Does Environment link to Economic Growth?

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Abstract

Recently, the question of link or the relationship between the global climate change and the level of economic activity becomes the major issue and comes to the focal point of research. In this study we try to find out the linkage between environment and economic growth. Let us consider a certain level of income, up to which one may reasonably expect high green house gas-intensive income growth to affect adversely the climate globally. But beyond a critical level, climatic degradation may, in principle, reach a stage where further income growth becomes difficult. Thus, the human race faces the economic as well as social insecurity due to climate change. Climate may act as a constraint to income growth at this latter stage if the green house gas-intensive income growth process is continued. Thus, the global economy faces a serious challenge from the global climate change. To save the world economy or in other way to protect humanity, proper environmental policy should be adopted at appropriate time.

The effective environmental policy prescription depends on the actual position of the economy: at what stage of growth/development the economy is. This study finds the evidence of the linking of economic growth and environment. To be specific, we are interested to observe how economic growth is systematically linked to the position of the economy as well as that of the environment. Our model predicts that the average growth rate of output is inversely related to the initial level of output and directly related to that of environment (viz., protected natural resources). Thus, the human race will be protected through protecting natural capital, which may control the vulnerability of the climate change.

JEL *Classification Number***:** C_{33}, O_{41}, Q_{20}.

Key Words: Economic growth, Two-sector growth model, Environmental Capital, climate change, Pollution, Abatement, Convergence, CO_2 emission.

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Does Environment link to Economic Growth?

1. Introduction

Human-induced climate change is the most troubling and complex environmental problem facing the world as a whole. The Earth's climate is changing at an unprecedented rate, and its future implications are wide-ranging, particularly, the security implications of changes in the natural environment. Climate change is expected to have considerable impacts on natural resource systems, and thereby changes in the natural environment can affect human sustenance or livelihoods (i.e., economic activities). The unique combination of environmental, economic and human security concerns embodied in the climate problem. A growing body of research has developed to explore the concept of vulnerability and its link to recent climate change. The question of link or the relationship between the global climate change and the level of economic activity becomes the major issue and comes to the focal point of research. In this study we try to find out the linkage between environment and economic growth.

The plan of this paper is as follows: Section 2 provides the evidence of climate change and food security. Section 3 provides a causal linkage between economic growth and climate change (or emission). Section 4 shows the relationship between economic growth and environment applying growth model. Section 5 provides empirical model and Section 6 provides empirical results and finally, Section 7 concludes the paper suggesting a possible policy for the future world.

2. Climate Change and Food Security

The economy based on agricultural activities becomes vulnerable and risky particularly to the climate change. Indian agriculture, in particular, highly depends on the climatic conditions and thereby economic growth becomes vulnerable to climate change.

> BANGALORE, APRIL 8. A sharp decline in the rate of growth of agriculture from 4.1 per cent to 1.5 per cent in the last few years has affected the overall economic growth rate, the Union Minister of State for Planning, M.V. Rajashekaran, said here today. Inaugurating the 40th Annual Rice Group Meeting at the University of Agricultural Sciences (UAS) here, he said the mid-term appraisal meeting of the Tenth Five Year Plan, chaired by the Prime Minister, Manmohan Singh, on April 4, took note of the decline in the growth rate in the farm sector on account of the **erratic monsoon, decline in soil fertility** and water logging (Published in *The Hindu*, April 9, 2005).

