

Environmental Sustainability and Income: Evidence from Cross-Country Analysis

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ABSTRACT

There are various types of relationships between per capita income and different environmental indicators and Environmental Kuznets Curve is one of them. Some very clear patterns of relationship between environmental degradation and income emerge from the analysis. Most of the environmental indicators improve with rising income. A monotonic decrease of environmental degradation along a country's development path suggests that policies that accelerate economic growth also lead to rapid environmental improvements. 'Agricultural methane emissions', 'agricultural nitrous oxide emissions', 'forest area' and 'bird species threatened' have inverted U type relationship with income. These indicators improve after the turning point when incomes are higher. Before that point, at lower income levels, environmental quality deteriorates as income began to rise. Other indicators like 'carbon dioxide emissions', 'other green house gases emissions', 'HFC gas emissions', 'industrial nitrous oxide emissions', 'organic water pollutant' and 'fish species threatened' have inverted N type relationship with income. In these indicators improvement begins after the second turning point at a much higher per capita income level. So the Environmental Kuznets Curve hypothesis is supported by the study for ten environmental indicators.

Keywords: Environment, Economic Growth, Environmental Degradation.

JEL Classification: O13, O44, Q01, Q55

INTRODUCTION

Economic growth is an essential means for enabling development, but in itself is a highly imperfect proxy for progress. The attainment of sustained and equitable development remains the greatest challenge facing the human race. The fundamental role of development is to provide the opportunities to the people who are not much better off, can reach their potential (World Development Report, 1992).

Development is no longer considered identical with growth. It is taken to mean growth plus change. There are qualitative dimensions in the development process which may be missing in the growth of an economy expressed in terms of an increase in national product or product per capita. Development economists are no longer impressed by the growth performance of the country which gets reflected in the rise in its GNP only, they now concentrate more directly on the development process and sustainable development.

Economic development is that process which with increase in per capita income and output, results in an improvement in standard of living of people along with reduction in poverty, unemployment and inequality in the economy. World Bank, during 1980's, defined economic development in terms of improvement in quality of life along with cleaner environment, greater individual freedom and richer cultural life.

Growth has also been accompanied by alarming rate of environmental degradation, which has reduced its benefits and in some cases threatens the very foundations of economic activity. Although the desirability of development is universally recognized, recent years have witnessed rising concern about whether environmental constraints will limit development and whether development will cause serious environmental damage in turn impairing the quality of life of the present and future generations. Therefore the choice between development and environmental balance is difficult. (World Development Report, 1992)

Environmental protection is one of the important part of development. Without adequate environmental protection, development is undermined, but without development resources, environmental protection will fail. Thus, there is a two-way relationship between environment and development. First, “environmental quality is itself part of welfare that development attempts to bring. If benefits from rising income are offset by the costs imposed on health and quality of life by pollution, this cannot be called development”. Second, “environmental damage can undermine future productivity. Soils that are degraded, aquifers that are depleted and ecosystems that are destroyed in the name of raising incomes today can jeopardize the prospects for earning income tomorrow” (World Development Report, 1992).

In this paper, an attempt has been made to understand the relationship between economic growth and environment. The primary focus of the study is to examine the nature and extent of relationship between economic growth and environmental quality. In this study we have used a cross section and time series i.e. panel database of the countries for the period 1962-2014. The ultimate sample size depends upon the availability of data for the relevant variables. The environmental indicators used in the study are:

- (i) Carbon Dioxide (CO₂) emissions (metric tons per capita)
- (ii) Methane emissions (kt of CO₂ equivalent)
- (iii) Nitrous oxide emissions (thousand metric tons of CO₂ equivalent)
- (iv) Other green house gases emissions, HFC, PFC and SF₆ (thousand metric tons of CO₂ equivalent)
- (v) HFC gas emissions (thousand metric tons of CO₂ equivalent)
- (vi) PFC gas emissions (thousand metric tons of CO₂ equivalent)
- (vii) SF₆ gas emissions (thousand metric tons of CO₂ equivalent)
- (viii) PM₁₀ - particulates matter less than ten microns in diameter at country level (micrograms per cubic meter)
- (ix) Industrial nitrous oxide emissions (thousand metric tons of CO₂ equivalent)
- (x) Agricultural methane emissions (thousand metric tons of CO₂ equivalent)
- (xi) Agricultural nitrous oxide emissions (thousand metric tons of CO₂ equivalent)
- (xii) Forest area (% of land area)
- (xiii) Annual total freshwater withdrawals (billion cubic meters)
- (xiv) Organic Water Pollutant (BOD) emissions (Kg per day)
- (xv) Bird species threatened
- (xvi) Fish species threatened

- (xvii) Mammal species threatened
- (xviii) Plant species threatened

On the economic side, GDP per capita (constant 2000 US \$) has been used to represent the economic development. The data for all the variables are taken from various issues of World Development Indicators, published by the World Bank

Regression Models:

The regression models used in this study are panel data regression models. The environmental indicators are taken as dependent variable and GDP per capita as independent variable in regression models. There are various techniques for estimating the curve, but in order to test the EKC model, the regression must take a quadratic form. The following log linear, quadratic and cubic regression equations are used to test the various possible relationships between the indicators of environment and income per capita:

$$\text{Ln}E = \beta_0 + \beta_1 \text{Ln}Y + \beta_2 t + e \quad (1)$$

$$\text{Ln}E = \beta_0 + \beta_1 \text{Ln}Y + \beta_2 (\text{Ln}Y)^2 + \beta_3 t + e \quad (2)$$

$$\text{Ln}E = \beta_0 + \beta_1 \text{Ln}Y + \beta_2 (\text{Ln}Y)^2 + \beta_3 (\text{Ln}Y)^3 + \beta_4 t + e \quad (3)$$

Where log E is the dependent variable (in this case log E represents the natural log of the value of environmental indicators); Y is the explanatory variable - natural log of GDP per capita, t is the time trend and e is the error term.

