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Environmental Kuznets curve and India: Evidence from autoregressive distributed lag model

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Abstract. *The present study examined the presence of Environmental Kuznets Curve hypothesis in the context of India. The study employed the autoregressive distributed lag model over the period 1971 to 2016. The negative square of GDP indicates that the existence of the EKC hypothesis in India. This confirms that the negative sign of the square GDP coefficient suggests that the presence of the EKC hypothesis in India. The statistical significance of the error correction term ECTt-1 with an appropriate sign (-) is an indication of the speed of adjustment towards the long-run equilibrium after disequilibrium in the short run.*

Keywords: energy consumption, EKC, ARDL, cointegration, error correction, India.

JEL Classification: C3, Q4.

1. Introduction

India is one of the rapidly developing economies in the world. International Monetary Fund (IMF) accounts India is the 11th largest in terms of nominal GDP in the world and 3rd largest by purchasing parity (PPP). India's industrial and agriculture sector accounts for 28.6% and 14.6% of the country's GDP while the service sector contributes 57.2% respectively. Nevertheless, "there is widespread inequality as 42% of the Indian population survives under $1.25 a day (Planning Commission of India). To provide an acceptable standard of living and economic wellbeing India needs to grow more than 8% for the next couple of decades. (Integrated Energy Policy, IEP document, Planning Commission, GOI".

Inadequate energy supply affects India's economic growth badly. However, India is considered the 5th largest consumer of energy in the international rankings. In the year 2009 India's per capita energy consumption is 650 koe which is far below the world average. International Energy policy estimated that India is expected to raise its major energy supply 3 o 4 times by 2031 to keep GDP growth 8 per cent. Because of the huge availability of coal reserves, India's 55 per cent energy supply rest on coal energy. However, coal is considered an unclean fuel, consumption of coal emits a huge amount of carbon dioxide. At the international level, India is considered the 4th largest carbon emitter after the USA, China, and Russia. Whereas, in terms of per capita CO2 emission India is significantly below the world average. Therefore, the Indian economy facing the challenges between economic progress and environmental security like other developing nations.

At the early stage of economic growth, the EKC hypothesis indicates a direct linkage between environmental pollution and economic growth but the level of pollution declines after reaching a certain level of economic growth. Therefore, the Environmental Kuznets Curve hypothesis shows an inverted U-shaped linkage between pollution and economic growth. The shape of the EKC curve is based on three effects such as composition effect, technical effect and scale effect. At the beginning phase of industrialization, the level of pollution will be high due to heavy economic activity. This effect is considered a scale effect. When the level of economic activity rises, organizations adopted the use of cleaner technology as a consequence the pollution levels declines. This effect is known as a technological effect. When the organizations produce intensive goods in the production method the composition effects take place.

EKC studies specific to India

Literature by Khanna and Zilbermen (2001) and Bhattacharya and Ghoshal (2009) obtained the EKC hypothesis in their study; though Dietzenbacher and Mukhopadhyay (2007) Mukhopadhyay and Chakrobarty (2005) have denied the presence of EKC hypothesis. Managi and Jena (2007) empirically establish the presence EKC in the case of India Jayanthakumaran et al. (2012) empirically found that there is no linkage between CO2 emission and economic growth.

Theoretical background

Most EKC studies suggested that in the early stage of economic growth the environmental quality declines and successively improves in the well along. The analysis also found that

environmental pollution surges quicker than the increase in income in the initial stage of economic growth and reduces with the rise in income level.

Possible explanations for the EKC are seen in the following ways.

I. The transformation of economic activity from agrarian structure to polluting industrial stage than to a progressive clean service economic structure.
II. Higher the income of the inhabitants will increase the performance for environmental quality.

The presence of EKC in the literature has been questioned on various grounds. Some of them are quality parameters namely local pollutants, which indicates the presence of the Environmental Kuznets Curve. Nevertheless, past literature could not predict the level of income in which the level of environmental pollution declining.

The key motivation of this study is based on whether economic growth is a solution or problem of environmental pollution.

