (0.6526)	0.7107 (0.7614)	0.7389 (0.7700)
Fisher – ADF	20.0838 (0.4527)	9.9847 (0.9684)	17.4590 (0.6230)	17.8877 (0.5948)	17.9868 (0.5883)	12.0813 (0.9132)	10.2067 (0.8556)	13.2379 (0.8669)
Fisher – PP	27.2461 (0.1285)	8.4012 (0.9889)	23.1811 (0.2800)	17.5040 (0.6200)	13.9513 (0.8330)	12.8305 (0.8845)	20.2549 (0.4421)	12.2354 (0.9077)
Hadri	6.5233 (0.0000)	12.2343 (0.0000)	7.3411 (0.0000)	8.1268 (0.0000)	9.3219 (0.0000)	3.9713 (0.0000)	9.5939 (0.0000)	6.0473 (0.0000)
First differences								
Levin, Lin, and Chu	-15.3692 (0.0000)	-14.5035 (0.0000)	-10.5340 (0.0000)	-10.6510 (0.0000)	-9.6422 (0.0000)	-20.3003 (0.0000)	-15.2169 (0.0000)	-15.3798 (0.0000)
Breitung	-7.3039 (0.0000)	-19.6008 (0.0000)	-7.1954 (0.0000)	-7.3948 (0.0000)	-7.7655 (0.0000)	-20.6773 (0.0000)	-11.6037 (0.0000)	-12.2027 (0.0000)
Im, Pesaran and Shin	-19.6081 (0.0000)	-18.9577 (0.0000)	-15.4517 (0.0000)	-15.1663 (0.0000)	-14.7330 (0.0000)	-20.0596 (0.0000)	-15.9078 (0.0000)	-18.3860 (0.0000)
Fisher – ADF	277.343 (0.0000)	239.039 (0.0000)	189.339 (0.0000)	180.785 (0.0000)	171.039 (0.0000)	251.285 (0.0000)	361.310 (0.0000)	339.883 (0.0000)
Fisher – PP	342.218 (0.0000)	531.741 (0.0000)	214.762 (0.0000)	202.783 (0.0000)	192.766 (0.0000)	561.840 (0.0000)	810.952 (0.0000)	366.481 (0.0000)
Hadri	2.0567 (0.1199)	0.1899 (0.4247)	2.9565 (0.1116)	1.9978 (1.2278)	1.6969 (0.1449)	1.0439 (0.1483)	3.6494 (0.1651)	0.5687 (0.2847)

LLC = Levin, Lin, Chu (2002), Breitung (2000), IPS = Im, Pesaran, Shin (2003), based on ADF and PP, these test statistics are asymptotically distributed as standard normal with a left hand rejection area. The null hypothesis of non stationarity. Hadri (2000) unit root statistics are asymptotically distributed as standard normal with a right hand side rejection area. The null hypothesis of stationarity process. The selection of lag is based on modified Akaike information criterion. Newly – West selection using Bartlett kernel. Fisher tests are asymptotic chi-square distribution. Figure in the parentheses are p – value to understand the significance level.

Table 2 presents the results of panel unit root test through LLC, Breitung, IPS, Fisher ADF & PP and Hadri models for new industrialized countries to check the stationarity and integration properties of the selected variables. The result reported that all the variables were non stationarity at level but got stationarity at first difference, of course at different level of significance. This lead to a conclusion that the series are non-stationary and integrated at order one i.e. I (1) with identifying the data being integrated at first order panel cointegration test was applied to investigate the existence or otherwise of long run relationship between the variables.

#### 4.3. Panel Cointegration Test

The panel cointegration test attempts to identify the long run relationship between CO<sub>2</sub> emission, energy consumption and economic growth of new industrialized countries if exists. In this section both homogeneous and heterogeneous

panel cointegration tests are applied. For homogenous Kao (1999), Pedroni (1999) and for non-homogenous Fisher combine Johansson (1998) test for the null hypothesis of no cointegration were applied.