Turning Points

The turning points for equations are obtained as:

For quadratic equation (equation 2):

$$Y = \exp(-\beta_1/2\beta_2) \quad (4)$$

For cubic equation (equation 3):

$$Y = \exp\left(\frac{-\beta_2 \pm \sqrt{\beta_2^2 - 3\beta_1\beta_3}}{3\beta_3}\right) \quad (5)$$

The panel data for different countries have been used in this study. Three panel data regression models viz. pooled OLS model, Fixed effect model and Random effect model have been used for analysis. Tests like chow F-test, Breush and Pagan Langrangian multiplier (LM) test and Hausman specification test are applied to find out the appropriate model. Chow F-test and Breush and Pagan Langrangian multiplier (LM) test are used to check the consistency of fixed effect model and random effect model respectively. If both the models are found to be consistent based on these results, then Hausman specification test (5 per cent significance level) is applied to choose the appropriate one. If both the models are inconsistent, then pooled OLS model is most appropriate.

This paper has been divided into four sections. Section I describes the relationship between environmental indicators ('CO₂ emissions', 'methane emissions', 'nitrous oxide emissions', 'other green house gases emissions', 'HFC gas emissions', 'PFC gas emissions' and 'SF₆ gas emissions') and income. Environmental indicators ('PM level', 'industrial nitrous oxide emissions', 'agricultural methane emissions' and 'agricultural nitrous oxide emissions') and income relationship has been analyzed in section II. In section III, the relationship between environmental indicators ('forest area', 'fresh water withdrawals', 'organic water pollutant', 'bird species threatened', 'fish species threatened',

'mammal species threatened' and 'plant species threatened') and income has been examined. The whole discussion has been concluded in section IV.

SECTION – I

In this section an effort has been made to analyze the relationship between environmental indicators viz. 'CO₂ emissions', 'methane emissions', 'nitrous oxide emissions', 'other green house gases emissions', 'HFC gas emissions', 'PFC gas emissions' and 'SF₆ gas emissions' and income. Rise in per capita income is considered to be best available overall index of economic development. The result of panel data regression analysis for the relationship between environmental variables and GDP per capita is shown in table 1. The environmental indicators were taken as dependent variable and GDP per capita as independent variable in panel data regression model. The time trend variable has been used as a proxy for other exogenous time dependent variables such as the trend in pollution abatement, environmental policy change and technological change. The linear and non-linear (quadratic and cubic) regression equations have been used to test the various possible relationships between the indicators of environment and income.

Greenhouse gas is a natural part of the atmosphere. It absorbs solar radiation and keeps the earth warm enough to support life. Human activities including burning fossil fuels for energy, land clearing and agriculture have increased the amount of greenhouse gases in the atmosphere. The green house gases under consideration are:

- Carbon dioxide
- Methane
- Nitrous oxide
- Hydrofluorocarbons (HFC)
- Pefluorocarbons (PFC)
- Sulphur hexafluoride (SF₆)

The first three occurs naturally in the atmosphere, while the last three are synthetic, and are either used in industry or created as a by-product of industrial processes.

Carbon dioxide (CO₂) is the primary greenhouse gas emitted through human activities. CO₂ is naturally present in the atmosphere as part of the earth's carbon cycle. The main sources of CO₂ emissions are electricity generation, transportation and industry. The effect of all this extra carbon dioxide in the atmosphere is that the overall temperature of the planet is increasing (global warming).

In case of 'CO₂ emissions' all the three models i.e. linear, quadratic and cubic turns out to be significant but cubic model fits the best. The results of the three regression models are presented in table 1. Table shows that cubic model which fits the best depicts the inverted N-shaped type relationship indicating that 'CO₂ emissions' first decreases up to some initial level of income, then starts increasing with increase in per capita income level and again after achieving maximum level starts declining. The results of the cubic model reveals that with one unit increase in per capita income, there is 4.8 units decrease in 'CO₂ emissions' initially, but after first turning point at per capita income level of \$ 56.475, 'CO₂ emissions' increase by 0.83 units with one unit increase in per capita income. Further increase in per capita income

Table 1: Results of Regression Analysis between Environmental Indicators and Income

