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NEXUS BETWEEN ENERGY CONSUMPTION AND ENVIRONMENTAL DEGRADATION (CO_2 EMISSIONS) IN INDIA

GOPAL JI SINGH[1]

Department of Economics, Gaya College, (Magadh University), Gaya, Bihar, India

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ABSTRACT

This paper has tried to analyse dynamic relationship among variables, i.e. CO_2, EC and GDP by using data for the period 1991 to 2015.ARDL bound testing approach to coitntegration developed by Pesaran, Shin and Smith (2001) is used to find out cointegration among variables. Findings of this paper show existence of cointegration among variables. Economic growth (GDP) has positive impact on CO_2 emissions in long run whereas energy consumptionhas positive effect on CO_2 emissions in long run but negative effect in short run.

KEY WORDS: Environmental degradation, Global warming, Greenhouse gas, Energy consumption, Fossil fuel, Renewable energy, Eco-friendly technology

INTRODUCTION

Global warming and consistent climate change due to increase in greenhouse gases, especially CO_2 emissions has become a major threat for all nations of the world. Greenhouse gas is exposed by human activities. CO_2 gas emitted by the use of fossil fuel, constitutes more than 60% of this greenhouse gas (IEA, 2013). Ultimate goal of each nation is to achieve desired level of economic growth and try to maintain this level for a long time. This desired level of economic growth can be achieved through faster production. But this production negatively affects environment and creates pollution. Energy is required for the productionof goods because it is used as input in the production process. Fossil fuels are used as source of this energy. Fossil fuels has more carbon and lesser hydrogen content. Socombustion of fossil fuels emit more CO_2.

After 1990, debates have been started among economists about relationship between environmental quality and economic growth. Environmental Kuznets Curve (EKC) hypothesis is used as one of the important technique to explain relationship between these two. According to this hypothesis, income causes increase in pollution in initial stage of industrialization. But after reaching threshold level, this trend will be reversed.This EKC depends on interaction of three effects. These three effects are scale effect, composition effect and technology effect. Scale effect has positive impact on environment as CO_2 emission increases due to increase in production. Composition effect can have both positive and negative effect on environment. It depends on type of goods whether it is dirty goods or clean goods. If product composition changes from clean to dirty goods, environmental degradation increases. But if composition of goods changes from dirty to clean goods, environmental degradation decreases. Impact of technological effect is negative on environmental degradation (Kumbaroglu, 2008).

India has adopted policy of LPG in 1991. After 1991, India is also running to achieve higher economic growth at the cost of utilizing fossil fuel (non-renewable energy). Intensive use of energy for more production is causing increase in demand of fossil fuel. The race of achieving higher economic growth through more production has resulted increase in CO_2 emissions in India.

Review of Literature

Chebbi, *et al;* (2011) used cointegration technique on data of Tunisia over period 1961-2004 and found positive impact of trade openness on CO_2 emissions

***Corresponding author's email:** gopal533@gmail.com

in short run as well as in long run. Jalil and Mahmud (2009) used ARDL bound testing approach on data of China over period of 1975-2005 and found that trade has positive but statistically insignificant impact on CO_2 emissions. Zhang and Cheng (2009) and Soytas and Sari (2009) examined causal relationship among variables i.e. energy consumption, economic growth and CO_2 emission. No causal relationship among variables is found. Both study suggest for energy saving as well as CO_2 reducing policy. Ismail and Mawar (2012);Shahbaaz(2013) and Tiwari (2013) also examined causal relationship among variables i.e. energy consumption, economic growth and CO_2 emissions. They found long run causality among these variables. Alam, Begum, Buysse and Huylenbroeck (2012) examined causal relationship among variables, i.e. energy consumption, economic growth and CO_2 emissions of Bangladesh over period 1972-2006 and found bidirectional causality between energy consumption and economic growth andunidirectional causality from energy consumption to CO_2 emissions in short run and bidirectional causality in long run. Aslan (2013) used panel data analysis on data of 47 US states over period 1997-2009 and found bidirectional causal relationship between energy consumption and economic growth. Omri (2013) has taken data of 14 MENA countries over period 1990-2011 and found bidirectional causality between economic growth and CO_2 emissions and unidirectional causality from energy consumption to CO_2 emissions. Shahbaaz **(2013)** has taken data of economic growth, energy consumption, financial development, trade openness and CO_2 emissions in Indonesia. Bidirectional causality between energy consumption to CO_2 emissions is found. Besides this unidirectional causality from financial development to CO_2 emissions is found.

