Society & Change
Vol. XVI, No.4, October-December 2022
ISSN: 1997-1052 (Print), 2227-202X (Online)

Environmental Kuznets Curve for CO_2 Emission in India: Way for Pollution Control and Sustainable Growth

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Abstract

This papertries to examine how emission of CO_2 responds to the growth of per capita GDP, changing share of manufacturing and international trade in India for the period 1960 to 2020. The ARDL and Cointegration methods are employed to examine the short and long run quadratic relationships of the time series data. The results suggest that a long run relation exists among CO_2 emission, economic growth, manufacturing output and export as a percentage of GDP. The existence of an EKC in India is however associated with short run insignificant relation of CO_2 emissions with manufacturing output and export in proportion to GDP. The long-run existence of EKC hypothesis in India, proves that economic growth is the means to environmental improvement in the long run. However, the positive relation of manufacturing share in GDP with CO_2 emissions alerts for taking care of growth of manufacturing but with serious environmental management and control of emission standard and overall pollution.

Keywords: EKC, ARDL, Cointegration, CO_2 Emission, Income

Background

EKC is now a widely researched topic and a large number of studies tried to establish or refute the inverted U hypothesis relating degradation of environmental quality with the level of development or economic progress by using cross country level data. It has been largely confirmed that the very poor economies, representing early stages of development use environmental deteriorating technology in various production units for the progress of the nation. Hence with rising per capita income (GDP) these nations experience higher concentration of pollutants, green-house gasses, carbon footprints. In line with this argument, the middle-developed countries are mostly found to exhibit greater deterioration of environmental quality. While the highly developed nations are in general

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found to use mostly environment friendly technologies for sustaining their growth process with the realization of higher social cost associated with environmental damage. Also, the demand for environmental quality rises with growth after a certain stage of development (Deacon and Norman, 2004). Thus, growing investment and innovation in less pollution intensive production technology with knowledge expansion and research are observed at higher level of development (Sun, 2011).

In comparison to using cross country level data and panel analysis, limited studies are found to examine the process of temporal changes in environmental quality with the development of a single country over time (Aung et al, 2017). It is highly likely that at the early stages of global development only a few nations led the economic progress, by registering rapid industrial revolutions and the realization of environmental degradation comes much later. The reason would be their control over global socio-political space and a competition among a few in their grid for faster development in earning. Also, there remained less international pressure for maintaining environmental standard from large number of low developed countries, who lagged far behind in industrial progress and record lesser environmental damage. When these lesser developed nations try to catch up the progress of advanced nations through agricultural and industrial progresses, trade etc, on several occasions they face the opposition from the erstwhile developed nations for rapid global environmental damage. Further, with rapid progress in knowledge, information technology, these nations may have own realization about the adverse environmental consequences of development activities much earlier than the formerly developed countries. Therefore, quality of environment starts improving in these nations at middle level of development (with comparatively moderate income and low altitude peak of environmental damage) as compared to those few highly developed nations who undertook necessary steps towards environmental management after reaching a high per capita income and higher altitude peak of environmental damage.

It may be likely that middle or lower-middle income countries despite late starter and yet large dependence on traditional technology, take necessary steps towards adopting environment friendly technology and control emission of pollutants early. Since the pattern of EKC varies across countries, a time series analysis in respect of a single country would yield a better understanding of the income environmental quality relationship (Jalil et al. 2010).

Objective

This paper, instead of considering a cross country level or longitudinal data only followed the data on pollution (CO_2 emission) per unit of GDP and the per capita GDP, share of manufacturing etc in India since 1960. Using the data, we tried to examine how emission of CO_2 responds to the growth of per capita GDP (i.e., development), rising share of manufacturing (though it is still low in India),international trade (export as percentage of GDP) and urbanization (Shukla and Parikh, 1992; Stern et al. 1996; Aung et al, 2017).The research question to be answered here if the positive externality through experience of earlier development elsewhere and progress of knowledge in recent decades caused faster realization and it is possible to maintain the tempo of growth despite adopting environment friendly technologies.Here the ARDL and Cointegration methods are employed to examine the short and long run quadratic relationships of the time series data.

In the next section of the paper, reviews of a relevant selected literature encompassing EKC and the variables included in the analysis is incorporated. Thereafter, the theoretical and the econometric model for estimation is narrated. The empirical findings and discussion are reported in the following section, which is followed by the conclusion and policy implications.

Studies on Environmental Quality or Emission of Green-House Gas and Economic Growth

Plethora of studies are there on environmental quality and economic development trade. There are studies that reflect the direct consequence of economic growth on the environmental quality due to anthropogenic growth-related activities. Also, studies are there on development activities which create conditions and necessitate some policy and activity changes ushering adverse environmental consequences.

After the Club of Rome arguments (Meadows et al, 1972) a series of events drew serious attention of people and governments across the countries in regard to saving the environment and simultaneously maintain the tempo of economic growth. There were several studies on cross country data, demonstrating inverted U relation between environmental pollution (degradation) and economic growth (Shafik and Bandyopadhyay, 1992; Panayotou, 1993; Selden and Song 1994;Grossman and Krueger, 1995; Galeotti and Lanza 1999; Millimet and Stengos 1999;Bradford et al. (2000), Halkos (2003);Hilton 2013;Kasman and Duman (2015); Neequaye and Oladi (2015); Gökmenoğlu and Taspinar (2016); Narayan et al. (2016); Javid and Sharif(2016); Haq et al. (2016); Esso and Keho (2016); Ahmad et al. (2017); Katircioğlu and Taşpinar (2017); Abdouli and Hammami (2017); Shahzadet al. (2017); Antonakakis et al. (2017); Sapkota and Bastola(2017); Sinha and Shahbaz(2018). Most of these studies have confirmed inverted-U relation of carbon dioxide emissionper capita income. In other words, CO_2 emission increases first with the growth of per capita income and it reaches a peak level and then declined with further growth of per capita income.