S. No.	Dependent Variable	Model	Constant	GDP	GDP ²	GDP ³	Time	F Value	Wald Chi ²	R ²	F value for Fixed Effects	LM Chi ²	Hausman Specification Test	Turning Points	No. of Observations
01.	Carbon dioxide emissions	Country	-5.006*** (-34.70)	0.672*** (33.64)	-	-	0.007*** (15.25)	1795.07 ($p=0.00$)	0.95	172.63 ($p=0.00$)	$\chi^2 = 29.08$ ($p=0.00$)				4410
		Fixed Effects	-9.56*** (-35.25)	2.005*** (28.27)	0.093*** (-19.52)	-	0.0111*** (21.52)	1429.14 ($p=0.00$)	0.95	181.73 ($p=0.00$)	$\chi^2 = 65.42$ ($p=0.00$)			48029.46	4410
		Effects	6.103*** (6.80)	-	0.837*** (16.36)	-	0.0098*** (19.49)	1273.79 ($p=0.00$)	0.96	197.50 ($p=0.00$)	$\chi^2 = 50.57$ ($p=0.00$)			56.475	4410
02.	Methane emissions	Country	6.628*** (14.84)	0.353*** (-12.67)	0.040*** (-18.26)	-	-0.003 (-0.46)	29.76 ($p=0.00$)	0.99	365.70 ($p=0.00$)	$\chi^2 = 13.61$ ($p=0.00$)			20255.76	496
		Fixed Effects	5.583*** (3.71)	0.611* (1.70)	-0.015 (-0.73)	-	-0.001 (-0.19)	19.99 ($p=0.00$)	0.99	364.85 ($p=0.00$)	$\chi^2 = 13.91$ ($p=0.00$)				496
		Effects	7.157 (1.21)	0.034 (0.002)	0.053 (0.21)	-0.002 (-0.28)	0.0014 (-0.16)	14.97 ($p=0.00$)	0.99	363.45 ($p=0.00$)	$\chi^2 = 18.88$ ($p=0.00$)				496
03.	Nitrous oxide emissions	Country	4.942*** (9.42)	0.445*** (7.32)	-	-	-0.0244** (-2.59)	28.03 ($p=0.00$)	0.99	309.21 ($p=0.00$)	$\chi^2 = 28.61$ ($p=0.00$)				484
		Fixed Effects	2.597 (1.53)	1.024** (2.53)	-0.034 (-1.45)	-	-0.019** (-2.00)	19.44 ($p=0.00$)	0.99	307.91 ($p=0.00$)	$\chi^2 = 64.34$ ($p=0.00$)				484
		Effects	10.131 (1.53)	-1.748 (-0.73)	0.298 (1.05)	-0.0131 (-1.181)	-0.018* (-1.88)	14.95 ($p=0.00$)	0.99	306.31 ($p=0.00$)	$\chi^2 = 45.96$ ($p=0.00$)				484
04.	Other green house gases emissions	Country	22.146*** (3.40)	-	2.667*** (-3.52)	-	1.271*** (10.61)	58.79 ($p=0.00$)	0.90	20.13 ($p=0.00$)	$\chi^2 = 48.39$ ($p=0.00$)				488
		Fixed Effects													
		Effects													

"	Country Fixed Effects	-6.898 (-0.32)	4.524 (0.87)	-0.435 (-1.40)	1.328*** (10.51)	39.95 (p= 0.00)	0.90	20.16 (p= 0.00)	$\chi^2 = 49.90$ (p= 0.00)	488
	Time Fixed effects	119.06 (1.62)	-48.01* (-1.82)	5.92* (1.90)	-0.22* (-1.85)	66.51 (p= 0.00)	0.31	4.72 (p= 0.00)	$\chi^2 = 52.14$ (p= 0.00)	488
05.	HFC gas emissions	35.59*** (4.76)	- (-5.56)	- (-5.56)	2.37*** (17.18)	153.94 (p= 0.00)	0.88	14.30 (p= 0.00)	$\chi^2 = 67.90$ (p= 0.00)	476
	Country Fixed Effects	31.081 (1.23)	-3.713 (-0.61)	-0.067 (-0.19)	2.380*** (16.29)	102.36*** (p= 0.00)	0.88	14.20 (p= 0.00)	$\chi^2 = 64.29$ (p= 0.00)	476
"	Time Fixed Effects	298.13*** (4.20)	- (-4.43)	13.51*** (4.49)	- (-4.43)	62.27 (p= 0.00)	0.36	14.30 (p= 0.00)	$\chi^2 = 84.14$ (p= 0.00)	1046.649 32877.27
	PFC gas emissions	-8.98*** (-2.92)	0.810** (2.27)	- (-2.27)	-0.054 (-0.96)	2.60 (p= 0.00)	0.98	113.84 (p= 0.00)	$\chi^2 = 17.41$ (p= 0.00)	476
"	Country Fixed Effects	-19.40* (-1.87)	3.386 (1.36)	-0.155 (-1.05)	-0.034 (-0.57)	2.10 (p= 0.10)	0.98	111.80 (p= 0.00)	$\chi^2 = 21.16$ (p= 0.00)	476
	Country Fixed Effects	-161.7*** (-4.04)	55.65*** (3.86)	- (-3.76)	0.248*** (3.68)	5.01 (p= 0.00)	0.98	114.46 (p= 0.00)	$\chi^2 = 47.68$ (p= 0.00)	3532.773 9465.703
07.	SF6 gas emissions	- (-13.87)	3.415*** (13.59)	- (-13.87)	-0.237 (-0.88)	92.35 (p= 0.00)	0.28			472
	Pooled OLS	-2.920 (-0.20)	-3.34 (-1.00)	0.390** (2.02)	-0.263 (-0.98)	63.33 (p= 0.00)	0.28			72.388
"	Pooled OLS	124.75 (1.58)	- (-1.75)	5.891* (1.76)	-0.214 (-0.91)	48.35 (p= 0.00)	0.29			472

Figures in parenthesis are z-values in random effects models and t-values in case of pooled OLS and fixed effects models (***) significant at the 1%, (**) 5% and (*) 10% levels of significance.

level beyond the second turning point (per capita income level of \$ 20255), 'CO₂ emissions' starts declining at rate of 0.04 units with one unit increase in per capita income. Analysis further reveals that there were only 20 countries in the sample which had high enough per capita income when the 'CO₂ emissions' started falling. Thus the relationship between environment and economic development is of Environmental Kuznets Curve (EKC) type relationship in case of 'CO₂ emissions' variable, which describes that there is first increase in environmental degradation and after achieving higher level of income it starts declining. The result of the study confirms that the problem of 'CO₂ emissions' can be solved only by achieving higher level of development, which in case of our analysis is represented by the per capita income level of \$ 20255.