##### 4.3.1. Kao Cointegration Test

To study causal relationship among variables in homogenous panel the residual based panel cointegration suggested by Kao (1999) is employed which assumes homogeneous slope coefficient across individuals. This tests is based on the residuals  $\hat{\epsilon}_{it}$  of the OLS panel estimation by applying two types of panel cointegration tests i.e. Dickey – Fuller (DF) and Augmented Dickey – Fuller (ADF).

$$\begin{aligned}\hat{\epsilon}_{it} &= \rho \hat{\epsilon}_{it-1} + v_{it} \\ \hat{\epsilon}_{it} &= \rho \hat{\epsilon}_{it-1} + \sum_{j=1}^p \varphi_j \Delta \hat{\epsilon}_{it-j} + v_{itp}\end{aligned}\quad (3)$$

The null hypothesis of no cointegration can be written as  $H_0 : \rho = 1$  is tested against the alternative hypothesis of stationary residuals i.e.  $H_a : \rho < 1$ .

**4.3.2. Pedroni Cointegration Test**

Pedroni (2000) cointegration test applies to heterogeneous panels, where in heterogeneous slope coefficient, fixed effects and individual specific deterministic trends are permitted. This panel cointegration allows to test the null hypothesis of no cointegration and the residuals, based on the panel analogue of Engle and Granger (1987) statistics to test the distributions.

The Pedroni (2000) panel cointegration regression is as follows

$$S_{it} = \alpha_i + \delta_i t + \beta_{1i} X_{1it} + \dots + \beta_{mi} X_{mit} + \varepsilon_{it} \quad t = 1 \dots T, i = 1 \dots N. \quad (4)$$

Pedroni (1999) developed seven cointegration statistics, of which the first is a type of non-parametric variance ratio statistics. The second is a panel version non-parametric analogues to the familiar PP-rho stat. The third statistics is also non-parametric, analogues to the PP – statistics. The fourth statistics corresponds to ADF statistics. These four statistics are based on within dimensions. The rest of the three statistics are based on a group mean approach, where

the first one is analogous to the PP-rho statistics and rest two are analogous respectively to the PP and ADF statistics.

**4.3.3. Fisher Combined Johansson Test**

To determine the cointegration among variables in non-stationary data series Johansen (1998) proposed the likelihood ratio trace statistics as well as maximum eigenvalue statistics. The following equations are used to find the trace statistics and maximum eigenvalue statistics that are derived by fitting the equation below.

$$\lambda_{trace}(r) = -T \sum_{i=r+1}^n \ln(1 - \hat{\lambda}_i) \quad (5)$$

$$\lambda_{max}(r, r + 1) = -T \ln(1 - \hat{\lambda}_{r+1})$$

Here T is the sample size, n is total number of variables  $\hat{\lambda}_i$  is the i th largest canonical correlation between residuals from the three dimensional processes. For the trace test the null hypothesis of less than or equal to r Cointegration vector against the alternative hypothesis of full rank  $r = n$  Cointegration vector, the null and alternative hypothesis of maximum eigenvalue statistics is to check the r cointegrating vectors against the alternative hypothesis of r+1 cointegrating vectors.

**Table 3. Kao residual homogeneous co-integration test.**

	t – stat	p – value
Model 1: CO <sub>2</sub> , EU, GDP, GDP <sup>2</sup> , GDP <sup>3</sup>	-4.5464 ***	0.000
Model 2: CO <sub>2</sub> , EU, GDP, GDP <sup>2</sup> , GDP <sup>3</sup> , LR, TO, CF	-4.9558 ***	0.000

The Kao Residual Co-integration test are described in details in Kao (1999). Homogeneous assumptions: individual intercept and no individual trend, Lag selection based on Akaike information criterion, Newly – West automatic bandwidth selection with Bartlett Kernel. \*\*\*- significance at 1% level.

The results of Kao (1998) homogeneous panel

cointegration tests to tests the hypothesis that there is no cointegration between CO<sub>2</sub> emission energy consumption and economic growth are given in the table – 3. The result rejected null of no cointegration and in turn indicated that CO<sub>2</sub> emissions, energy consumption and economic growth have long run relationship.