Agricultural lands worldwide have become vulnerable to degradation processes such as soil erosion, nutrient depletion and loss of organic matter, and have suffered a consequent decline in soil productivity or soil fertility. As a consequence we observe that agricultural productivity also decreases worldwide. Despite the continued development of new and improved modern varieties and greater use of chemical fertilizers[1], yield growth began to slowdown in the latter part of the 20th century. The world's annual cereal yield growth rate has declined from an average of 2.2 percent in the 1970s to 1.1 percent in the 1990s. Wheat yields in Asia grew at an average annual rate of 4.3 percent during the 1970s, but it dropped to 0.7 percent per year during 1990 –1997. After rapid growth of almost 2.4 percent per year during 1980s, rice yield growth fell to 1.5 percent per year in 1990s in Asia (Table 1). In Sub-Saharan Africa, the situation is even more dramatic, with cereal

[1] Fertilizers are added to supplement nutrients in the soil. Fertilizers intended for enriching the soil often contain numerous toxic metals that have no benefit for crop and plant growth. Chemical fertilizers increase the yield, but with heavy damage to the environment, causing eutrophication.

yield growth decreasing steadily from 1.9 per cent during the 1970s to 0.7 per cent in the 1990s.

Table 1: Agricultural production growth rates in last three decades

	Item	1970s	1980s	1990s
Asia	Wheat	4.3		0.7
	Rice		2.4	1.5
Sub-Sahara Africa	Cereal	1.9		0.7
World	Cereal	2.2		1.1

This global slowdown has raised concerns that yield growth may have reached a plateau or begun to decline in many of the world's most fertile areas (See Gruhn et. Al 2000). This definitely leads the world population to face food scarcity. In this context it should be mentioned that net availability of foodgrains in India (per day) initially increases till 1991 and thereafter it declines (Table2).

Table 2: Net Availability of Foodgrains in India (grams per capital per day) during 1951-2003.

Year	Rice	Wheat	Other Cereals	Cereals	Gram	Pulses	Foodgrains
1951	158.9	65.7	109.6	334.2	22.5	60.7	394.9
1971	192.6	103.6	121.4	417.6	20	51.2	468.8
1991	221.7	166.8	80	468.5	13.4	41.6	510.1
2001	190.5	135.8	56.2	386.2	8	30	416.2
2003	183.4	178.9	44.9	407.1	8.3	29.1	436.3

source:*Agricultural statistics, Department of agriculture and cooperation, Ministry of Agriculture, Govt of India*

Thus, the global economy faces a serious challenge from the global climate change. In other word, human race faces the economic as well as social insecurity due to environmental degradation or climate change.

3. Causal linkage to Emission or Climate Constraint

Recently, the question of linkage or the relationship between the global climate change and the level of economic activity becomes the major issue and comes to the focal point of research. Concerned with the problem of increasing environmental degradation, researchers have been examining the nature of relationship between the level of economic activity or income and environmental quality indicators. Using cross-country and panel data, there have been extensive empirical studies to testify the environmental degradation-economic growth relationship -viz., Environmental Kuznets Curve (EKC) hypothesis[2], which postulates *an inverted U-shaped relationship between level of economic activity and environmental pressure (defined as the level of concentration of pollution or flow of emissions, depletion of resources etc.).* The literature on EKC has mostly considered EKC as an empirical phenomenon and examined the presence or otherwise of significant statistical association between the level of economic activity and environmental degradation without explicitly discussing the nature of causation between these variables. However, the fact that in the description of the EKC the environmental degradation is shown as the dependant variable suggests that while examining the EKC hypothesis empirically a unidirectional causal relationship is implicitly assumed – viz., a change in the level of economic activity/per capita income causes a consequent change in the environmental quality. While such a postulate may apparently sound reasonable, it may not hold in all circumstances. Take, for example, the question of relationship

[2] See, e.g., Grossman and Krueger 1995, Suri and Chapman 1998, Selden and Song 1994, Panayatou 1998, Carson et al. 1997, Kahn 1998, McConnell 1997, Torras and Boyce 1998, List and Gallet 1999, Koop and Tole 1999, Tucker 1995 for EKC studies for pollution indicators other than CO_2, and Holtz-Eakin and Selden 1995, Shafik 1994, Sengupta 1997, Cole et al. 1997, Moomaw and Unruh 1997, de Bruyn et al. 1998, Unruh and Moomaw 1998 for EKC studies using CO_2 emission as the pollution indicator.

between the global climate and the level of per capita world income/economic activity. Up to a certain level of income, one may reasonably expect high green house gas-intensive income growth to affect adversely the climate globally. But beyond a critical level, climatic degradation may, in principle, reach a stage where further income growth becomes difficult. Climate may act as a constraint to income growth at this latter stage if the green house gas-intensive income growth process continues. Thus, the global economy faces a serious challenge from the global climate change. In other word, human race faces the economic as well as social insecurity due to environmental degradation or climate change.