Amidst there have been several counterarguments and empirical results of non-existence of the EKC relation between economic growth and environmental quality either in the short run or long run (Dasgupta and Heal, 1979; Simon, 1981; Mayers, 1991; Repetto, 1989; Harbaugh et al., 2002; Haq *et al.*, 2016; De Bruyn *et al.*, 1998). It brought about controls at different levels irrespective of the level and stages of development across the world.

The US Environmental Protection Agency (US EPA) reported that the global net GHG emissions associated with various anthropogenic activities increased by about 35% between 1990 and 2000, with about 46 billion metric tons (US EPA 2014).Organization for Economic Cooperation and Development(OECD) also projected an increase of around 52% in GHG emissions by2050 if further measures are not taken to mitigate climate change (Sohag et al. 2017).CO_2 is one of the major green-house gases that contributes substantially to the global warming (Tang et al. 2015). A few studies in recent past also examined the EKC hypothesis by using ARDL method (Narayan and Narayan 2010 and Al-Mulali et al. 2015).

In various empirical studies on EKC, interlinkage of different environmental indicators with the indicator of development (say per capita income or GDP) are examined across the countries that reflected varied outcomes. There is study investigating the existence of EKC for water pollution in some 30 countries sharing major rivers by using pooled mean group(PMG) estimation method (Thompson, 2014). Also, a study reveals non-existence of EKC relation between water pollution and per capita income (Barua and Hubacek, 2009). Further, the EKC relationship for deforestation differsin studies across the regions (Choumertet al. 2013). Studies on relationship between various atmospheric pollutants and economic growth observed mixed results. The relations between energy consumption, trade openness, emission or concentration of CO_2, SO_2, CH_4etc have been examined by Zambrano-Monserrate et al. (2016), Ang (2007), Pao and Tsai (2011), Ali et al. (2015), Davalos (2016), Jacint and Manuel (2016), Zambrano-Monserrate et al. (2016a, b), Al-Mulali et al. (2016), Saboori and Sulaiman (2013a, b), Alabdulrazag and Alrajhi (2016),Jungho (2015), Lachehed et al. (2015), Mazzanti et al. (2008), Cho et al. (2014), Parlow (2014), Aung et al (2017), Zambrono-Monserrate and Fernandez (2017).

Overall, a large number of studies have investigated the EKC hypothesis in both the developed and developing countries, by using different econometric methods, tools and variables. In most of these studies, relation between the emission of CO_2 or fossil fuel consumption with GDP growth per capita got prominent attraction assuming the importance of fossil fuel use and greenhouse emissions on the climate change scenario and its possible impacts. In order to examine the EKC hypothesis in the long or short run, researchers applied simple quadratic regression, cointegration, ARDL, ECM, VECM, panel error correction methods depending upon the nature of data (time series, longitudinal) and suitability of the method. Several studies found inverted U type EKC relation, and against these a few analyses observed relation like N or linear rejecting the hypothetical EKC relation.

There are very few studies conducted in India examining the existence of EKC despite significant structural changes in economic growth and policy evolutions in the last few decades. The climate change scenario has also been reflected in erratic rainfall and spatio-temporal temperature variations.

Materials and Methods

In order to examine the relationship between CO_2 emissions and economic growth in India for the period 1960 to 2020, data on yearly CO_2 emissions (per unit of GDP at 2010 USD), GDP and per capita GDP (at 2010 USD), manufacturing output share of GDP, share of export, import to GDP, percentage of urban population to total population have been extracted from the World Bank website (https://data.worldbank.org). Thereafter, CO_2 has been plotted against various variables like time, per-capita GDP, manufacturing share of GDP, export, urbanization. All the bi-variate relations appear to fit a quadratic function of inverse U type. Further, the rate at which the CO_2 is observed to rise with the growth of per-capita GDP, export or urbanization; after reaching its peak the speed of decline with further growth of per capita GDP, export or urbanization is found to be slower. The results of bi-variate simple and log-linear regressions with respect to various variables before and after the peak point are presented in Tables 1 and 2.

Looking at the scattered diagram we tried to fit the quadratic relation of theoretical EKC type. Logarithms of the variables are considered as it reduces the fluctuations and improve consistency as well as to get the elasticity directly in the form of demand for environmental quality with the rise in relevant explanatory variables.

$$Ln(CO_2)_t = \beta_1 + \beta_2 LnY_t + \beta_3 (LnY_t)^2 + \beta_4 LnManu_t + \beta_5 (LnManu_t)^2 + \beta_6 LnExp_t + \beta_7 (LnExp_t)^2 + + U_t \dots\dots\dots (1)$$

where $(CO_2)_t$ is the emission of CO_2in India during year t;$Y_t$is the per capita GDP (at 2020 USD) in the year t; $Manu_t$ is the percentage share of manufacturing in t^{th} year; Exp_t represents total export as a percentage of GDP in t^{th}year; Urb_t is the urbanizationin t^{th} yearand U_t is the random disturbance term.With rising per capita income, demand for environmental quality may rise and hence the coefficient of $(LnY_t)^2$ is expected to be negative. Similarly, in the initial years, growing manufacturing activities is expected to enhance CO_2 emissions with more and more fossil fuel consumption. But after a certain stage demand for clean energy is expected to rise and thus coefficient of $(LnManu_t)^2$ is hypothesized to be negative.Some studies have considered energy consumption as an explanatory variable for explaining changes in CO_2 emission (Aung et al 2017; Muhammad et al, 2010). Assuming manufacturing consumption is highly energy intensive, here in the absence of energy consumption data, we used manufacturing share of GDP as an explanatory variable.More share of export means production and rise in pollution intensive goods in the early years, which comes down with the growing international pressure on demanding pollution free goods and availability of such technology. In the same way, with urbanization first CO_2 emission is expected to and then decline after reaching a peak. Hence, the coefficients of all squared variables on the right-hand side of equation-1 are expected to have negative sign.