**Table 4. Pedroni (1999) Heterogeneous Panel Co-integration tests.**

Statistics	Within-dimension		Statistics	Between-dimension	
	Value	P – Value		Value	P – Value
<i>Model 1: CO<sub>2</sub>, EU, GDP, GDP<sup>2</sup>, GDP<sup>3</sup></i>					
Panel v- stat	1.722 **	0.042			
Panel rho – stat	-16.719 ***	0.000	Group rho – stat	-22.623 ***	0.000
Panel PP – stat	-13.207 ***	0.000	Group PP – stat	-21.499 ***	0.000
Panel ADF – stat	-12.966 ***	0.000	Group ADF – stat	-20.010 ***	0.000
<i>Model 2: CO<sub>2</sub>, EU, GDP, GDP<sup>2</sup>, GDP<sup>3</sup>, LR, TO, CF</i>					
Panel v- stat	-1.000	0.841			
Panel rho – stat	-9.232 ***	0.000	Group rho – stat	-10.601 ***	0.000
Panel PP – stat	-15.014 ***	0.000	Group PP – stat	-18.913 ***	0.000
Panel ADF – stat	-13.938 ***	0.000	Group ADF – stat	-16.773 ***	0.000

The Pedroni statistics are described in detail in Pedroni (1999). Heterogeneity assumptions: individual intercept and individual trend, Lag selection based on Akaike information criterion, Newly – West bandwidth selection with Bartlett Kernel. \*- significance at 10% level, \*\*- significance at 5% level, \*\*\*- significance at 1% level.

Table 4 presents the result of Pedroni (1999) panel cointegration tests. The results indicate cointegration of variables rejecting the null of no cointegration. Thus it can be concluded that there is existence of long run relationship between the variables.

Table 5. Johansen Fisher Panel Co-integration test.

Statistics	Fisher stat		Fisher stat	
	Trace test	P – Value	Max – Eigen test	P – Value
<i>Model 1: CO<sub>2</sub>, EU, GDP, GDP<sup>2</sup>, GDP<sup>3</sup></i>				
None	247.8 ***	0.0000	189.8 ***	0.0000
At most 1	81.32 ***	0.0000	69.96 ***	0.0000
At most 2	32.02 **	0.0431	21.26	0.3822
At most 3	23.65	0.2582	23.29	0.2748
At most 4	19.25	0.5058	19.25	0.5058
<i>Model 2: CO<sub>2</sub>, EU, GDP, GDP<sup>2</sup>, GDP<sup>3</sup>, LR, TO, CF</i>				
None	394.6 ***	0.0000	200.0 ***	0.0000
At most 1	174.6 ***	0.0000	80.88 ***	0.0000
At most 2	104.6 ***	0.0000	49.03 **	0.0003
At most 3	63.38 ***	0.0000	34.94 **	0.0204
At most 4	36.69 **	0.0127	22.32	0.3235
At most 5	23.94	0.2450	16.99	0.6538
At most 6	18.86	0.5310	16.53	0.6830
At most 7	23.48	0.2659	23.48	0.2659

The Johansen Fisher panel co-integration test are described in details in Johansen Fisher test (1998). Homogeneous assumptions: Linear deterministic trend, Lag selection interval was 1, 1. \*- significance at 10% level, \*\*- significance at 5% level, \*\*\*- significance at 1% level.

The results of Fisher Johansen combined cointegration test results are presented in the table – 5. The results shows that null of no cointegration can be rejected based on both trace as well as max-eigen statistics. Hence it can be concluded that CO<sub>2</sub> emission, energy use and economic development are having long term relationship. Overall, both the homogenous as well as heterogeneous models found that there exists a long run relationship between the variables. Further this study attempted to evaluate short run relationship by employing panel error correction model.

#### 4.4. Panel Vector Error Correction Model (VECM)

After finding the existence of long run relationship through cointegration tests error correction model is explored to examine the nature of the relation. Error correction model has been applied to find out short term relationship, if any, for the relationship between CO<sub>2</sub> emission, energy use and

economic growth for countries under study. This test measures the multivariate cointegration framework with N individuals with time trend dimension T and the set of first difference variables. The heterogeneous vector cointegration model takes the following form;

$$\Delta Y_{it} = \Pi_i Y_{i,t-1} + \sum \Gamma_{ik} \Delta Y_{i,t-k} + \varepsilon_{it} \quad i = 1, \dots, N \quad (6)$$

Where Y is a  $px1$  vector of variables and the long run matrix  $\Pi$  is of order  $pxp$ . This equation is estimated for each individual N, using the maximum likelihood method, and the trace statistic is calculated. The null hypothesis tested here is that all N individuals have the same number of cointegrating vectors (r) among the p variables. In other words H0: rank ( $\Pi$ ) =  $r_i < r$ , against the alternative hypothesis, H1: rank ( $\Pi$ ) = p for all I = 1...N.