The initial study found an inverted U shaped hypothesis in the NBER working paper by Grossman and Kruegar (1991). This hypothesis defined the 'U' curve as the Intensity Use Hypothesis. This states that the intensity of material use diminishes beyond a certain level of income.

Kuznets (1955) investigated the linkage between per capita income and income inequality. The study shows that in the initial stage both the variables shows a positive direction but when it reaches the turning point then it started declining. This linkage between the two variables characterized in the form of a bell-shaped curve. This bell-shaped curve is known as the Kuznets curve. After the 1990's this Kuznets curve gets a new insight into the EKC literature. This EKC defined the per capita income and environmental pollution follow the inverted U shaped. Later this u shaped relationship between environmental pollution and per capita income known as Environmental Kuznets Curve. A set of studies like Grossman and Kruger (1991); Shafik and Bandyppadhyay (1992) Panayotou (1993) initially examined an inverted U shaped relationship between per capita income and pollution. Neverthless, Panayotou (1993) created this relationship as the Environmental Kuznets Curve or EKC Hypothesis.

In the initial phase of economic growth, environmental problems, and awareness is low and insignificant. The development of environmental-friendly technologies is not available. As a consequence pollution level rises with increasing per capita income for a certain level beyond which the quality of the environment increases so as income. As economic progress takes place with the strength of sectoral development the waste generation limit increases. When the economy achieved a higher level of development environmental awareness, better technology, environmental regulation and the level of environmental expenditure rises. As a result of which the level of environmental pollution gradually diminishes and the quality of the environment boosted.

This EKC hypothesis deals with a process of dynamic change. The analysis of EKC hypothesis is unambiguous about the time factor. The EKC studies have been examined empirically and various econometric tools have been employed for single and multi countries as well. In this study, the EKC hypothesis studied with yearly data from 1970-2016.

The EKC studies have been examined empirically and various econometric tools have been employed both for single and multiple nations. In this study, the EKC hypothesis examined the relationship between carbon emission, energy consumption, economic growth, population density, and trade liberalization with yearly data from 1971 to 2016.

The reminder of this paper is prepared as follows: Review of literature described in the second section. Data and variables are given in the third section. Model selection is presented in the fourth section. Empirical results explained in the fifth section and concluding remarks are discussed in the sixth section.

2. Review of literature

Kanjilal and Ghosh (2013) examined the presence of EKC hypothesis in the context of India from 1971-2008. The variable of the study includes per capita energy use, carbon emission, GDP and Trade openness. All the variables collected from World Development Indicators. By employing the threshold cointegration approach the empirical result found that carbon emission is highly elastic concerning real per capita income and energy consumption in India. The study also suggests that there is a long-run relationship between the variables.

Jalil and Mahmud (2009) investigated the environmental Kuznets curve hypothesis between carbon emission and GDP growth in the context of China from 1975- 2005. The variables include energy consumption, carbon emission, foreign trade, and income for the analysis. By employing the Granger causality and autoregressive distributed lag model the empirical result shows the existence of the EKC hypothesis in the study period in the context of China. The findings also reveal that unidirectional causality runs from economic growth to carbon emission.

Ahmed and Long (2012) studied the presence of EKC hypothesis in the case of Pakistan throughout 1971-2008. The study used economic growth, CO_2 emission, energy consumption, and trade liberalization, and population density for the analysis. All the variables sourced from WDI. The study used the ARDL and error correction econometric model. The empirical result suggests that the U-shaped relationship found both in the short-run and long-run between carbon emission and economic growth. The findings reveal that energy consumption and economic growth causes environmental pollution in Pakistan. Furthermore, the result also indicates population density harms the environment whereas, the openness of trade supports improving the environment.