The reason for this could be that environmental regulations were imposed in developed countries during the 1970s and 1980s and given that it could take at least a decade to actually observe the effects of these regulations in terms of improved environmental quality, the reason earlier studies were not able to capture that effect. It has now been more than three decades since the imposition of environmental regulations, that enabled as to observe some impacts of regulation. The results of our study are in line with Dutt, 2009.

Table further shows that time variable also has a positive and significant effect on 'CO₂ emissions' with value of coefficient at 0.0098 which means that 'CO₂ emissions' are increasing over the period of time.

'Methane emissions' are the second most prevalent greenhouse gas emitted from human activities. Methane is emitted from industry, agriculture and waste management activities. Methane levels have more than doubled over the last 150 years because of human activities like fossil fuel use and intensive farming.

Table 1 shows that only linear model works the best i.e. there is significant positive linear relationship between 'methane emissions' and per capita income level. The positive value of coefficient shows that with one unit increase in per capita income, there is 0.353 units increase in 'methane emissions'. Study reveals that this measure of air quality tends to worsen with economic growth. Further, time has negative effect on 'methane emissions' but coefficient turns out to be insignificant.

Nitrous oxide (N₂O) is another green house gas emitted from natural and human activities such as agriculture, transportation and industrial activities. Nitrous oxide is naturally present in the atmosphere as part of the earth's nitrogen cycle and has a variety of natural sources. However, about 40 per cent of total nitrous oxide emissions come from human activities.

A linear model fits the best in the case of 'nitrous oxide emissions' also. Table shows that this measure of environmental quality tends to worsen with rising per capita income. By one unit increase in per capita income, there is 0.445 units increase in 'nitrous oxide emissions'. Technology as proxy by time has favorable effect on 'nitrous oxide emissions' as

value of coefficient is negative and significant that means 'nitrous oxide emissions' are decreasing over the period of time.

'Other green house gases' included in this study are by-product emissions of hydro fluorocarbons (HFC), per fluorocarbons (PFC) and sulphur hexafluoride (SF6). These gases have no natural sources and only come from human-related activities. They are emitted through a variety of industrial processes such as aluminium and semiconductor manufacturing.

Table 1 confirms a cubic relationship for 'other green house gases emission'. The estimated relationship turns out to be negative up to a first turning point \$ 489.048 revealing that the emissions decline by 48.01 units with one unit increase in per capita income. For incomes above \$ 489.048, study found a inverted U shaped relationship i.e. Environmental Kuznets Curve (EKC) which means there is increase in 'other green house gases emission' by 5.92 units with increase of one unit of per capita income till the second turning point (\$ 126365), and after this turning point, it starts decreasing at the rate of 0.22 units with one unit increase in per capita income. It is pertinent to mention that in case of this variable, no country in the sample has achieved the level of per capita GDP at which second turning point occurs and the 'other green house gases emission' starts falling. The results show only a trend which means that further increase in per capita income i.e. higher level of economic development is necessary for the emissions to decrease.

Kolstad (2006) states that one of the difficulties of interpreting the Environmental Kuznets Curve (EKC) in the context of 'green house gases emissions' is the weak link between demand for higher environmental quality to prevent damage from climate change and the environmental regulations that limit emissions at the country level. He points out that the weak link between regulatory actions at a global levels and benefits to citizens in an individual country is part of the reason why it is so difficult to implement international agreements on green house gases.

Hydro fluorocarbons (HFC), used as a replacement for chlorofluorocarbons (CFC), are used mainly in refrigeration and semiconductor manufacturing. The major emissions source of these compounds is their use as refrigerants--for example, in air conditioning systems in both vehicles and buildings.

In case of 'HFC gas emissions', cubic relationship turns out to be significant. The result indicates an inverted N-shaped type relationship between GDP per capita and the 'HFC gas emissions'. The emissions tend to decrease by 112.6 units with one unit increase in income per capita, up to first turning point which is achieved at per capita income level of \$ 1046.64. Emissions start increasing beyond first turning point till the second turning point at the per capita income level of \$ 32877.27. The emissions increases by 13.51 units with one unit increase in per capita income. Study further found that emissions start declining after the second turning point. The value of coefficient indicates that the emissions are expected to decline by 0.519 units with per unit increase in income per capita. Perusal of the data reveals that 15 out of 119 countries in the sample have achieved this high level of per capita GDP (\$

32877.27), remaining countries are still to reach the level from which emissions starts decreasing.

Per fluorocarbons (PFC) are compounds produced as a by-product of various industrial processes associated with aluminium production and the manufacturing of semiconductors.

In case of 'PFC gas emissions', the N type relationship has been found. Table shows that first there is positive relationship between 'PFC emissions' and income per capita up to first turning point (per capita income of \$ 3532.773). After this turning point relationship turns out to be negative i.e. the environmental quality improves by 6.445 units with one unit increase in per capita income. After touching second turning point at per capita income of \$ 9465.703, further increment in per capita income leads to decline in environmental quality in terms of this variable. Time has negative but insignificant effect on this indicator.