Table 6. Panel Vector Error Correction Model.

Variable	Co – eff	S.E.	t- stat	P - value
C	0.00601	0.003387	1.774706	0.0765
Δ EU	0.010399 **	0.003202	3.247733	0.0012
Δ GDP	-0.33426	1.617806	-0.20661	0.8364
Δ GDP2	0.163867	0.240767	0.680604	0.4964
Δ GDP3	-0.00755	0.011661	-0.64783	0.5174
Δ LR	-0.00041	0.001078	-0.3814	0.7031
Δ TO	0.002768	0.032988	0.083914	0.9332
Δ CF	0.000903	0.001734	0.520525	0.6029
U(-1)	0.008752	0.044582	0.196311	0.8444
Wald test	20.6257			0.5364

Lag selection interval was 1 and 2. Ut – Error Correction Term. Wald F-stat calculated through coefficient of wald co-efficient restriction test. \*- significance at 10% level, \*\*- significance at 5% level, \*\*\*- significance at 1% level.

The panel error correction model results suggests variable having negative indication and significant value will be treated of having a long run relationship. Whereas the variable having negative indication but not significant value indicate of having short run relationship only. Further confirmation of the model one can see wald – F statistics. For overall model can be predicted by error term (U<sub>t</sub>) for the

relationship. Table 6 presents the VECM result, from the results GDP, GDP3 and labour show short run relationship among the variables. Overall model, error correction term was found positive with insignificant value hence it can be concluded that the model does not support short run relationship between CO<sub>2</sub> emission, energy use and economic development of new industrialized countries. The study also

confirmed the relationship by using Wald statistics which was found to be insignificant and confirmed that there exist no short run relationship between the variables.

**4.5. Panel Granger Causality Test**

After finding out short run relationship the study used granger causality test to understand the cause and effect between the variables. The present study used panel granger causality test which is based on Granger’s (1969) concept. Causality tests measures the cause and effect relationship with bivariate data and the results can be expressed by univariate or bivariate relationship. The panel Granger causality tests takes the following form;

$$Z_{it} = \sum_{j=1}^p \Gamma_{ijt} Z_{i,t-j} + \mu_{it} + \varepsilon_{it}, i = 1, \dots, N \text{ \& } t = 1, \dots, T \quad (7)$$

With  $Z_{it}$  K-dimensional, for the bivariate models K=2 with  $Z_{it} = [\text{CO}_2 \text{ emissions}_{it}, \text{Energy consumption}_{it}, \text{Economic growth}_{it}]$  with “L” indicating natural logarithms, the vector

$\mu_{it}$  contains individual specific i.e. new industrialized countries and period fixed effects:  $\mu_{it} = \alpha_i + \beta_t$ , accounting for both common shocks and general growth difference between the countries. Accordingly, at most period effects was allowed. The disturbances  $\varepsilon_{it}$  are assumed to be independently distributed across individuals and time, with means 0 and variances  $\alpha^2_i$ , permitting individual heteroscedasticity. The parameter matrices,  $\Gamma_{ijt}$ , potentially vary with I, j and t. As all coefficients cannot differ, for temporal heterogeneity in causal links that are assumed homogeneous across individuals, and the converse case of individual specific causal links that are invariant over time were allowed. A specific element of  $\Gamma_{ijt}$  is denoted by  $\gamma_{ab,ijt}$ , which are of interest in granger no causality using Wald statistic, where we test  $H_0 : \gamma_{21,ijt} = 0 \Phi i, j, t$  to determine the relationship between CO<sub>2</sub> emissions is granger non-causal for energy consumption and economic growth.