Further, both the short and long-term relations have been examined by ARDL bound test model developed by (Pesaran and Pesaran,1997; Pesaran et al., 2001)and cointegration (Johensen, 1988).We applied augmented Dickey–Fuller (ADF) (Dickey and Fuller, 1979) and Phillips and Perron (PP) test (1988) todetect the stationarity of data series.Depending on the order of integration, Johansen cointegration test (1988) is applied to testlong run relationship between variables.

Of course, the autoregressive distributive lag model can be applied without investigating theorder of integration (Pesaran and Pesaran, 1997). The ARDL approachto cointegration is expected to provide better outcome(Haug, 2002) for small sample as compared to the traditional approach of cointegration developed by Engle and Granger (1987), Johansen and Juselius(1990) and Philips and Hansen (1990). Another advantageof ARDL bounds testing is that the unrestricted model of ECM has sufficient flexibility toaccommodate lags that captures the data generating process in a general-to-specific framework ofspecification ((Laurenceson and Chai, 2003). Further, appropriate modification of theARDL model may simultaneously correct the residual serial correlation andproblem of endogeneity (Pesaran and Shin, 1999).

The unrestricted ADRL model is written as

$$\Delta LnCO_2 = \alpha_1 + \alpha_2\, LnY_{t-1} + \alpha_3\, (LnY_{t-1})^2 + \alpha_4\, LnManu_{t-1} + \alpha_5 LnExp_{t-1} + \alpha_6 LnUrb_{t-1} +$$

$$\sum_{i=1}^{p} \alpha_i \Delta \mathrm{Ln}CO_{2,\ t-i} + \sum_{j=0}^{q} \alpha_j \Delta \mathrm{Ln}Y_{t-j} + \sum_{k=0}^{r} \alpha_k \Delta (LnY_{t-k})^2 + \sum_{l=0}^{s} \alpha_l \Delta \mathrm{Ln}Manu_{t-l} + \sum_{m=0}^{u} \alpha_m \Delta \mathrm{Ln}Exp_{t-m} + \sum_{n=0}^{v} \alpha_j \Delta \mathrm{Ln}Urb_{t-n} + \mu_t$$

Here, the ARDL bounds testing approach to cointegration is based on the tabulated critical values byPesaran et al. (2001) to make a decision about cointegration among the variables. The null hypothesis is that $\alpha_2 = \alpha_3 = \alpha_4 = \alpha_5 = \alpha_6 = 0$. Cointegration among the chosen variables exist if the computed F value is greater than the tabular upper critical bound. If the long run relationship among the variables exists, the short run behavior of variables is examined by the following ECM model.

$$\Delta \mathrm{LnCO}_2 = \delta_1 + \eta ECM_{t-1} + \sum_{j=0}^{q} \delta_2 \Delta \mathrm{Ln}Y_{t-j} + \sum_{k=0}^{r} \delta_3 \Delta (LnY_{t-k})^2 + \sum_{l=0}^{s} \delta_4 \Delta \mathrm{Ln}Manu_{t-l} + \sum_{m=0}^{u} \delta_5 \Delta \mathrm{Ln}Exp_{t-m} + \sum_{n=0}^{v} \delta_{j6} \Delta \mathrm{Ln}Urb_{t-n} + €_t$$

The error correction term represents the short run changes in dependent variabletowards long-run equilibrium path (Masih and Masih, 1997). The relevance of theARDL model is checked through stability tests such as cumulative sum of recursive residuals (**CUSUM**) and cumulative sum of squares of recursive residuals (**CUSUMSQ**).

Observations and Findings

Figure 1 reveals that there was steady rise in emission of CO_2 in India from 1960 till 1992 that coincides the year of Kyoto Protocol and it declined thereafter. At the global level also, overall CO_2 emission per PPP USD of GDP decreased steadily since 1993 (World Bank, https://data.worldbank.org/indicator/EN.ATM.CO2E.PP.GD). The pattern of change fits a quadratic equation against time; after reaching a peak emission level of 1.29 kg per unit of GDP at 2010 USD it started declining. Simple linear regression of emission level per unit of GDP on t (time) and t^2 is found to be $Y_t = 0.752 + 0.024\ t - 0.000352\ t^2$ … … … (1)$R^2 = .751$