Sulphur hexafluoride (SF₆) is used in electrical transmission equipment, including circuit breakers. It is the most potent greenhouse gas that the Intergovernmental Panel on Climate Change (IPCC) has evaluated.

Table shows that in case of 'SF₆ gas emissions' indicator, linear model gave the best results. The parameter representing the effect of economic growth on emissions is positive and significant indicating that economic growth has a positive influence on the growth of emissions. The environmental quality tends to worsen by 3.415 units with one unit increase in per capita income. The effect of time is negative but insignificant.

SECTION – II

In this section an effort has been made to analyze the relationship between environmental indicators like 'PM level', 'industrial nitrous oxide emissions', 'agricultural methane emissions' and 'agricultural nitrous oxide emissions' and income.

Particulate matter concentrations refer to fine suspended particulates less than 10 microns in diameter (PM₁₀) that are capable of penetrating deep into the respiratory tract and causing significant health damage. The state of a country's technology and pollution controls is an important determinant of particulate matter concentrations. Particle pollution is made up of a number of components, including acids (such as nitrates and sulfates), organic chemicals, metals and soil or dust particles.

'PM level' follows an N shaped curve. Table 2 shows that initially when there is increasing trend, 'PM level' increased by 1.548 units with one unit increase in per capita income, and after first turning point (\$ 110.618), it decreased by 0.228 units with per unit income increase. Again after second turning point at per capita income of \$ 195399, it is expected to increase by 0.009 units for one unit increase in income. It was found that not even a single country in the sample of 157 countries has achieved the second turning point of income level. The result shows only trend and this level is far from reachable. Time has played no significant role in case of this variable.

'Industrial nitrous oxide emissions' are emissions produced during the manufacturing of adipic acid and nitric acid, which is used to make synthetic commercial fertilizer, and in the production of adipic acid, which is used to make fibers, like nylon and other synthetic products. (Singh, 2020)

In 'Industrial nitrous oxide emissions', the relationship turns out to be inverted N shaped. First there is decline in emissions by 225.03 units with one unit increase in income per capita up to the first turning point (\$ 616.17). Then there is an increase by 11.83 units for one unit increase in per capita income. After touching second turning point (\$ 21436.98), further increase in income by one unit leads to decline in emissions level by 0.481 units. The effect of time variable is negative but insignificant.

Table 2: Results of Regression Analysis between Environmental Indicators and Income

S. No.	Dependent Variable	Model	Constant	GDP	GDP ²	GDP ³	Time	F Value	Wald Chi ²	R ²	F value for Fixed Effects	LM Chi ²	Hausman Specification Test	Turning Points	No. of Observations
01.	PM level	Country Fixed Effects	4.938*** (40.66)	-0.103*** (-6.38)			- 0.032*** (-60.54)	3564.86 (p=0.00)		0.96	374.21 (p=0.00)		$\chi^2 = 10.28$ (p=0.00)		3140
"		Country Fixed Effects	6.767*** (26.72)	-0.646*** (-9.49)	0.038*** (8.20)		- 0.034*** (-61.25)	2451.83*** (p=0.00)		0.96	382.84 (p=0.00)		$\chi^2 = 27.05$ (p=0.00)	4914.769	3140
"		Time Fixed Effects	1.038 (0.92)	1.548*** (3.38)	- 0.228*** (-3.79)	0.009*** (3.74)		337.25 (p=0.00)		0.30	14.82 (p=0.00)		$\chi^2 = 29.05$ (p=0.00)	110.6186 195399.4	3140
02.	Industrial nitrous oxide emissions	Pooled OLS	- 24.577*** (-9.41)	2.672*** (9.30)			-0.177 (-0.58)	43.25 (p=0.00)		0.15					476
"		Pooled OLS	- 61.055*** (-3.71)	11.238*** (2.94)	-0.494** (-2.25)		-0.144 (-0.47)	30.77 (p=0.00)		0.16				87072.29	476
"		Pooled OLS	225.03** (2.52)	-92.44*** (-2.88)	11.83*** (3.12)	- 0.481*** (-3.25)	-0.102 (-0.34)	26.19 (p=0.00)		0.18				616.170 21436.98	476
03.	Agricultural methane emissions	Country Fixed Effects	6.54*** (15.77)	0.257*** (4.77)			- 0.046*** (-5.41)	17.60 (p=0.00)		0.99	682.97 (p=0.00)		$\chi^2 = 27.15$ (p=0.00)		480
"		Country Random Effects	4.610*** (4.81)	0.936*** (3.68)	- 0.053*** (-3.06)		- 0.029*** (-3.21)		33.23 (p=0.00)	0.36		708.28 (p=0.00)	$\chi^2 = 4.54$ (p=0.20)	6837.577	480
"		Country Fixed Effects	3.946 (1.30)	1.130 (0.91)	-0.0817 (-0.50)	0.0017 (0.25)	- 0.038*** (-4.05)	10.15 (p=0.00)		0.99	687.09 (p=0.00)		$\chi^2 = 61.11$ (p=0.00)		480
04.	Agricultural nitrous oxide emissions	Country Fixed Effects	4.620*** (9.84)	0.407*** (7.48)			- 0.038*** (-4.49)	28.33 (p=0.00)		0.99	635.51 (p=0.00)		$\chi^2 = 48.60$ (p=0.00)		476
"		Country Fixed Effects	-0.481 (-0.31)	1.669*** (4.47)	- 0.076*** (-3.41)		- 0.028*** (-3.21)	23.33 (p=0.00)		0.99	652.51 (p=0.00)		$\chi^2 = 29.60$ (p=0.00)	58704	476
"		Country Fixed Effects	11.77* (1.93)	-2.833 (-1.29)	0.465* (1.78)	- 0.0213** (-2.08)	- 0.026*** (-2.99)	18.75 (p=0.00)		0.99	654.08 (p=0.00)		$\chi^2 = 29.43$ (p=0.00)	76.788 27253.53	476

Figures in parenthesis are z-values in random effects models and t-values in case of pooled OLS and fixed effects models
 (****) significant at the 1%, (***) 5% and (*) 10% levels of significance.