**Table 7. Panel Granger Causality test results.**

	$\Delta \text{CO}_2$	$\Delta \text{EU}$	$\Delta \text{GDP}$	$\Delta \text{GDP}^2$	$\Delta \text{GDP}^3$	$\Delta \text{LR}$	$\Delta \text{TO}$	$\Delta \text{CF}$	<b>Result</b>
$\Delta \text{CO}_2$	-	0.2403 (0.7865)	13.3463 (2.0006)	11.3276 (2.0005)	11.5748 (1.0005)	1.6480 (0.1934)	1.4890 (0.2266)	0.9786 (0.3765)	
$\Delta \text{EU}$	7.1552 (0.0009)	-	0.4634 (0.6294)	0.0394 (0.9613)	0.0445 (0.9565)	5.2934 (0.0053)	2.6326 (0.0728)	0.7695 (0.4638)	EU → CO <sub>2</sub> GDP → CO <sub>2</sub>
$\Delta \text{GDP}$	4.8137 (0.0085)	2.5246 (0.0811)	-	56.3826 (7.0023)	39.7568 (8.0017)	0.54623 (0.5795)	0.6475 (0.5238)	0.0541 (0.9473)	GDP2 → CO <sub>2</sub> GDP3 → CO <sub>2</sub>
$\Delta \text{GDP}^2$	6.5446 (0.0016)	1.9315 (0.1460)	50.2497 (1.0020)	-	24.9268 (5.0011)	0.4401 (0.6417)	0.4959 (0.6093)	0.1670 (0.8462)	GDP → EU
$\Delta \text{GDP}^3$	8.2533 (0.0003)	1.6897 (0.1856)	43.9986 (2.0018)	31.1375 (2.0013)	-	0.3712 (0.6900)	0.2951 (0.7445)	0.3302 (0.7189)	EU → LR EU → TO
$\Delta \text{LR}$	0.7905 (0.4541)	0.0636 (0.9384)	0.9080 (0.4039)	0.7467 (0.4744)	1.2239 (0.2949)	-	4.1073 (0.0170)	0.0775 (0.9254)	TO → GDP TO → GDP <sup>2</sup>
$\Delta \text{TO}$	3.2122 (0.0411)	1.0991 (0.3339)	4.4803 (0.0118)	3.9100 (0.6760)	3.4952 (0.0311)	0.6113 (0.5430)	-	0.0045 (0.9955)	TO → GDP <sup>3</sup> CF → LR
$\Delta \text{CF}$	0.9681 (0.3805)	0.0745 (0.9282)	0.7144 (0.4899)	0.3919 (0.6760)	0.3639 (0.6951)	2.6361 (0.0726)	0.1435 (0.8663)	-	

Statistics are asymptotically distributed as normal. The test of Panel Granger causality test lags of 2. Figures in the parentheses are probability value.

Table 7, presents panel granger causality results for the relationship between carbon dioxide emissions, energy consumption and economic growth of new industrialized countries. The lag selection criteria based on Akaike information here was found to be in 2 lags for better results. Based on panel granger causality results it could be understood that all the variables are causing variables in uni-directional relationship mode. The result revealed that energy consumption causing carbon dioxide emissions whereas GDP and trade openness causing carbon dioxide emissions. Similarly GDP having granger cause with energy use and energy consumption causing trade openness. The variables of trade openness causing GDP. It is very interesting to observed that high economic growth countries are depending on energy use, though which they get high succeed GDP and also high emissions of carbon dioxide. Since the international trade influences the countries economic development, resultantly it also produce high CO<sub>2</sub> emissions. From overall granger

causality results it can be concluded that carbon dioxide emission is influenced by energy use and economic growth as well as international trade. Thus the factors like energy use, economic growth and international trade may be considered as the influential factors emitting high level of carbon dioxide.

**4.6. Impulse Response Function**

The sensitivity of one variable on the other can be studied by impulse response function. In applied research it is necessary to know the reaction of one variable with another variable when shocks are given to residuals. Impulse response function finds out reaction of one variable in relation to another variables when one positive standard deviation shocks is given to residuals for future ten years. The positive and negative relationship, if any, for future periods can be identified with the impulse response function.



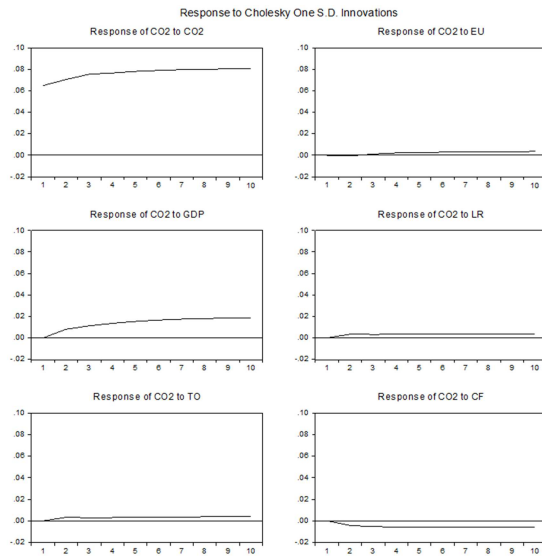


Figure 1. Impulse response function result.