Data and methodology

Annualtime series data of CO_2 emissions, energy consumption and real GDP per capita are used over the period 1991 to 2015. Data has been taken from World Development Indicators (WDI, 2019) of World Bank. All data are converted into natural logarithms. CO_2 emission is used as proxy variable for environmental degradation in this paper. Data of CO_2 emissions per capita used are measured in metric tons. Real GDP per capita (GDP) is measured at constant 2010 US dollars. Real GDP per capita is . Energy consumption is amount of energy used for the production of goods. Energy consumption is used as proxy variable for total energy use per capita.Data of energy consumption is measured in kg of oil equivalent per capita. Functional form of model with natural logarithms is as follows—

$$log(CO_{2t}) = \alpha + \beta_1 log(GDPt) + \beta_2 log(EC_t) + U_t \quad ..(1)$$

Unit Root Test

Used variables in this paper are EC, CO_2 and GDP. ADF unit root test is used to test whether series is stationary or not. ADF test includes optimal lags to remove autocorrelation from the model. Optimal lags for unit root test are determined according to AIC, SIC and HQ.

Cointegration

In this paper "ARDLBound Testing Approach" developed by Pesaran, *et al;* is used to examine cointegration among variables. ARDL model uses first difference of dependent variable and lagged values of first difference of explanatory variables, which capture short run as well as long run effects. Hendry's General to Specific Approach (1979) is used to determine lag length. F statistic is used as criterion of test.

$$\Delta CO_{2(t)} = a_0 + \Sigma^n_{i=0}\ a_{1i}\ \Delta CO_{2(t-i)} + \Sigma^n_{i=0}\ a_{2i}\ \Delta GDP_{(t-i)} + \Sigma^n_{i=0}\ a_{3i}\ \Delta EC_{2(t-i)} + \alpha_2 GDP_{(t-1)} + \alpha_3 EC_{(t-1)} + U_1 \quad .. (2)$$

α_1, α_2 and α_3 shows long run effect in ARDL model whereas a_{1i}, a_{2i} and a_{3i} shows short run effect. Null hypothesis of H_0: $\alpha_1 = \alpha_2 = \alpha_3 = 0$ (no cointegration) among variables in equation (2) can be tested against alternative hypothesis of

H_1: $\alpha_1 \neq \alpha_2 \neq \alpha_3 \neq 0$ (cointegration).

Vector Error Correction Model (VECM)

Once cointegrationamong variables is established by ARDL bound testing approach, VECM can be used to examine short run dynamics (shocks) of the model. VECM is suitable method to detect causal relationship among variables, if series are found to be stationary at first difference Error Correction Termshows speed of convergence of model from short run disequilibrium to long run equilibrium path. Statistical significant with negative sign of ECTconfirms presence of long run causal relationship among variables.

$$\Delta CO_{2(t)} = a_0 + \Sigma^n_{i=0}\ a_{1i}\ \Delta CO_{2(t-i)} + \Sigma^n_{i=0}\ a_{2i}\ \Delta GDP_{(t-i)} + \Sigma^n_{i=0}\ a_{3i}\ \Delta EC_{2(t-i))} + \eta_1 ECT_{(t-1)} + U_2 \quad .. (3)$$

RESULTS DISCUSSION

Unit root Test

Variables CO_2, GDP and EC are non-stationary at level. All these variables are integrated of order one i.e. I (1) both with constant and trend. (Table 1)

Cointegration Test

SIC, HQ and AIC are minimum at lag four, but model is not stable at this lag. So lag three is selected. Model is stable, homogenous and no serially correlated at lag three.Following is estimated ARDL model at lag three—

$$\Delta CO_2 = -1.82 + 1.16\,\Delta CO_2(-1) + 0.28\,\Delta CO_2(-2) + 1.47\Delta CO_2(-3) - 0.036\,\Delta GDP(-1) + 1.05\,\Delta GDP(-2) - 0.14\,\Delta GDP(-3) - 1.40\,\Delta EC(-1) - 1.54\,\Delta EC(-2) + 0.26\,\Delta EC(-3) - 0.99\,CO2(-1) + .17GDP(-1) - 1.24\,EC(-1) \quad .. (4)$$

Table 2 shows that estimated F statistic is 4.79, which is more than Pessaran's (2001) upper bound F statistic at 5% level of significance (i.e. 4.35). So null hypothesis of no cointegration can be rejected. This test shows existence of cointegration among variables, i.e. CO_2, GDP and EC. Therefore, both short run and long run causality will exist with ECTfor equation (CO_2/GDP, EC).