Fig. 1

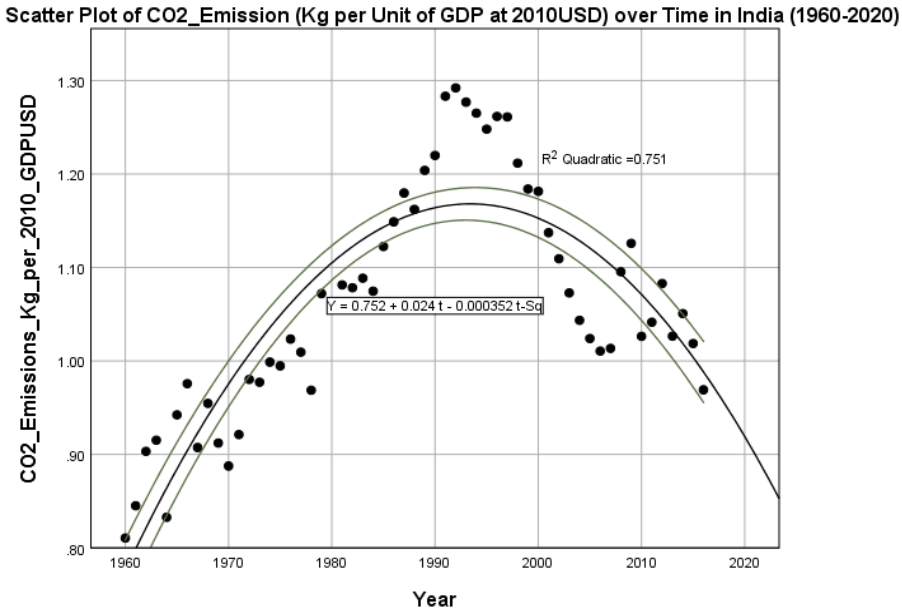


Fig. 2

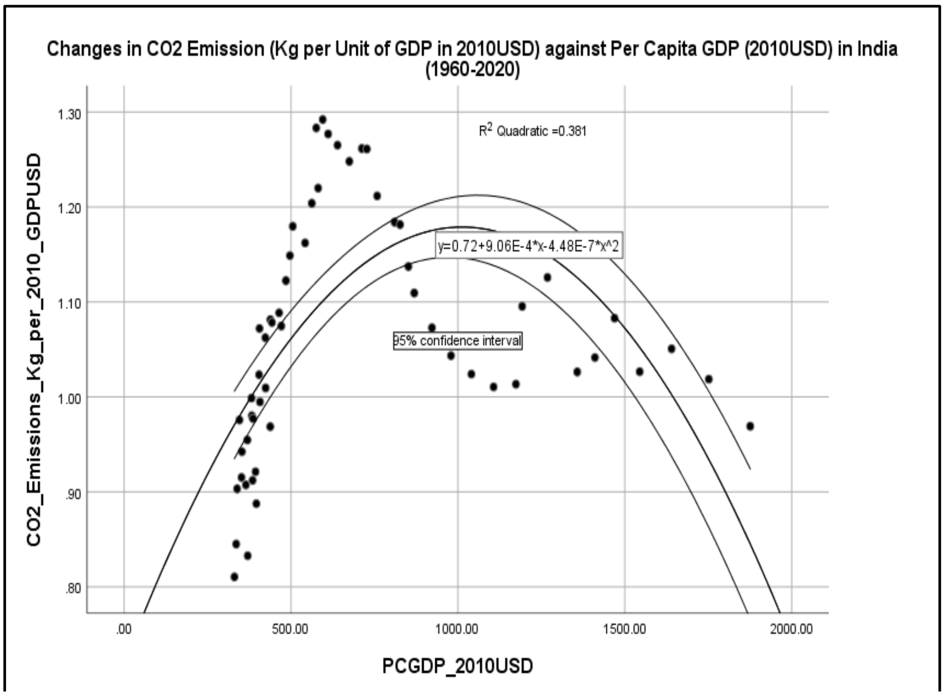


Fig. 2 reveals inverted U relation between CO_2 emission per unit of GDP with per capita GDP (in 2010USD) in India which reached its peak (1.29 KG per unit GDP) at per capita GDP (520 USD) and then declined till 2020.The diagram fits much better when the emission and per capita GDP is log transformed, as shown in Fig. 3. The fitted line displays inflection (2^{nd} order derivative) value of -0.4 with R^2 value of 0.69. The estimated simple linear regression (OLS) is $LnCO_2 = -17.544 + 5.306\ LnPCGDP - .397\ (LnPCGDP)^2$, … … (2), $R^2 = .692$

Fig. 3: Changes in LogCO_2 against Log Per Capita GDP at constant 2010 USD

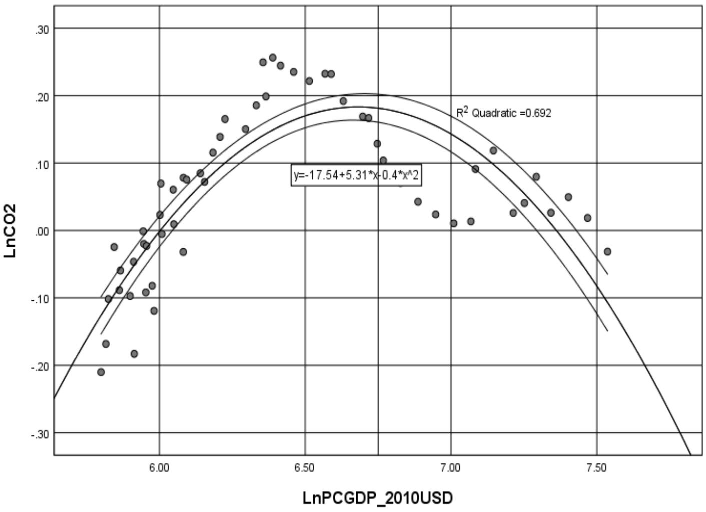


Fig 4 reveals a similar inverse U relation of CO_2 emission per unit of GDP with urbanization in India, where emission reached its maximum at around 27 percent urbanization. A similar relation is observed between CO_2 emission per unit of GDP with export as percentage of GDP (Fig 4). Whereas, the relation of CO_2 emission per unit of GDP with share of manufacturing output in GDP is not found to be very strong (Fig 5). It is due to the fact that share of manufacturing to GDP in India has not increased significantly over the years. It is the tertiary sector growth that has been taking place exponentially and economic growth in India registered a direct shift from primary to tertiary sector, bypassing the secondary sector.