He and Richard (2010) investigated the Environmental Kuznets Curve hypothesis in the context of Pakistan for 1971-2009. The variable includes in this study are per capita carbon emission, real GDP per capita, and squared of real GDP, energy use and trade openness. Carbon emission and energy consumption data are obtained from World Development Indicators (WDI). The real GDP and trade openness data are cumulated from The Economic Survey of Pakistan (2008-09). By using the ARDL cointegration and Granger causality test, the result shows that the long-run linkage among the variables and the study supports the presence of the EKC hypothesis in the context of Pakistan. The result also

shows unidirectional causality from economic growth to carbon emissions. Rising energy consumption raises carbon emission in the short-run as well as in the long run. However, the openness of trade helps to decline carbon emission in the long run.

Bekhet (2014) examined the existence of EKC and the causal linkage between energy consumption, carbon emission, and population in UAE and Saudi Arabia countries for the period 1975-2011. The variable includes CO_2 emission per capita is in metric tons, real GDP per capita is in constant 2005 US dollars, energy consumption per capita is in kt of oil equivalent, and the total population. The study employed the ARDL econmtric model. All variables are sourced from WDI. The empirical result found that EKC is not applied in both countries UAE and Saudi Arabia. The cointegration result confirms that there is a long-run linkage among the variables. The result also reveals unidirectional causality from GDP to CO_2 emission. Energy consumption increases CO_2 emission both in the short-run and long-run in Saudi Arabia but the UAE case only in the long run.

Aslanidis and Iranzo (2009) re-addressed the linkage between per capita income and pollution in 77 Non-OECD developing nations spanning from 1971-1997. The analysis includes per capita carbon dioxide emission and national income. The methodology used by the study is Non-linear Least Square (NLS) and Panel Smooth Transition Regression (PSTR) model for the analysis. The empirical result shows the absence of EKC in the context of all these nations.

Table 1. *Summary of review of literature*

Authors	Country	Time Period	Methodology	EKC Hypothesis
Ang (2008)	Malaysia	1971-1999	VECM, GC	NO
Halicioglu (2009)	Turkey	1960-2005	ARDL, GC	YES
Iwata et al. (2010)	France	1960-2003	ARDL	YES
Fodha, and Zaghdcod (2010)	Tunisia	1961-2004	VECM, GC	YES
Saboori et al. (2011)	Malaysia	1980-2009	ARDL, VECM, GC	YES
Tiwari (2011)	India	1971-2007	VAR, GC	YES
Shahbaz et al. (2012)	Pakistan	1971-2009	ARDL, GC	YES
Kareem et al. (2012)	China	1971-2008	VECM, GC	NO
Shahbaz et al. (2013)	Romania	1980-2010	ARDL	YES
Tiwari et al. (2013)	India	1966-2011	ARDL, VECM, GC	YES
Jali and Mahmud (2009)	China	1975-2005	ARDL, GC	YES
Ahmed and Long (2012)	Pakistan	1971-2008	ARDL	YES
He and Richard (2010)	Canada	1948-2004	Semiparametric	YES
			flexible	
			parametric	
Ang (2007)	France	1960-2000	ARDL, VECM	YES
Soytas et al. (2007)	USA	1960-2004	Toda-Yamamoto GC	NO
Ang (2008)	Malaysia	1971-1999	VECM, Granger Causality	No
Chebbi (2010)	Tunisia	1971-2004	VECM, Impulse Response (IRF)	No
Halicioglu (2009)	Turkey	1960-2005	ARDL, Granger causality	YES
Ghosh(2010)	India	1971-2008	ARDL, Johansen Juselius	YES
Ahmed and Long (2012)	Pakistan	1971-2008	ARDL	YES
Alam et al. (2012)	Bangladesh	1972-2006	ARDL	YES
Esteve and Tamarit (2012)	Spain	1857-2007	Threshold Cointegration Test	YES
Fosten et al. (2012)	UK	1850-2002	Non-linear threshold	YES
			cointegration and Error Correction Test	
Fosten et al. (2012)	United States	1900-2000	Ordinary Least Square (OLS)	YES
Saboori et al. (2012)	Malaysia	1980-2009	ARDL	YES
Giovanis (2013)	UK	1991-2009	Dynamic Panel Dta	No