Consider next the question of causal relationship between per capita income and per capita CO_2 emission through use of commercial energy. For an economy facing no major constraint in respect of supply of fuel, the volume of CO_2 emission per capita would be identically determined as per capita income times the energy intensity of income times the CO_2 intensity of the energy used, thus suggesting income to causally determine CO_2 emission. On the other hand, in case of an economy facing a serious fuel supply constraint, it should be the quantity of fuel used and hence the amount of CO_2 emission that would determine the level of income generated in the economy.

The examples given above suggest that the direction of causality between the level of income and environmental quality need not always be unidirectional from income to environmental quality. In fact, the presumption of a direction of causality may hamper a fuller understanding of the true nature of the environment-income relationship[3]. Further, as the direction of causation between CO_2 emission/energy consumption and economic growth has significant policy implications, any presumption about the direction of causality may lead to erroneous policy conclusions[4]. Thus, for example, if for a country the causality runs from income to CO_2 emission/energy consumption, an energy conservation policy may be implemented with little or no adverse effects on economic growth. If, on the other hand, the causality runs from energy consumption/CO_2 emission to income, reducing energy consumption (by a carbon tax policy[5], say) may lead to fall in income.

Yang (2000), Glasure and Lee (1997), Cheng (1996, 1999) and Yu and Choi (1985) examined the issue of causality between energy consumption and GDP. Using time series data for Taiwan for the 1954-1997 period, Yang examined the causality between energy consumption and GDP by applying Granger causality test (GCT) (Granger 1969). His results suggest a bi-directional causality between total energy consumption and GDP. Furthermore, for energy consumption of different forms (viz., coal, oil, gas and electricity) the directions of causality with GDP were found to be different. Glasure and Lee examined the nature of causality between energy consumption and GDP for South Korea and Singapore. Their results based on the techniques of co-

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[3] In some studies of EKC whether income level is at all an important determinant of environmental quality has been examined. See, e.g., Agras and Chapman (1999), who observe that when energy price and trade related variables are used as explanatory variables along with income, energy price becomes the significant determinant of environmental quality (i.e., CO_2 emission) or energy demand and the effect of income becomes non-significant. In a way thus the Agras and Chapman study raises a question about the desirability of presuming any causal relationship between environmental quality and income level.

[4] See, Goulder and Schneider (1999).

[5] See, Agostini et al. (1992).

integration and subsequent error-correction model estimations also indicate presence of a bi-directional causality for the countries in question. However, the use of GCT showed absence of any causal relationship for South Korea and presence of uni-directional causal relationship from energy consumption to GDP for Singapore. Applying Johansen's technique of co-integration to data for India, Cheng found energy consumption, economic growth, capital and labour to be co-integrated. Further, using Hsiao's version of the GCT (Hsiao, 1981) together with co-integration and error-correction model analysis, he obtained unidirectional causality from economic growth to energy consumption both in short and long-run. Yu and Choi found no causal relationship between GNP and energy consumption in USA, UK and Poland, causality from GNP to total energy consumption in South Korea and causal linkage from total energy consumption to GNP in Philippines. The results just mentioned above seem to reinforce the need to make deeper probe into the causality aspect of the income- climate change/environment relationship.

In this study we also try to find out the linkage between environment and economic growth. The present study makes such an attempt.