'Agricultural methane emissions' are emissions from animals, animal waste, rice production and agricultural waste burning. The result for 'agricultural methane emissions' in table 2 shows an inverted U type relationship. In case of this variable, the turning point i.e. maximum level has been found at income level \$ 6837.57. Before this level, emissions has been increased by 0.936 units with one unit increase in per capita income and after the maximum level, for one unit increase in income, the emissions tend to decline by 0.053 units. 'Agricultural methane emissions' have decreased at an average annual rate of 2.9 per cent. Thus study reveals that this environmental problem can essentially be solved by economic growth by achieving higher level of income.

'Agricultural nitrous oxide emissions' are produced through fertilizers use (synthetic and animal waste), animal waste management and agricultural waste burning. The result for 'Agricultural nitrous oxide emissions' also indicates an inverted U shaped relationship between GDP per capita and agricultural nitrous oxide emissions fits the best. The emissions tend to increase by 1.669 units as per capita income rises by one unit up to the turning point of \$ 58704. Beyond this, further increases in per capita GDP are related to a decrease in emissions by 0.076 units for increase in one unit of per capita income. Time variable shows that annual rate of decrease in 'agricultural nitrous oxide emissions' is 2.8 per cent.

SECTION – III

In this section an effort has been made to analyze the relationship between environmental indicators like 'forest area', 'fresh water withdrawals', 'organic water pollutant', 'bird species threatened', 'fish species threatened', 'mammal species threatened' and 'plant species threatened' and income.

'Forest area' is a land under natural or planted trees which stands at least 5 meters, whether productive or not and excludes trees in agricultural production systems (for example, in fruit plantations and agro forestry systems) and trees in urban parks and gardens.

In the case of 'forest area', the table 3 shows a U shape relationship. Initially there is decline in 'forest area' by 0.366 units as per capita income rises by one unit that means environmental quality deteriorates first up to the income level \$ 1510.204. After achieving this level of income, environmental quality improves with increase in forest area by 0.025 units for increase in one unit of income. But time has a negative effect on 'forest area' as shown by negative coefficient, so 'forest area' declined over the period of time due to other exogenous time dependent variables.

Table 3: Results of Regression Analysis between Environmental Indicators and Income

S. No.	Dependent Variable	Model	Constant	GDP	GDP ²	GDP ³	Time	F Value	Wald Chi ²	R ²	F value for Fixed Effects	LM Chi ²	Hausman Specification Test	Turning Points	No. of Observations
01.	Forest area	Country	2.57*** (9.08)	0.051 (1.62)			-0.017* (-1.78)		3.66 (p=0.16)	0.78		474.11 (p=0.00)	χ ² = 0.46 (p= 0.79)		483
		Random													
		Effects													
"	"	Country	4.27*** (4.59)	-0.366* (-1.67)	0.025* (1.92)		-0.02** (-2.07)			7.38 (p=0.06)	0.73	473.74 (p=0.00)	χ ² = 1.27 (p= 0.73)	1510.204	483
		Random													
		Effects													
"	"	Country	2.27 (0.58)	0.373 (0.27)	-0.064 (-0.38)	0.003 (0.53)	-0.02** (-2.07)		7.64 (p=0.10)	0.74		471.46 (p=0.00)	χ ² = 2.97 (p= 0.39)		483
		Random													
		Effects													
02.	Fresh water withdrawals	Country	2.027*** (3.29)	-0.132* (-1.76)			0.057** (2.47)	3.05 (p= 0.05)		0.99	638.72 (p= 0.00)		χ ² = 9.37 (p= 0.00)		224
		Fixed													
		Effects													
"	"	Country	2.84 (1.57)	-0.329 (-0.79)	0.011 (0.48)		0.058** (2.49)	2.10 (p= 0.10)		0.99	626.02 (p= 0.00)		χ ² = 26.26 (p= 0.00)		224
		Fixed													
		Effects													
"	"	Country	9.37 (1.25)	-3.03 (-1.09)	0.360 (1.07)	-0.014 (-1.06)	0.035 (1.56)		4.41 (p=0.35)	0.64		110.42 (p=0.00)	χ ² = 9.06 (p= 0.05)		224
		Random													
		Effects													
03.	Organic water pollutant	Time	7.127*** (12.43)	0.406*** (6.62)						0.67		4.47 (p=0.03)	χ ² = 0.03 (p= 0.86)		369
		Random													
		Effects													
"	"	Time	-10.74*** (-3.09)	4.576*** (5.70)	-				74.08 (p=0.00)	0.72		4.59 (p=0.03)	χ ² = 0.00 (p= 0.99)	14964.64	369
		Random													
		Effects													
"	"	Time	66.86*** (3.02)	-	2.985*** (3.28)	-			88.97 (p=0.00)	0.83		4.60 (p=0.03)	χ ² = 0.00 (p= 0.99)	576.755 18424.63	369
		Random													
		Effects													
04.	Bird species threatened	Country	4.84*** (5.64)	-			0.065 (1.21)		11.27 (p=0.00)	0.77		144.16 (p=0.00)	χ ² = 0.17 (p= 0.91)		350
		Random													
		Effects													
"	"	Country	-7.050 (-1.28)	2.498* (1.94)	-0.161** (-2.19)		0.066 (1.22)		16.28 (p=0.00)	0.72		143.47 (p=0.00)	χ ² = 0.17 (p= 0.98)	2339.667	350
		Random													
		Effects													