Authors	Country	Time Period	Methodology	EKC Hypothesis
Saboori and Sulaiman (2013)	Malaysia	1980-2009	ARDL, Johansen Juselius	YES
Shabbaz et al. (2013)	South Africa	1965-2008	ARDL	YES
shabbza et al. (2013)	1980-2009	Malaysia	VECM, GC Test	YES
Farhani et al. (2014)	1971-2008	Tunisia	ARDL	YES
Lau et al. (2014)	Malaysia	1970-2008	ARDL, GC	YES
Yong and Zhao (2014)	India	1970-2008	GC & Directed Acyclic Graphs (DAG)	YES
Multi-Country Analysis				
Pao and Tsai (2010)	BRIC COUNTRIES	1971-2005	VAR &ECM	YES
Jounky (2010)	36 High inocme countries	1980-2005	VECM	YES
Orubu and Omotor (2011)	47 African countries	1990-2002	Longitudial Panels data	YES
Arouri et al. (2012)	12 MENA countries	1981-2005	Bootstrap Panel and cointegration techniques	YES
Wang (2013)	150 nations	2005-2011	Oradinary Leaste Square (OLS)	No
Apergis and Payne (2014)	7 Central American countries	1980-2010	Panel cointegration Test	YES
Apergis and Payne (2014)	189 countries	1990-2011	Panel Fully Modified Least Square (OLS)	Yes
Farhani et al. (2014)	10 MENA countries	1990-2010	Panel data Method	YES'
Cowan et al. (2014)	The BRICS countries	1990-2010	Panel Causality Test	YES
Menash (2014)	6 African countries	1980-2000		
Onafowora and Owoye (2014)	8 countries	1970-2010	ARDL	only for 2 countries

3. Description of variables, data and period of study

In this study, we have used annual data spanning the period from 1971 to 2016 in the context of India. The variables used in this study are GDP per capita in constant 2010 US $ as a proxy for economic growth, square of per capita GDP, per capita energy consumption (kg of oil equivalent). Trade openness, per capita CO2 emission metric tons, and Foreign Direct Investment (FDI). All the variables are sourced from World Development Indicators (WDI) website. All the variables used after logarithm transformation.

4. Model specification

To examine the long-run relationship among the variables the analysis used the linear logarithmic quadratic functional form.

$$CO_2 = \alpha_0 + \beta_{01} Y_t + \beta_{02} Y_t^2 + \beta_{03} E_t + \beta_{04} T_t + \beta_{05} FDI_t + \epsilon_t \quad (1)$$

t = defined time period = 1, 2,…, n.

Where ϵ_t is the error term, T defined as foreign trade.

"If the EKC hypothesis is true, the expected sign of β_{01} is positive and β_{02} is negative. The statistical significance of β_{02} implies a monotonically increasing relationship between per capita carbon emission and income. The coefficient of per capita energy use β_{03} is expected to be positive as higher energy consumption leads to higher carbon emission. The expected sign of β_{04} is mixed depending mainly on the development stage and

environmental aspects of the production process of an economy. In the case of the developed economy the sign of expected to be negative because a developed economy prefers to import pollution-intensive products from developing economies where environmental protection law is less stringent. Due to this reason, the expected sign for a developing economy is positive (Grossman and Krueger, 1991)". "The expected sign of T_t is also dependent on if the economy is export and import oriented. The coefficient of T_t can be negative in a developing economy if majority of its manufacturing products are imported from a developed country."