Given a time series data set on measures of level of economic activity and corresponding environmental change, one may use time series econometric techniques like Granger Causality Test (GCT) to examine whether a statistically significant causality exists between the two variables and if so, what is the direction of causality. Using a panel data set on per capita income and per capita CO_2 emission for a large number of countries, we have tried to do a careful statistical analysis primarily using the GCT and Engel-Granger error correction model. To make the investigation comprehensive and exhaustive, we have examined presence or otherwise of a causal relation between income and CO_2 emissions for groups of similar countries. Using the cross-country panel data set on income and emission we examined the income-emission causality patterns for country groups (OECD and Non-OECD) formed out of the 88 countries covered in the data set. As is to be expected, the results are obtained showing different directions of causality for different groups of countries. Table 3 presents the causality results of all three possible models (Pooled (OLS), Fixed and Random Effect) in panel data sets.

Table 3: Results of F value of Causality Test

	Non-OECD		OECD	
	I	II	I	II
OLS (pool)	1.44	4.45	4.08	1.81
Fixed Effect	1.31	3.89	4.02	1.34
Random Effect	1.55	3.94	3.99	1.37

Model I: Income =f(income_Lags, emission_Lags), Model II: Emission =f(income_Lags, emission_Lags)

Table 4: Summary results of causality test

	Non-OECD	OECD
OLS (pool)	GDP $\Longrightarrow$ CO_2 Emission	GDP $\Longleftarrow$ CO_2 Emission
Fixed Effect	GDP $\Longrightarrow$ CO_2 Emission	GDP $\Longleftarrow$ CO_2 Emission
Random Effect	GDP $\Longrightarrow$ CO_2 Emission	GDP $\Longleftarrow$ CO_2 Emission

The results suggest a definite direction of causality for each country-groups – viz. OECD and Non-OECD. In OECD country group CO_2 emission is the cause of growth of income whereas the growth of income is the cause of CO_2 emission in Non-OECD country group (Table 4). It is quite natural that in Non-OECD countries environmental degradation / pollution level increases as income level rises. In OECD countries environmental degradation becomes constraint and/or without further environmental degradation income generation is impossible.

In fact, it is true that whether a change in the level of economic activity would cause or would be caused by a change in the climate /environmental quality should depend upon various characteristics of the economy under consideration.

4. Economic growth and Environment

The motivation for the mostly empirical studies in 1990's is only to find out the cause of environmental problems and policy suggestions[6]. The effective policy prescription depends on the actual position of the economy. By position we mean at what stage of growth the economy is. Our motivation for this study is to search for the evidence of the linking of economic growth and environment. To be specific, we are interested to observe how economic growth is systematically linked to the position of the economy as well as that of environment. This systematic link is a foundation for the convergence of an economy towards steady state. Convergence applies if a poor economy tends to grow faster than rich one, so that the poor country tends to catch up with the rich one in terms of the level of per capita income or product. This property corresponds to the concept of

[6]Before adopting any policy, it is important to understand the nature and causal relationship between economic growth and environmental quality.

so-called β-convergence. In this context, convergence also occurs if the cross-sectional dispersion declines over time. We call this process σ-convergence. Convergence of first kind tends to generate convergence of the second kind. Thus, β-Convergence is a necessary but not a sufficient condition for σ-convergence. It should be noted that the poorer economies grow faster than rich ones if only difference across countries is initial levels of capital. All the economies move towards one common steady state level. This is known as absolute (or unconditional) β-convergence. Where there are structural differences across countries there will be conditional β -convergence: countries converge to different steady states but at a common speed. The conditional convergence is more realistic than absolute convergence in cross-country study.