Result of Long Run Model

$$CO_2 = -1.08^{***} + 0.15^{*}\,GDP + 1.15^{**}\,EC \quad .. (5)$$

Estimates of long run model show that coefficient of GDP and EC are significant (respectively at 10% and 1% level of significance) and positively affecting CO_2. 1% increase in GDP will lead to about 0.15% increase in CO_2. Still India has not reached at threshold level of economic development. Economic development isresponsible for environmental degradation in India. Result explains that CO_2 emissions is relatively more elastic with energy consumption. 1% increase in energy consumption will lead to 1.15% increase in CO_2 emissions.

Error Correction Model (ECM)

$$\Delta CO_2 = 0.002 + 1.15\,\Delta CO_2(-1) + 0.31\,\Delta CO_2(-2) + 1.15\,\Delta CO_2(-3) - 0.23\,\Delta GDP(-1) + 0.64\,\Delta GDP(-2) + 0.17\,\Delta GDP(-3) - 1.11\,\Delta EC(-1) - 0.77\,\Delta EC(-2) - 1.23\,\Delta EC(-3) - 1.48\,ECT(-1) \quad .. (6)$$

Estimates of error correction model show that error correct term (ECT) is negative and significant at 5% level of significance. It showspresence of a stable dynamic equilibrium model. This ECM

Table 1. Result of Unit Root Test for CO_2, ECand GDP

Variables	At level		At First Difference	
	With Constant	With Trend	With Constant	With Trend
CO_2	0.986749	-0.923695	-4.246965***	-4.466433***
EC	-0.553582	-0.553582	-3.655686**	-4.594878***
GDP	1.967791	-3.170243	-4.904221***	-5.088298***

Mackinnon (1996)-P values- ***=P<0.001(1%), **=P<0.005(5%), *=P<0.1(10%)
Source: Calculation based on World Development Indicator (2018-19)

Table 2. Result of Bound Test for Cointegration (CO_2 is Dependent Variable)

Equation	Dependent variable	F statistic	No of lags
(CO_2/GDP,EC)	CO_2	4.787535**	3

Mackinnon (1996)-P values- ***=P<0.001(1%), **=P<0.005(5%), *=P<0.1(10%) Source: - Calculation based on World Development Indicator (2018-19)

Table 3. Diagnostic Tests

Tests	Test Statistic	P-Value
Heteroskedasticity Test (ARCH Test)	0.619405	0.6139
Jarque-Bera Normality Test	0.462592	0.7935
Breusch-Godfrey Serial Correlation Test	4.092488	0.5168

Source: Calculation based on World Development Indicator (2018-19)

shows speed of adjustment to restore equilibrium in dynamic model with a disturbance term. Coefficient of ECT is -1.48, which is relatively more elastic. This coefficient explains that deviation from long run equilibrium is corrected by 1.48% each year. Short run effect of energy consumptionis negative on CO_2 emissions per capita, but coefficient is significant only for lag one and three. Short run coefficients of energy consumption is relatively more elastic.

Diagnostic Tests

Table 3 shows that null hypothesis of presence of serial correlation,heteroscedasticity and no normality are rejected. These diagnostic tests elucidates that estimated model with lag threehas passed all diagnostic tests. It means model is not serially correlated, homoscedastic and normal in nature.

CONCLUSION

Results of this paper showpresence of conitegrationamong variables; i.e. CO_2, EC and GDP.Energy is an important factor for boosting economic growth. Energy is used in production process to transfer raw materials into goods. Increasing use of energy is raising demand of fossil fuel thereby depletion of scarce natural resources. Result of this paper depicts that effect of energy consumption on CO_2 emissions is positive and relatively more elastic in long run.1% increase in energy consumption will lead to about 1.15% increase in CO_2 emissions. It means energy consumption is responsible for environmental degradation in India. But effect of EC is negative on CO_2 emissions in short run. Inefficient use of energy is causing pollution in long run. More share of fossil fuel in total energy consumption and less use of renewable energy is responsible for this. So India should shift from fossil fuel to renewable and clean energy sources. Government should also support renewable energy development and encourage production of renewable energy. Indian government has responsibility to provide clean and healthy environment to their citizens. For this government should adopt strict environmental policies and also encouraged eco-friendly technologies that allow use of renewable energy rather than fossil fuel.

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