The results of impulse response function shows that when one positive standard deviation (s. d.) shocks given to residuals the variables like carbon dioxide emissions, GDP, labour and trade openness reacted positively over the periods of future ten years. Whereas energy use reacted negatively in the initial stage and later it displayed positive reaction. The other variable i.e. capital formation showed negative reaction for all the future ten years. This indicates that variables of CO<sub>2</sub>, GDP, labour, trade openness will show the positive results even in any kind of situation for ten years hence.

4.7. Variance Decomposition

Variance decomposition analysis indicates influence on information one variable in relation to another variable in the auto regression. This analysis also enables to forecast the extent of error variance being explained by the exogenous shocks to other variables.

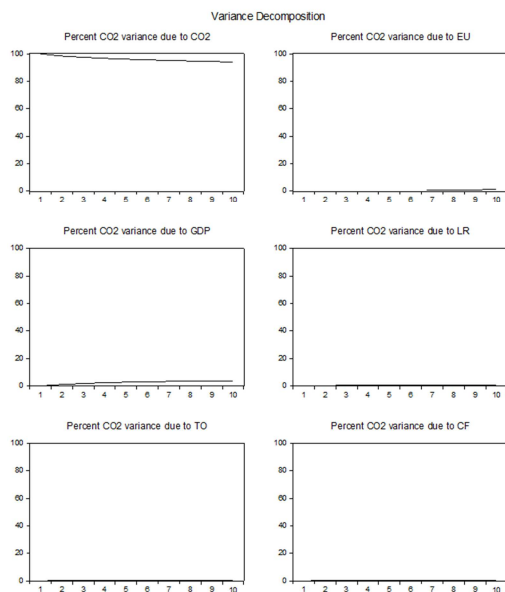


Figure 2. Variance decomposition test result.

The graphic presentation of variance decomposition that the variables like energy use, GDP, trade openness influencing positively on CO<sub>2</sub> emission for the future ten years. The amount of CO<sub>2</sub>, GDP, and energy use influence highly as well as positively in parlance with carbon dioxide emissions for the future ten years. Whereas the other variables like labor and capital formation influence over CO<sub>2</sub> emission is through positive but minimal for the future ten years.

5. Concluding Remarks

The empirical investigation on the relationship between carbon dioxide emissions, energy consumption and economic growth of new industrialized countries. The present study is tried to investigate the relationship between CO<sub>2</sub> emission, energy consumption and economic growth of new industrialized countries i.e. South Africa, Mexico, Brazil, China, India, Indonesia, Malaysia, Philippines, Thailand and Turkey over the period of 1960 to 2014 and the result reveal that higher level of energy consumption will lead to increase the country's economic growth and high level of carbon dioxide emissions among new industrialized countries. It is also found that the present study supports inverted N – shaped EKC hypothesis. The EKC result leads to the inference that for new industrialized countries, as income level increases gradually and environmental quality will initially improve and later decline and at the end again will improve. The modelling suggest that there exists long run relationship and causality between CO<sub>2</sub> emissions, energy consumption and economic growth of new industrialized countries. Based on the results it can be concluded that carbon dioxide emission increased due to energy use, economic growth and trade openness. The variables like energy use, GDP and international trade parsed their influential on carbon dioxide emissions for new industrialized countries through the result of the analysis. Impulse response function shows CO<sub>2</sub>, GDP, labour and trade openness responding positively for future ten years, whereas variance decomposition shows that CO<sub>2</sub>, energy use and GDP reacted positively in relation with CO<sub>2</sub> emissions for future years. Overall results imply that energy consumption, economic growth, trade openness may be the influential factors for increasing carbon dioxide emissions. Hence these variables should be given priority for policy decision directed towards controlling environmental degradation of new industrialized countries. Further the study suggest that new industrialized countries are mainly energy dependent so these countries would take essential steps for energy policy such as oil reservation apparatus, develop energy efficiency and swap for oil usage in order to reduce energy catastrophes on economic development.

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