From the textbook literature (like, Sala-i-Martin (1995)), β -Convergence (assuming y_{it}^{*} remains constant between $t-t$ and t, the relationship) is

$$y_{it} = e^{-bt} y_{it-t} + (1 - e^{-bt}) y_{it}^{*} \qquad (1)$$

where y_{it} is income per capita of ith country for time t, and y_{it}^{*} is the steady state level of per capita income. Adding a serially independent, zero mean disturbance term u_{it} yields econometric model for β -Convergence

$$y_{it} = e^{-bt} y_{it-t} + (1 - e^{-bt}) y_{it}^{*} + u_{it} \qquad (2)$$

Consider one sector growth (Solow type growth) model and its steady state condition i.e., $f_k = n + d + r$, where f_k is the marginal productivity of capital, n, d and r are population growth rate, depreciation rate and discount rate, respectively. Now consider the situation that climate change has impact on the steady state exogenously. We measure the impact of climate change (e, say) on n, d and r as $\frac{\partial n}{\partial e} \prec 0$, $\frac{\partial d}{\partial e} \succ 0$ and $\frac{\partial r}{\partial e} \succ 0$, respectively. For example, as climate changes some new disease may be grown up and that may affect human growth n and thereby affect steady state growth rate. Similarly, discount rate for future consumption increases as climate continuously deteriorates/changes.

Following Shioji (2001), now we introduce environment as a public capital in β - Convergence model. Equation (2) implies that steady state output per capita between $t-t$ and t depends positively on the value of the environmental capital at the beginning of the period (E_{it-t}), assuming that environment per capita remains constant during the period. So, we postulate the following relationship:

$$y_{it}^{*} = yE_{it-t} + \tilde{y}_{it} \qquad (3)$$

where $y > 0$ measures the effect of environmental capital on steady state output per capita. All other factors affecting steady state output per capita are captured by the group/ region-specific constant $\tilde{y}_{i.}$. Plugging the equation (3) into equation (2), we obtain

$$y_{it} = e^{-bt} y_{it-t} + (1-e^{-bt})yE_{it-t} + (1-e^{-bt})\tilde{y}_{i.} + u_{it} \qquad (4)$$

Thus, the growth of income has a direct link to the environment. Using two sector endogenous growth model we also obtain the similar relationship.

In this two sector endogenous growth model, two capitals are used – one is composite (physical and human) capital and other environmental (natural) capital that is public good by nature[7]. This paper focuses on the behaviour of capital-environment ratio, relative price and its implications for conditional convergence. In our earlier empirical study, we also observe that both income and emission converge[8] towards their equilibrium. A fall in emission growth rate means an improvement in the environment, *ceteris paribus*. So, economic growth rate is inversely related to income level and directly related to the environment.

The natural question is whether the data support these predictions concerning the determinants of income growth. In other words, we want to investigate whether growth rate of income is high in a country having higher environmental stocks and low in a country having lower environment. This is true, (under certain assumptions), low growth country has high level of emission (or pollution) but the high growth country has low emission level. For example, in the USA, annual average economic growth rate is low, approximately 2 percent, with higher level of emission[9] (USA emits 23.58 percent of global emission[10] in the World in 1997), while in India and China, economic growth rates are high with low emissions compared to the USA. In India, average economic growth rate is 5 percent to 6 percent and in China it is 8 percent to 10 percent. Emission levels in India and China, are 4.3 percent and 5.6 percent, respectively, in 1997 (See, ORNL). Thus, high growth rate is directly linked to the high level of environmental stock that is naturally associated with low level of physical capital stock. This is the basic feature of

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[7] Generally, the social assets could be private property of the society because other society could not use that asset. We assume that central planner is the owner of the social assets, so, E can be treated as private property of the planner.

[8] Actually, convergence of emission is the mirror image of income- convergence.

[9] High environmental stock may exist. Recently one report points out that Environmental stocks especially protected forest covered area has reached roughly 44 percent of the state of Michigan, in USA (See, Hayward 2001).

[10] See, Web site of Oake Ridge National Laboratory (ORNL), USA.

under developed economy. Low growth rate associated with huge capital stock is obviously related to low natural resources or environmental stock. This is the typical feature of developed economy.