"	Country	20.27	-7.29	0.989	-0.044	0.068	17.05	0.68	143.36	$\chi^2 = 0.13$	350
	Random Effects	(0.63)	(-0.64)	(0.74)	(-0.86)	(1.25)	(p=0.00)		(p=0.00)	(p= 0.98)	
05. Fish species threatened	Country	2.912***	-0.019			0.073***	92.24	0.44	174.38	$\chi^2 = 0.46$	350
	Random Effects	(3.61)	(-0.21)			(9.22)	(p=0.00)		(p=0.00)	(p= 0.79)	
"	Country	3.045	-0.050	0.0017		0.073***	91.96	0.56	174.38	$\chi^2 = 0.53$	350
	Random Effects	(0.80)	(-0.06)	(0.04)		(9.20)	(p=0.00)		(p=0.00)	(p= 0.91)	
"	Country	42.56**	-	1.603**	-0.060**	0.074***	98.64	0.67	174.37	$\chi^2 = 0.67$	350
	Random Effects	(2.48)	(-2.34)	(2.36)	(-2.36)	(9.44)	(p=0.00)		(p=0.00)	(p= 0.88)	1920.988
											28297.15
06. mammal species threatened	Country	0.780	0.157**			-0.0015	3.17	0.99	8825.46	$\chi^2 = 28.52$	346
	Fixed Effects	(1.29)	(2.29)			(-0.52)	(p= 0.04)		(p= 0.00)	(p= 0.00)	
"	Country	8.127***	-1.53***	0.095***		-0.0011	9.95	0.99	9184.24	$\chi^2 = 27.48$	346
	Fixed Effects	(4.95)	(-4.25)	(4.77)		(-0.38)	(p= 0.00)		(p= 0.00)	(p= 0.00)	
"	Country	-22.57***	9.414***	-	0.046***	0.003	41.13	0.73	172.29	$\chi^2 = 5.05$	346
	Random Effects	(-3.54)	(4.29)	1.156***	(4.97)	(1.25)	(p=0.00)		(p=0.00)	(p= 0.28)	1073.958
				(-4.65)							17580
07. Plant species threatened	Country	8.216***	-			0.109	10.83	0.88	141.19	$\chi^2 = 0.01$	350
	Random Effects	(3.56)	0.841***			(0.71)	(p=0.00)		(p=0.00)	(p= 0.99)	
"	Country	-10.45	3.56	-0.253		0.110	12.49	0.74	140.94	$\chi^2 = 0.06$	350
	Random Effects	(-0.70)	(1.02)	(-1.27)		(0.72)	(p=0.00)		(p=0.00)	(p= 0.99)	
"	Country	123.41	-44.40	5.38	-0.217	0.118	15.07	0.78	140.51	$\chi^2 = 0.09$	350
	Random Effects	(1.42)	(-1.44)	(1.49)	(-1.57)	(0.77)	(p=0.00)		(p=0.00)	(p= 0.99)	

Figures in parenthesis are z-values in random effects models and t-values in case of pooled OLS and fixed effects models (***) significant at the 1%, (**) 5% and (*) 10% levels of significance.

'Annual freshwater withdrawals' refer to total water withdrawals. Withdrawals for agriculture and industry are total withdrawals for irrigation and livestock production and for direct industrial use (including withdrawals for cooling thermoelectric plants). Withdrawals for domestic uses include drinking water, municipal use or supply and use for public services, commercial establishments and homes.

World uses about 70 per cent of fresh water for irrigation, about 20 per cent for industry and about 10 per cent for domestic use. [World Water Assessment Programme (WWAP)].

'Fresh water withdrawal' is another environmental problem that is essentially solved by higher incomes. Table 3 shows a linear negative relationship between 'fresh water withdrawal' and per capita income. Increase in income per capita by one unit leads to decline in 'fresh water withdrawal' by 0.132 units. The reason for decline in 'fresh water withdrawal' is that at higher incomes people start using techniques of water treatment plant and prefers to use recycled water instead of fresh water. But over the period of time 'fresh water withdrawal' increased by 5.7 per cent annually due to other factors that are not correlated with income.

Emissions of organic water pollutants are measured by biochemical oxygen demand, which refers to the amount of oxygen that bacteria in water will consume in breaking down waste. This is a standard water-treatment test for the presence of organic pollutants.

Table 3 shows an inverted N type relationship of 'organic water pollutant' with income. Initially 'organic water pollutant' decrease by 23.04 units with per unit increase in per capita income up to a first turning point of income level of \$ 576.755. For income above this level, however, the relationship turned into inverted U-shaped i.e. Environmental Kuznets Curve that means there is an increase in organic water pollutant by 2.985 units for one unit increase in per capita income up to second turning point at per capita income of \$ 18424.63. After this turning point with further increase in per capita income, 'organic water pollutant' is expected to decline by 0.123 units with one unit increase in income per capita.