ARDL bound testing cointegration approach

The ARDL model estimates the unrestricted error correction model. The model representation is shown in equation 2.

$$\begin{aligned}\Delta CO_2 = \ \alpha_0 + \sum_{i=1}^{n} b_{1i}\Delta CO_{2t-i} + \sum_{i=1}^{n} b_{2i}\Delta Y_{t-i} + \sum_{i=1}^{n} b_{3i}\Delta Y_{t-i}^2 + \sum_{i=1}^{n} b_{4i}\Delta E_{t-i} \\ + \sum_{i=1}^{n} b_{5i}\Delta T_{t-i} + \sum_{i=1}^{n} b_{6i}\Delta FDI_{t-i} + \ \delta_1 CO_{2t-1} + \delta_2 Y_{t-1} + \ \delta_3 Y_{t-1}^2 \\ + \delta_4 E_{t-1} + \delta_5 T_{t-1} + \delta_6 FDI_{t-1} \\ + \epsilon_{1t} \qquad (2)\end{aligned}$$

F-test is employed to test whether a cointegration linkage exists between the variables the null hypothesis of no cointegration among the variables in Eq- (2) is $H_0;\ \delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = \delta_6 = 0,$ against $H_1;\ \delta_1 \neq \delta_2 \neq \delta_3 \neq \delta_4 \neq \delta_5 \neq \delta_6 \neq 0$, which signified as FCO_2 (CO_2/Y, Y^2, E, T, FDI).