5. Empirical Model

We obtain the rate of convergence indirectly by estimating a linear equation:

$$r_t = \boldsymbol{a} + \boldsymbol{b}_1 y_{it-1} + \boldsymbol{b}_2 E_{it-1} + u_{it} \qquad (5)$$

where r_t is the economic growth rate, $\boldsymbol{b}_1 \prec 0$ and $\boldsymbol{b}_2 \succ 0$.

The significant $\boldsymbol{b}_1$ coefficient in (5) is interpreted as evidence of b -convergence in the convention. The significant $\boldsymbol{b}_2$ coefficient in (5) gives added flavour to the existing literature of b -convergence. For the quantitative analysis of equation (5), we need the data on Y as well as on E. But in reality, we do not have any data on E. Truly, E is the stock variable and it is difficult to measure properly. Actually E is not well defined for individual country. Major sink of pollutants or emission is the ocean which do not belonging to any nation. Next to the ocean, the forest is a major sink of carbon dioxide emission. Another important CO_2 absorber is soil. So, land and forest both act as carbon sequestration and reduce CO_2 from atmosphere, indirectly it helps to check the global warming. Therefore, the forest (green covered) area[11] of a country is a good proxy of E. The protected forest area absorbs CO_2 in one hand and it also helps to stop the depletion of natural resources.

[11] We can take national protected area of a country or the percentage of land under forest and woods as a proxy of environment. The data on percentage of land under forest for each country is available for the year 1970, 1975, 1980, 1985 and 1990.

6. Data and Results

6A: *Protected forest area*

Per capita protected forest area may be a good proxy of environmental stock (Bimonte 2002). The data on protected forest area (hector) is available only for 1970, 1980 and 1990. A few countries have data on it only in 1970 but more in 1980s. So, we consider the year 1980 as the base. These data are available in UNEP web site GEO-3 compendium. For the present study, we have used cross-country panel data on per capita GDP (measured at 1985 International Price i.e., PPP) which are compiled by Summers and Heston (Mark 5.6).

Table 5: Test Results of Conditional Convergence in Two-Sector Growth Model using Protected Forest Area as Environmental Capital.

Variables	OECD	Non-OECD	World
Constant	0.0098 (0.22)	0.0086 (0.66)	-0.0112 (-1.28)
$LogY_0$	-0.013 (-0.44)	-0.032*** (-2.79)	-0.027*** (-2.68)
$LogE_0$	0.012 (0.35)	0.029*** (2.71)	0.030*** (3.12)
$\overline{R}^2$	0.0304	0.0892	0.1060
N	21	58	80

Note: Figures in parentheses are t-ratios. `***', `**' and `*' denote statistical significant at 1%, 5% and 10% level, respectively.

We choose per capita protected forest area of a country as a proxy of E. Few data on forest are available for individual nations. Poor people in under developed economies mainly rely on common forest resources. It is evident that environmental protection necessitates closer attention to the qualitative characteristics of the process of development. As per capita protected forest area of nation, specifically less developed economy, increases as the growth rate of the economy also rises. This is because, the income of the people, who directly depends on forest, increases as protected forest area increases and the resource base of income will be widened. In this situation, income base is protected for further income generation in future also. Thus, poverty eradication[12] is possible through forest covered area protection in less developed countries.

Table 6: Test Results of Conditional Convergence adding population growth rate in Two-Sector Growth Model using Protected Forest Area as Environmental Capital.

Variables	OECD	Non-OECD	World
Constant	0.004 (0.07)	0.038*** (2.66)	0.023** (2.03)
$LogY_0$	-0.011 (-0.37)	-0.033*** (-3.22)	-0.029*** (-3.19)
$LogE_0$	0.012 (0.35)	0.025** (2.54)	0.025*** (2.81)
n	-0.31 (-0.52)	-1.09*** (-3.63)	-1.05*** (-4.23)
$\overline{R}^2$	0.0462	0.2567	0.2686
N	21	58	80

Note: Figures in parentheses are t-ratios. `***', `**' and `*' denote statistical significant at 1%, 5% and 10% level, respectively.