'Bird species threatened', 'fish species threatened', 'mammal species threatened' and 'plant species threatened' are those species whose prospects for survival is in danger, are in danger of extinction, vulnerable to specific changes in their habitat, considered rare because of small populations or restricted local distribution, requiring particular attention for reasons of the specific nature of habitat.

Every species has an ideal environment in which it can live and thrive. It takes thousands of years for a species to adapt to a particular environment. Once a species is removed from its zone of adaptation or its environment is changed anthropogenically or otherwise, the survival of that species will be threatened. Once the environment of one species is drastically disturbed, it not only affects that species but also has cascading effects on other species in the ecosystem (Kang, 2014).

As human population continues to grow, more fish and wildlife species have been put at risk by loss and fragmentation of critical habitat and due to disturbance.

Table 3 shows that 'bird species threatened' follows an inverted U-shaped curve. Lower income associated with increase in 'bird species threatened' with 2.498 units with per unit increase in income per capita. After reaching turning point of income level \$ 2339.667, 'bird species threatened' tends to decline by 0.161 units for one unit rise in per capita GDP. Time variable has positive but insignificant role in case of this variable.

In the case of 'fish species threatened', there is inverted N type relationship. First there is an improvement in environmental quality with rise in per capita GDP as 'fish species threatened' declined by 13.950 units by one unit per capita income increase. After reaching first tuning point of income level at \$ 1920.988, the environmental quality starts deteriorating with increase in 'fish species threatened' by 1.603 units with rise in one unit of per capita income. Further rise in per capita GDP beyond second turning point of income level at \$ 28297.15, there is a decline in 'fish species threatened'. Per unit increase in income per capita, 'fish species threatened' expected to decline by 0.06 units. 'Fish species threatened' have increased over the period of time as coefficient representing the time variable is significant and positive.

The relationship between 'mammal species threatened' and GDP per capita turns out to be N-shaped. Initially 'mammal species threatened' tend to increase by 9.414 units for one unit rise in per capita income up to first turning point (\$ 1073.958). Beyond this income level, it starts declining by 1.156 units with one unit increase in income per capita. After touching second turning point at per capita income level of \$17580, it again shows rising trend by 0.046 units with one unit income rise. Time coefficient is positive but insignificant in case of this environmental variable.

The result indicates a negative and linear relationship between 'plant species threatened' and economic growth i.e. higher income countries are associated with lower 'plant species threatened'. One unit increase in per capita income leads to 0.841 units decline in 'plant species threatened'. There is insignificant positive effect of time in case of this variable also.

SECTION - IV

CONCLUSION

There are various types of relationships between per capita income and different environmental indicators and Environmental Kuznets Curve is one of them. Some very clear patterns of relationship between environmental degradation and income emerge from the analysis. Most of the environmental indicators improve with rising income. The environmental indicators that are improved with higher incomes are 'carbon dioxide emissions', 'other green house gases emissions', 'HFC gas emissions', 'industrial nitrous oxide emissions', 'agricultural methane emissions', 'agricultural nitrous oxide emissions', 'forest area', 'fresh water withdrawal', 'organic water pollutant', 'bird species threatened', 'fish species threatened' and 'plant species threatened'. The indicators 'fresh water withdrawal' and 'plant species threatened' are monotonically decreasing with rising incomes. So these indicators clearly improve with increasing per capita income. A monotonic decrease of environmental degradation along a country's development path suggests that policies that accelerate economic growth also lead to rapid environmental improvements.

'Agricultural methane emissions', 'agricultural nitrous oxide emissions', 'forest area' and 'bird species threatened' have inverted U type relationship with income. These indicators improve after the turning point when incomes are higher. Before that point, at lower income levels, environmental quality deteriorates as income began to rise. Other indicators like 'carbon dioxide emissions', 'other green house gases emissions', 'HFC gas emissions', 'industrial nitrous oxide emissions', 'organic water pollutant' and 'fish species threatened' have inverted N type relationship with income. In these indicators improvement begins after the second turning point at a much higher per capita income level. So the Environmental Kuznets Curve hypothesis is supported by the study for ten environmental indicators. The reason behind this is that at sufficiently higher level of income people become aware and conscious about better environment. Also the government starts making investment for improving and safeguarding environment at higher levels of income. People in developed countries have resources and technologies to buffer themselves from the impact of environmental degradation. This will require substantial investments in pollution abatement technology and resource management. It is more difficult for poor countries to absorb these costs. The environmental efforts in these countries have to be funded at the expense of other social programs such as education, health services, and employment schemes which are already starved of funds. The environmental policies have the potential to solve environmental problems over the long run (at high incomes), but they are also capable of significant environmental damage in the short to medium run (at low to medium level incomes).

The improvement of the environment with economic growth is not automatic but depends on policies and institutions. GDP growth creates the conditions for environmental improvement by raising the demand for improved environmental quality and makes the resources available for supplying it. Whether environmental quality improvement materializes or not - when and how - depend critically on government policies, social institutions and the functioning of markets.

Some of the environmental indicators in the study worsen with rising income. The environmental indicators that deteriorate with higher incomes are 'Methane emissions', 'Nitrous oxide emissions', 'SF6 gas emissions', 'PFC gas emissions', 'PM level' and 'mammal species threatened'. In these indicators 'methane emissions', 'Nitrous oxide emissions' and 'SF6 gas emissions' are monotonically increasing with rising incomes. 'PFC gas emissions', 'PM level' and 'mammal species threatened' indicators worsen at higher income levels after the second turning point. So there is a need for strict environmental regulations in order to ensure sustainable scale of economic activities.

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