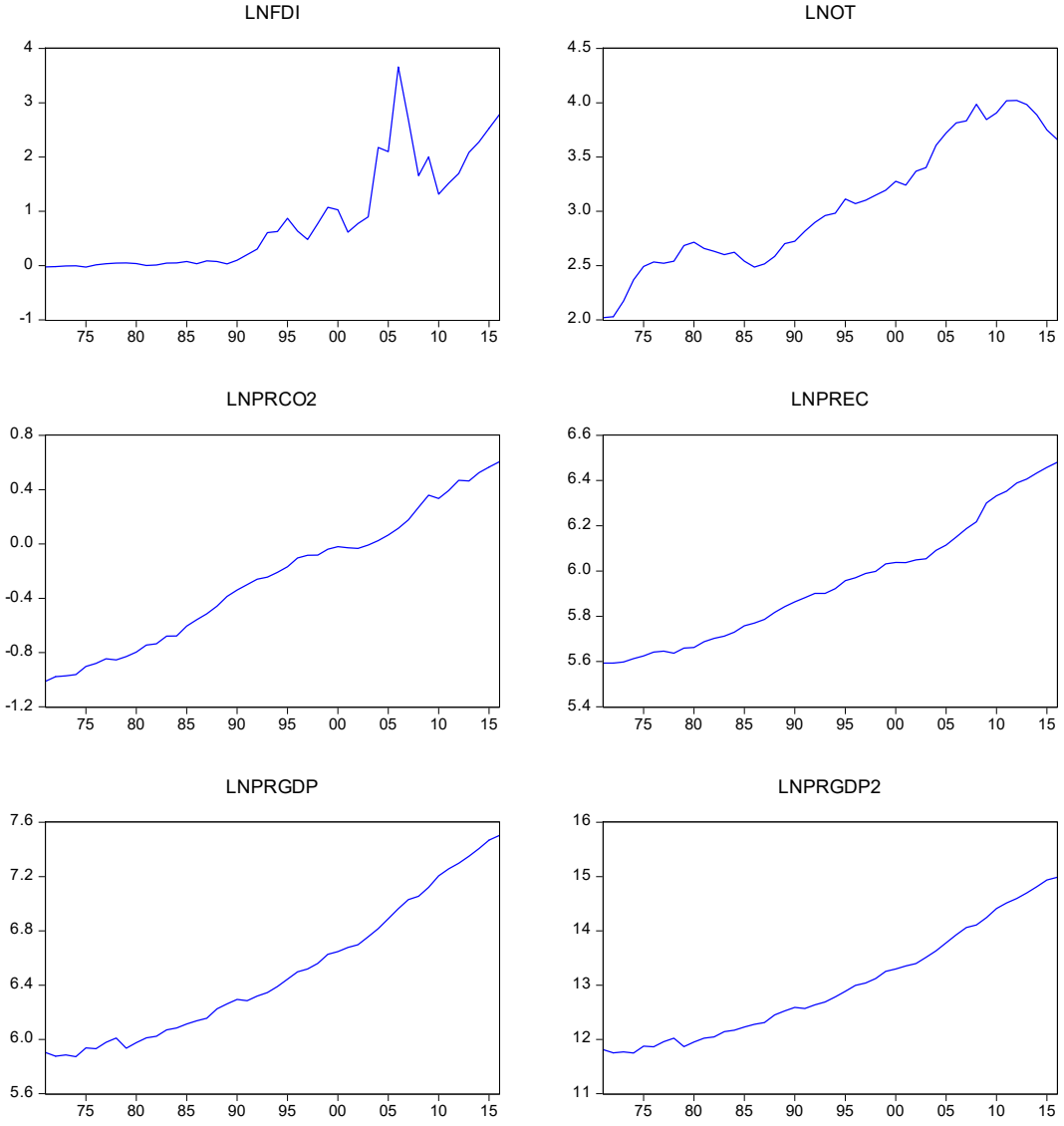
Unrestricted error correction test

To know the short-run dynamics we have estimated the error correction model (ECM), the equation as follows

$$\begin{aligned}\Delta CO_2 = \ \alpha_0 + \sum_{i=1}^{n} b_{1i}\Delta CO_{2t-i} + \sum_{i=1}^{n} b_{2i}\Delta Y_{t-i} + \sum_{i=1}^{n} b_{3i}\Delta Y_{t-i}^2 + \sum_{i=1}^{n} b_{4i}\Delta E_{t-i} \\ + \sum_{i=1}^{n} b_{5i}\Delta T_{t-i} + \sum_{i=1}^{n} b_{6i}\Delta FDI_{t-i} + \ \delta_1 CO_{2t-1} + \delta_2 Y_{t-1} + \ \delta_3 Y_{t-1}^2 \\ + \delta_4 E_{t-1} + \delta_5 T_{t-1} + \delta_6 FDI_{t-1} \\ + \theta\ ECT_{t-i} + \epsilon_{1t} \qquad (3)\end{aligned}$$

Here, the ECT_{-1} is the error correction term, and in the end, we estimate the stability of coefficients sum (CUSUM) and cumulative sum square (CUSUMSQ).

Figure 1. *Variable plots*



5. Empirical results and interpretation

The summary statistics are reported in Table 2. The table shows the coefficient of skewness is greater than zero for all variables. The coefficient of kurtosis is relatively high in the case of foreign direct investment. The result also indicates jb test rejects the null hypothesis of normal distribution for all the variables.

Table 2. *Descriptive statistics*

	LNFDI	LNOT	LNPRCO2	LNPREC	LNPRGDP	LNPRGDP2
Mean	0.82	3.05	-0.26	5.94	6.49	12.99
Median	0.54	2.97	-0.22	5.91	6.36	12.73
Maximum	3.65	4.02	0.60	6.48	7.50	14.98
Minimum	-0.03	2.01	-1.01	5.59	5.87	11.74
Std. Dev.	0.97	0.59	0.48	0.27	0.50	1.01
Skewness	1.06	0.21	0.07	0.44	0.52	0.51
Kurtosis	3.13	1.85	1.82	2.07	2.00	2.00
Jarque-Bera	8.79	2.89	2.66	3.15	3.97	3.97
Probability	0.01	0.23	0.26	0.20	0.13	0.13

The co-movement analysis is presented in the following Table 3. The result of correlation statistics indicates that there is a high correlation exist between the variables.

Table 3. *Co-movement analysis*

Variables	LNFDI	LNOT	LNPRCO2	LNPREC	LNPRGDP	LNPRGDP2
LNFDI	1					
LNOT	0.87* [12.10] (0.00)	1				
LNPRCO2	0.84* [10.34] (0.00)	0.94* [19.52] (0.00)	1			
LNPREC	0.86* [11.31] (0.00)	0.94* [19.98] (0.00)	0.98* [46.51] (0.00)	1		
LNPRGDP	0.88* [12.86] (0.00)	0.95* [21.42] (0.00)	0.97* [32.55] (0.00)	0.99* [71.25] (0.00)	1	
LNPRGDP2	0.88* [12.86] (0.00)	0.95* [21.50] (0.00)	0.97* [32.60] (0.00)	0.99* [71.24] (0.00)	0.99* [2931.12] (0.00)	1

Note: [ ] shows' statistics and ( ) indicates 'P' values and * indicates 1% level of significance.