We calculate per capita protected area for each country for the given year. Here base year income, Y_0 and base year environmental quality, E_0 are actually Y_{80} and E_{80},

[12] Poor people rely more on common forest resources. These common resources decrease as economy develops. So, income or livelihood of mass people decline and gradually fall into the poverty trap. So, protection of common resources is actually protecting the income of mass people. So, common resource protection should be one policy to eradicate poverty.

respectively. Using these we estimate eq. (5) and results are presented in Table 5 and 6. Statistically significant results are found only in the samples of Non-OECD and the World. The result of OECD countries is not significant. These findings suggest that as under developed countries increase their protected forest area, their economic growth rate also increase. High priority, in the national policy of poor or developing economies, should be given for the protection and preservation of natural resources in their territory. These protected resources would be the basis for future economic growth and development. The protected forest covered area should have a maximum limit (say, one-third land of a country) and beyond it growth may fall. Another point should be noted that the population growth rate has negative impact on economic growth particularly for less developed and developing countries (Non-OECD) and the World as a whole.

6B: *CO_2 Emission*

Other proxy of E could be the emission or pollution in some sense. In reality, environmental stock (E) is depleted with the flow of emission or pollutants (P). So, conceptually E and P are opposite in common sense. Thus, we assume the inverse relationship between E and P. The true relationship between E and P of a country, however, highly depends on available technology, sectoral composition of GDP and openness of the economy etc. Keeping all these constraint in mind, we now try to estimate the equation (5) using carbon emission data. For this, we may treat CO_2 emission as the proxy of E in different ways or in other sense. It should be noted that emission is a flow concept whereas environment is a stock. Actually, the flow of emission is accumulated year after year in the atmosphere. After a long time, this accumulated emission becomes the stock, which is one of the causes of global warming. In other way it is nothing but the accumulated environmental degradation. Thus, here, accumulated emission stock may provide some insights of the problem of quantification of environmental degradation.

Table 7: Test Results of Unconditional Convergence in Two-Sector Growth Model using Cumulated Emission as Environmental Capital.

Variables	OECD	Non-OECD	World
Constant	0.096*** (10.35)	0.058*** (4.15)	0.057*** (4.98)
$LogY_0$	-0.023*** (-7.86)	-0.017*** (-3.69)	-0.0166*** (-4.4)
$LogE_0$ Degraded env.al stock	0.003 (1.76)	0.011*** (5.03)	0.012*** (5.93)
$\overline{R}^2$	0.8410	0.2658	0.3020
N	21	67	88

Note: Figures in parentheses are t-ratios. `***' and `**' denote statistical significant at 1% and 5% level, respectively.

Carbon Dioxide Analysis Information Center (CDAIC) of Oak Ridge National Laboratory (ORNL), USA provides per capita CO_2 emission (measured in metric tons). Given the basic data, we have compiled a panel data (for income and emission) set of yearly observations covering 88 countries spread over the globe for the time period 1960 - 1990. Now, using the emission data, we consider the emission level cumulates year after year from 1960 to 1972. This accumulated emission damages the existing environmental quality and thereby reducing environmental stock. Calculated the per capita accumulated emission in 1972 (in other way) provides the existing environmental (stock) degradation per capita in 1972. So, per capita accumulated emission in 1972 could be a proxy of E_0. Thus, per capita accumulated emission in 1972 is taken as environmental (stock) damage at the base year 1972. Per capita income level in 1972 is the base year income, Y_0. We calculate average growth rate of per capita GDP for the period of 1972–90.