Fig. 4

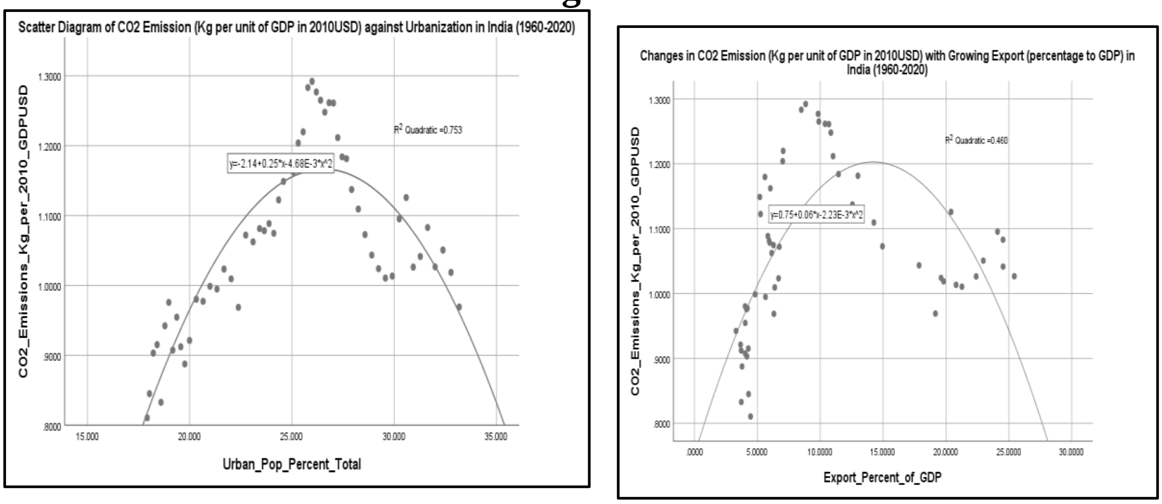
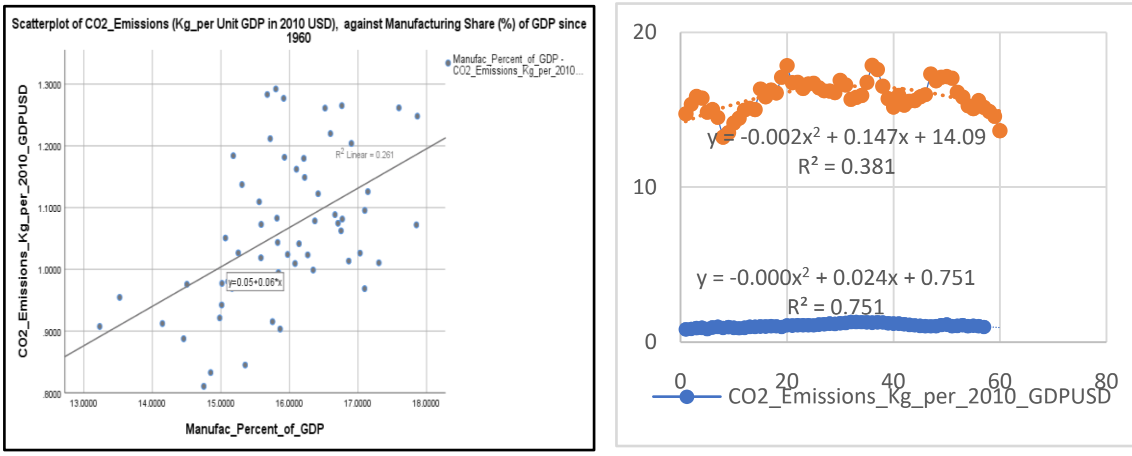


Fig. 5: Relation between CO_2 Emission and Manufacturing Output in India since 1960



The semi-log linear and log-log linear relation between CO_2 emission and share of manufacturing output to GDP over the years can also be expressed by ordinary linear regression (equations 3 and 4) in quadratic form. The coefficient of square term on the right-hand side is howeverobserved to be negative.

$LnCO_2 = -4.476 + 0.159\ LnManufact\_Output - 1.28E^{-27}\ Manufact\_Output^2$ … … (3), $R^2 = .60$

$LnCO_2 = -96.50 + 6.61\ LnManufact\_Output - 0.113\ (LnManufact\_Output)^2$ … … (4), $R^2 = .79$

Table 1: Regression of CO_2 on Various Explanatory Variables before and after 1992

1960-1992 (N = 33)		1993-2018 (N = 26)	
$CO_2 = .813 + .012\ t$ (59.15) (17.73)	$R^2 = .91$, $\bar{R}^2 = .907$, F = 314.25***	$CO_2 = 1.67 - .012\ t$ (25.72) (-8.66)	$R^2 = .773$, $\bar{R}^2 = .763$, F = 74.97***
$CO_2 = .364 + .002$ PCGDP (7.94) (14.67)	$R^2 = .874$, $\bar{R}^2 = .87$, F = 215.10***	$CO_2 = 1.347 - .000213$ PCGDP (35.75) (-6.52)	$R^2 = .66$, $\bar{R}^2 = .643$, F = 42.48***
$CO_2 = -.026 + .067$Manufacturing (-.092) (3.71)	$R^2 = .31$, $\bar{R}^2 = .29$, F = 13.76***	$CO_2 = .56 + .034$ Manufacturing (1.45) (1.432)	$R^2 = .09$, $\bar{R}^2 = .044$, F = 2.052
$CO_2 = .628 + .074$Export (12.73) (8.32)	$R^2 = .691$, $\bar{R}^2 = .681$, F = 69.213***	$CO_2 = 1.368 - .015$Export (36.15) (-7.04)	$R^2 = .693$, $\bar{R}^2 = .679$, F = 49.55***
$CO_2 = .64 + .058$Import (9.44) (5.83)	$R^2 = .523$, $\bar{R}^2 = .507$, F = 33.94***	$CO_2 = 1.322 - .011$Import (34.45) (-5.762)	$R^2 = .601$, $\bar{R}^2 = .583$, F = 33.20***
$CO_2 = .030 + .046$UrbanPop (.524) (17.27)	$R^2 = .91$, $\bar{R}^2 = .903$, F = 298.26***	$CO_2 = 2.232 - .038$UrbanPop (14.97) (-7.52)	$R^2 = .72$, $\bar{R}^2 = .71$, F = 56.5***