The unit root test is shown in Table 4. The result of the unit root test indicates that all the variables are integrated of order 1 i.e., I (1). This result provides strong evidence to investigate the long-run linkage between the variables by using the ARDL bound testing method which is independent of the order of integration.

Table 4. *Unit root test*

Variables	ADF Test		PP Test	
	Level	First Difference	Level	First Difference
lnprgdp	3.68 (1.00)	-6.01* (0.00)	4.93 (1.00)	-6.04* (0.00)
lnprgdp2	3.55 (1.00)	-6.03* (0.00)	4.30 (1.00)	-6.06* (0.00)
lnprco2	0.88 (0.99)	-6.31* (0.00)	0.83 (0.99)	-6.33* (0.00)
lnprec	3.20 (1.00)	-5.04* (0.00)	2.80 (1.00)	-5.18* (0.00)
lnot	-1.62 (0.46)	-2.84* (0.06)	-1.50 (0.52)	-4.64* (0.00)
lnfdi	-0.84 (0.79)	-7.54* (0.00)	-0.72 (0.82)	-7.51* (0.00)

Note: * shows 1% level of significances. ( ) denoted the probability value.

Table 5. *Unit root test with unknown structural break*

Variables	ADF Test at Level		ADF Test at First Difference	
	Statistics	Break Date	Statistics	Break Date
lnprgdp	0.87 (0.99)	1993	-7.59** (0.01)	1993
Lnprgdp2	0.76 (0.99)	1993	-7.59** (0.01)	1993
$Lnprco_2$	-0.84 (0.99)	2005	-6.84** (0.01)	2008
lnprec	-0.20 (0.99)	2004	-6.99** (0.01)	2009
lnot	-2.86 (0.75)	1988	-5.85** (0.01)	2013
Lnfdi	-3.69 (0.28)	2003	-8.33** (0.01)	2004
Significance				
CV 1%	-4.94			
CV 5%	-4.44			
CV 10%	-4.19			

Note: ** show the significance at 5% and ( ) parenthesis indicates the probability values.

Table 5 shows the unknown structural break unit root test result while employing the Augmented Dickey-Fuller (ADF) structural break. The result shows in the presence of structural break the variables are found to be non-stationary. The structural break found in 1993, 2005, 2004, 1988 and 2003.

Table 6. *Long-run and short-run analysis*

Dependent Variables: $lnCO_2$			
Long-run Results			
Variables	Coefficients	T-statistics	P-vale
Lnprec	2.56	14.57	0.00*
Lnprgdp	3.25	8.79	0.00*
Lnprgdp2	-0.27	-11.78	0.00*
Lnot	-0.00	-0.09	0.92
Lnfdi	0.02	1.16	0.12
C	-24.88	-30.43	0.00*
Short-run Results			
Variables	Coefficients	T-statistics	P-vale
D (lnprec)	1.86	7.86	0.00*
D (lnprgdp)	8.41	4.75	0.00*
D (lnprgdp2)	-0.70	-4.81	0.00*
D (lnot)	-0.09	-1.75	0.09
D (lnfdi)	0.00	0.30	0.76
$ECT_{(T-1)}$	-1.02	-3.75	0.00*

Note: * shows the 1% level of significance.

The long-run results are reported in Table 6. The result reveals that energy consumption has a positive impact on carbon emission. An increase in energy consumption will increase CO_2 emission. Furthermore, economic growth has a positive impact on carbon emission. High economic growth leads to high emissions. The negative coefficient of square GDP suggests that the existence of the EKC hypothesis. The result shows that a 1 per cent rise in economic growth will decrease carbon emission by 2.56% in the long run. While the negative sign of the square term seems to corroborate the decline of CO_2 emission and a higher level of economic growth. The long-run result also reveals that openness of trade and foreign direct investment does not have any impact on CO_2 emission.

The ECM_{T-1} short-run results are presented in Table 6. The short-run elasticity of CO_2 emission, concerning energy consumption, is positive and significant. The positive sign of per capita energy consumption is indicating that in India for each one per cent increase in energy consumption per capita CO_2 emission also increases by 1.86 per cent. Economic growth is another positive significant factor in the short-run which shows that increase in economic growth leads to more carbon emission. However, the square of economic growth is a negative and significant variable. The negative sign of the square of economic growth supports the existence of an environmental Kuznets curve in India. The openness of trade is negative and insignificant in the short-run and the foreign direct investment is positive and insignificant in the short run. The statistical significance of the error correction term ECT_{t-1} with an appropriate sign (-) is an indication of the speed of adjustment towards the long-run equilibrium after dis-equilibrium in the short run. This indicates that any deviation from the long-run equilibrium between CO_2 emission and other variables is corrected in each period and restored to the long-run equilibrium level after disequilibrium in the short run.

Table 7. *Diagnostics test of error correction model*

Tests	F-statistics	Prob.
Breusch Godfrey Serial Correlation LM Test	3.16	0.06
Breusch Pagon Godfrey- Heteroskedasticity Test	0.79	0.70
Heteroskedasticity Test: ARCH	1.82	0.18
Heteroskedasticity Test: Glejser	0.99	0.50

Table 7 reported the diagnostics test result which shows that the error correction model is free from serial correlation, autoregressive conditional heteroskedasticity, and functional from. And the model is well specified.

The empirical results of the ARDL bound testing result are shown in Table 8. The ARDL result shows that the estimated F-statistics is greater than the critical values of both upper bound and lower bound. This ARDL result confirms that there is a long-run equilibrium relationship between the variables.

Table 8. *ARDL result for cointegration*

F-Statistics	Optimal Lag Order	Lower Bound I (0)	Upper Bound I (1)
		Critical Values	Critical Values
5.688*	4, 4, 2, 2, 3, 1	3.74 (1%)	5.06 (1%)
		2.86 (5%)	4.49 (5%)
		2.45 (10%)	3.52 (10%)

Note: * Indicates 1% level of significance.

Table 9. *ARDL diagnostic test*

Tests	F-statistics	Prob.
Breusch Godfrey Serial Correlation LM Test	2.09	0.14
Breusch Pagon Godfrey- Heteroskedasticity Test	0.88	0.59
Heteroskedasticity Test: ARCH	0.27	0.60
Heteroskedasticity Test: Glejser	0.72	0.74

The ARDL diagnostic test result is reported in Table 9. Table 9 reveals that the ARDL bound testing approach is free from serial correlation, autoregressive conditional heteroskedasticity, and functional form and the model is well specified.

6. Concluding remarks and policy suggestions

The major objective of this study is to investigate the existence of an environmental Kuznets curve hypothesis in the context of India. The study employed the autoregressive distributed lag model over the period 1971 to 2016. The empirical result of the co-movement analysis found that there is a high correlation between the variables. The ordinary least square result confirms that economic growth has a positive and significant impact on carbon emission. The OLS result initially confirms that there is an existence of an environmental Kuznets curve for India. The ARDL bounds testing result suggests that there is a long-run equilibrium relationship among the variables when carbon emission is the dependent variable. The long-run cointegration result reveals that energy consumption has a positive impact on carbon emission. The negative square of GDP indicates that the existence of the EKC hypothesis in India. This confirms that the negative sign of the square GDP coefficient suggests that the presence of the EKC hypothesis in India. The error correction result shows that the positive sign of per capita energy consumption is indicating that in India for each 1 per cent increase in energy consumption per capita CO_2 emission also increases by 1.86 per cent. The statistical significance of the error correction term ECT_{t-1} with an appropriate sign (-) is an indication of the speed of adjustment towards the long-run equilibrium after disequilibrium in the short run.

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