Table 2: Estimation of Logarithmic Models by Least Square before and after 1992

1960-1992 (N = 33)		1993-2018 (N = 26)	
$lnCO_2$ = -.188 + .012 t (-14.69) (18.40)	R^2 = .92, $\bar{R}^2$ = .913, F = 338.60***	$lnCO_2$ = .596 - .011 t (10.30) (-8.59)	R^2 = .77, $\bar{R}^2$ = .76, F = 73.77***
$lnCO_2$ = -3.98 + .661*ln*PCGDP (-13.50) (13.57)	R^2 = .86, $\bar{R}^2$ = .851, F = 184.11***	$lnCO_2$ = 1.647 - .222*ln*PCGDP (8.544) (-8.012)	R^2 = .745, $\bar{R}^2$ = .733, F = 64.19***
$lnCO_2$ = -2.802 + 1.024*ln*Manufac (-3.85) (3.88)	R^2 = .33, $\bar{R}^2$ = .31, F = 15.04***	$lnCO_2$ = -1.244+ .49*ln*Manufac (-1.29) (1.40)	R^2 = .082, R¯^2 = .04, F = 1.96
$lnCO_2$ = -.614 + .384*ln*Export (-7.55) (7.86)	R^2 = .67, $\bar{R}^2$ = .66, F = 61.80***	$lnCO_2$ = .725 - .222*ln*Export (9.62) (-8.29)	R^2 = .76, $\bar{R}^2$ = .75, F = 68.75***
$lnCO_2$ = -.58 + .321*ln*Import (-4.86) (5.05)	R^2 = .451, $\bar{R}^2$ = .434, F = 25.50***	$lnCO_2$ = .651 - .188*ln*Import (8.27) (-7.002)	R^2 = .69, $\bar{R}^2$ = .676, F =49.03***
CO_2 = -2.914 + .954*ln*UrbanPop (-16.70) (16.81)	R^2 = .901, $\bar{R}^2$ = .898, F = 282.61***	$lnCO_2$ = 3.51 - 1.008UrbanPop (8.12) (-7.87)	R^2 = .74, $\bar{R}^2$ = .726, F = 61.86***

Table 3: Descriptive Statistics

Variables	N	Min	Max	Mean	Std. Dev
CO2 Emission (Kg/GDP 2010 USD)	57	.81	1.29	1.0626	.1229
Per Cap GDP (2010USD)	60	330.21	2151.73	776.326	501.9
Manufacturing % ofGDP	60	13.23	17.87	15.842	1.024
Export % ofGDP	60	3.31	25.43	10.749	7.038
UrbanPopulation (%)	60	17.924	34.472	25.389	4.788

Table 4: Result of Regression of LnCO2 on LnPCGDP, LnManufacturing, LnExport and their Square Terms

Variable	B	t	Sig.
(Constant)	-9.481	-.934	.355
LnPCGDP_2010USD	3.674	5.536	.000

LnManuf_Percent_GDP	-2.874	-.399	.692
LnExport_Percent_GDP	.509	3.123	.003
Sq_LnPCGDP	-.261	-5.300	.000
Sq_LnManuf_Percent_GDP	.567	.433	.667
Sq_LnExport	-.143	-4.157	.000
R^2 = 0.80, Adj R^2 = 0.78, F = 33.76			

It is observed from simple OLS regression that emission level has significant positive relation PCGDP and export as a percentage of GDP; while it has negative elasticity with respect to squares of PCGDP and export as a percentage of GDP. That means CO_2 follows the inverted U hypothesis with respect to per capita GDP and export intensity, while its relation with manufacturing is insignificant. Urbanization is excluded for the collinearity problem.

Table 5: Unit Root Test Results

	ADF			PP		
	Level	1^{st} Diff		Level	1^{st} Diff	
Variable	T	T	Info	T	T	Info
$LnCO_2$	-2.299	-8.411	I(1)	-2.281	-8.468	I(1)
LnPCGDP_2010USD	4.126	-6.356	I(1)	6.731	-6.485	I(1)
LnManuf_Percent_GDP	-1.873	-6.920	I(1)	-2.026	-6.908	I(1)
LnExport_Percent_GDP	-0.412	-4.141	I(1)	-0.495	-7.369	I(1)
Critical value: -3.55(1%), -2.92(5%), -2.59(10%)						

All the variables in logarithmic form are found to be integrated of order one. Hence, a long run relationship among them is expected. The bound test also reveals existence of cointegration among those chosen variables (Table 6).

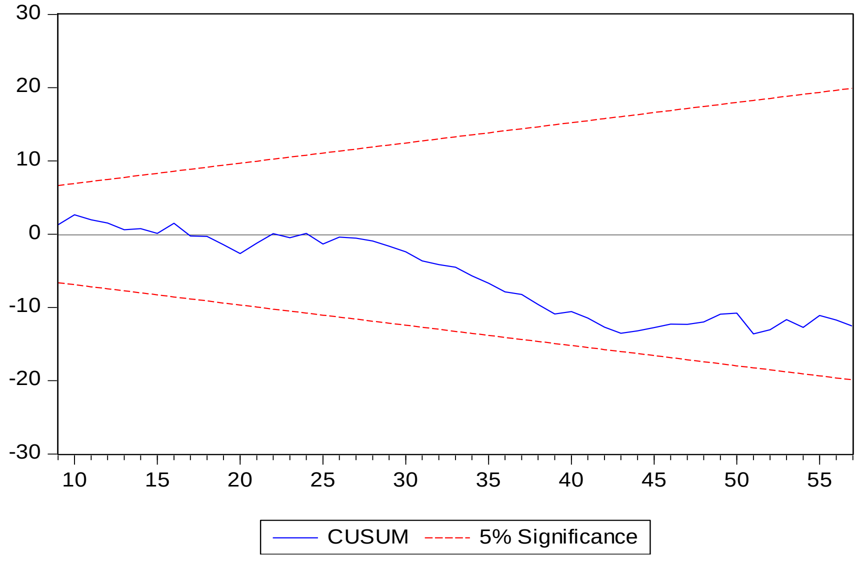
The ARDL model reveals strong inverse impact of current and previous years value of squared log per-capita GDP. Also, it further displays a significant positive relation of log manufacturing output as a percentage of GDP which is later on supported by the long run cointegrating relationship.

The long run relationship reveals a significant positive impact of per capita GDP on the CO_2 emission, while it is inversely related to the square of per capita GDP (Table 8). The elasticity of CO_2 with respect to per capita GDP is 11.875 indicating very high intensity of CO_2 emission with the economic activity.It means, for one percent increase in income per capita, CO_2 emission is increased by about 11.88 percent, which indicates intensive use of fossil fuel. But the elasticity is not highly significant with respect to manufacturing and export intensity per unit of GDP. It is because of low contribution of manufacturing to GDP and export of more non-pollution intensive goods. The elasticity of CO_2 with respect to squarred per capita GDP is -.128, which is significant at one percent level. It strongly validates the existence of EKC hypothesis in the longer term. The CUSUM and CUSUM of Square tests (Fig. 6 and Fig. 7) are found to be stable and in support of stability of the model with a long run relationship.

Table 6: The Results of Cointegration Test

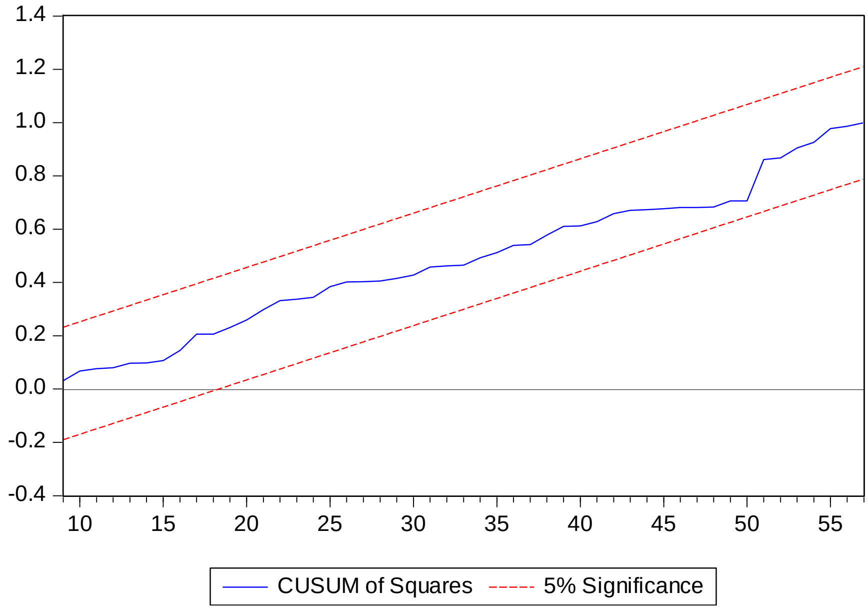
Bounds Testing of Cointegration		
Estimated Equation	***$LnCO_2$ = f(LnPCGDP, SQLnPCGDPlNManufac_Percent_GDP, LnExport_Percent_GDP)***	***CO_2 = f(PCGDP, SQPCGDP Manufac_Percent_GDP, Export_Percent_GDP)***
Optimal lag structure	2	1
F-statistics	7.9087	8.5871
Diagnostic Check		
Adjusted-R^2	0.9312	0.9409
F-statistics (Prob.)	124.99 (0.000)	108.56 (0.000)
J-B Normality test	2.16	1.21
Breusch-Pagan-Godfrey Test [2]	0.637	1.351
ARCH Test [1]	0.002	0.311
Ramsey RESET	1.184	1.132
CUSUM	Stable	Stable
CUSUMSQ	Stable	Stable
Note: Lag length is determined by AIC.1% and 5% critical value is 3.738, 2.763 for I(0) and 4.947, 3.813 for I(1).		

Figure 6: Plot of Cumulative Sum of Recursive Residuals



The straight lines represent critical bounds at 5% significance level.

Figure 7: Plot of Cumulative Sum of Squares of Recursive Residuals



The straight lines represent critical bounds at 5% significance level.

Table 7: Estimated ARDL Equation

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
LNCO2(-1)	0.8672	0.0686	12.635	0.0000
LNPCGDP_2010USD	0.5044	0.4966	1.016	0.3148
SQLNPCGDP	-0.115	0.0384	-2.992	0.0043
SQLNPCGDP(-1)	0.0814	0.0129	6.275	0.0000
LNMANUFAC_PERCENT_GDP	0.2078	0.0803	2.5867	0.0127

LNEXPORT_PERCENT_GDP	-0.0321	0.0304	-1.056	0.2961
C	-2.3096	1.6821	-1.373	0.1760
R-squared	0.9387	Mean dependent var		0.0588
Adjusted R-squared	0.9312	S.D. dependent var		0.1117
S.E. of regression	0.0293	Akaike info criterion		-4.1051
Sum squared resid	0.0421	Schwarz criterion		-3.8519
Log likelihood	121.9432	Hannan-Quinn criter.		-4.007
F-statistic (Prob)	124.99 (.000)	Durbin-Watson stat		2.249

Table 8: Long-term Relation of $LnCO_2$ with Other Variables

Variable	Coefficient	Std. Error
LNPCGDP_2010USD	11.875**	4.276
SQLNPCGDP	-0.128**	0.331
LNMANUFAC_PERCENT_GDP	2.196*	1.150
LNEXPORT_PERCENT_GDP	0.558	0.444
Note: ** and * indicate that the coefficient is significant at 1% and 10% level of significant respectively.		

Table 9: ECM - Short-term Relation of $LnCO_2$

Variable	Coef.	Std. Error	t-Statistic	Prob.
C	0.0316	0.006	4.985	0.0000
ECM(-1)	-0.1316	0.075	-1.754	0.0856
D(LNPCGDP_2010USD-1)	-1.4574	1.207	-1.2074	0.2331
D(SQLNPCGDP-1)	0.0433	0.090	0.479	0.6341
D(LNMANUFAC_PERCENT_GDP-1)	0.1088	0.110	0.984	0.3299
D(LNEXPORT_PERCENT_GDP-1)	-0.0476	0.045	-1.059	0.2948
R-squared	0.5468	AIC		-4.0704

Adjusted R-squared	0.5015	SIC	-3.8534
Log likelihood	119.97	Hannan-Quinn criter.	-3.9862
F-statistic (Prob)	12.067(.000)	JB Normality Test	2.070
Durbin-Watson stat	2.002	Breusch-Pagan-Godfrey Test	1.163
Serial Correlation LM	0.0165		
Ramsey Reset Test	0.010	ARCH Test	.0319

Table 9 reveals the short-term adjustment by 13.16 percent rate towards long run equilibrium. Apart from the ECM term other variables are not found to be significant in the short run. The evidence is in line with the outcome of studies by Zhang and Cheng (2009) and Jalil and Mahmud (2009) on China, Ghosh (2010) on India, and Shahbaz et al. (2010) on Pakistan.

Conclusion

In this present paper, we investigated the relationship among CO_2 emissions, economic growth, over the period of 1960 to 2020. The Environmental Kuznets Curve's (EKC) hypothesis has been tested by applying ARDL cointegration model. The results suggest that a long run relation exists among CO_2 emission, economic growth, manufacturing output and export as a percentage of GDP. The existence of an EKC in India is however associated with short run insignificant relation of CO_2 emissions with manufacturing output and export in proportion to GDP. Since the EKC hypothesis holds in India, the warning that economic growth itself is the means for environmental improvement holds in the long run (Stern's, 1996). The present findings are in line with the results obtained by Shahbaz et al (2010) in Portugal, Pao and Tsai (2011) in Brazil, Ali et al. (2015) in Pakistan, Alabdulrazag and Alrajhi (2016) in Saudi Arabia. Saboori et al. (2012a, b) however found the presence of EKC for CO2 emissions and GDP for both long and short run in Malaysia.

Though current outcome supports the argument of continuous growth in economic activity, it may be mentioned that much of the recent past growth has been due to the structural change of the economy and development of tertiary sector with information, services etc. took leading position in growth of GDP. It requires to take care of growth of manufacturing but with care for environmental management and control of emission standard and overall pollution.

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https://data.worldbank.org/indicator/NV.IND.MANF.ZS?locations=IN

Appendix 1: Test for Cointegration

Included observations: 55 after adjustments				
Trend assumption: Linear deterministic trend				
Series: LNCO2 LNPCGDP_2010USD SQLNPCGDP LNMANUFAC_PERCENT_GDP LNEXPORT_PERCENT_GDP				
Lags interval (in first differences): 1 to 1				
Unrestricted Cointegration Rank Test (Trace)				
Hypothesized		Trace	0.05	
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.**
None *	0.554552	98.87747	69.81889	0.0001
At most 1 *	0.443226	54.40040	47.85613	0.0107
At most 2	0.206041	22.19262	29.79707	0.2879
At most 3	0.142162	9.502860	15.49471	0.3209
At most 4	0.019251	1.069149	3.841466	0.3011
Trace test indicates 2 cointegrating eqn(s) at the 0.05 level				
* denotes rejection of the hypothesis at the 0.05 level				
**MacKinnon-Haug-Michelis (1999) p-values				
Unrestricted Cointegration Rank Test (Maximum Eigenvalue)				
Hypothesized		Max-Eigen	0.05	
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.**
None *	0.554552	44.47707	33.87687	0.0019
At most 1 *	0.443226	32.20779	27.58434	0.0118
At most 2	0.206041	12.68976	21.13162	0.4812
At most 3	0.142162	8.433711	14.26460	0.3363
At most 4	0.019251	1.069149	3.841466	0.3011
Max-eigenvalue test indicates 2 cointegrating eqn(s) at the 0.05 level				
* denotes rejection of the hypothesis at the 0.05 level				
**MacKinnon-Haug-Michelis (1999) p-values				
Unrestricted Cointegrating Coefficients (normalized by b'*S11*b=I):				
LNCO2	LNPCGDP	SQLNPCGDP	LNMANUFAC_	LNEXPORT_

	_2010USD		PERCENT_GDP	PERCENT_GDP
2.632958	31.26618	-2.970496	-5.781860	1.468669
-9.085945	36.48105	-2.270090	23.40462	-5.962863
-8.646768	112.8441	-8.035310	-3.878734	-4.178214
-13.67519	46.43540	-3.595342	-3.549834	0.906365
-4.516593	39.30985	-3.498751	1.431905	5.837018