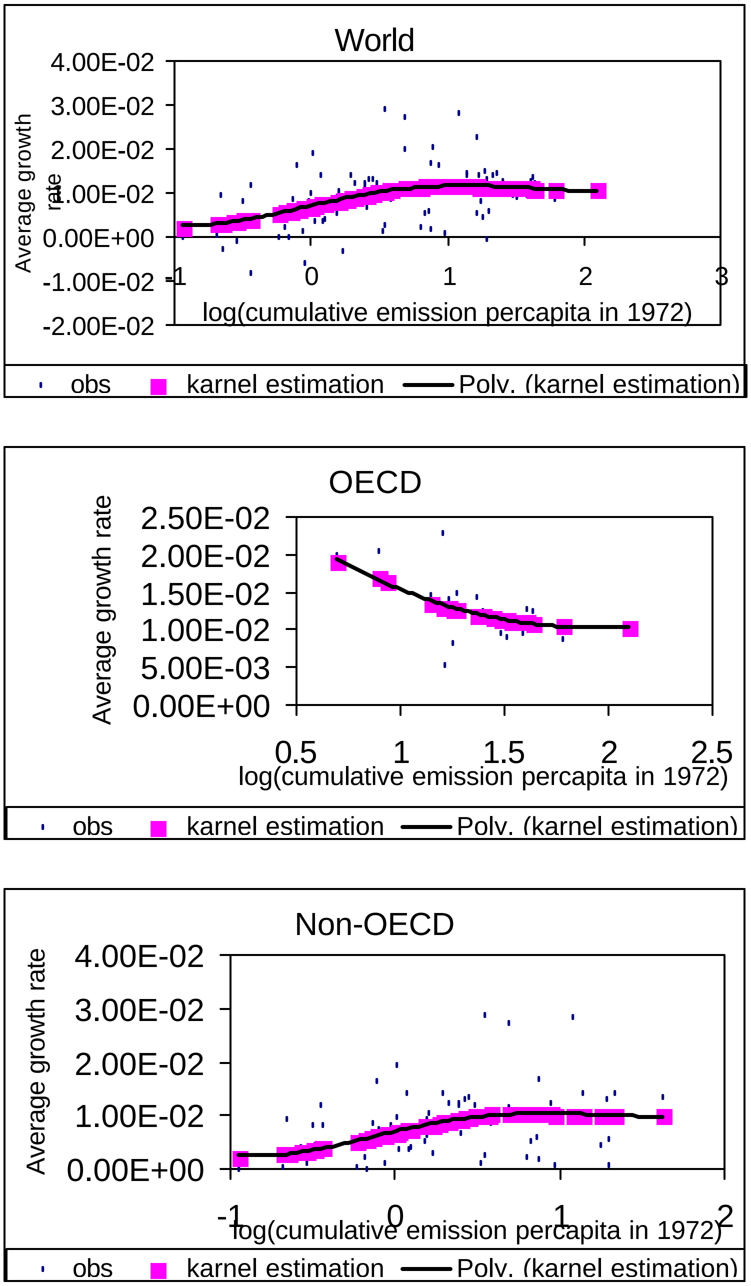
Table 8: Test Results of Conditional Convergence adding population growth rate in Two-Sector Growth Model using Cumulated Emission as Environmental Capital.

Variables	OECD	Non-OECD	World
Constant	0.082*** (7.09)	0.042*** (3.4)	0.043*** (4.28)
LogY_0	-0.021*** (-6.73)	-0.0119*** (-2.97)	-0.0117*** (-3.65)
LogE_0 Degraded env.al stock	0.0065** (2.72)	0.0085*** (4.13)	0.0086*** (4.92)
n	0.02 (0.07)	-0.33 (-1.49)	-0.5*** (-2.95)
$\overline{R}^2$	0.8581	0.4804	0.5425
N	21	67	88

Note: Figures in parentheses are t-ratios. `***', `**' and `*' denote statistical significant at 1%, 5% and 10% level, respectively.

We estimate the model and results are given in Table 7 and 8. The results of conditional convergence in two-sector endogenous growth model are given in Table 8. Results support our model (5). From Table 8, it should be noted that the population growth rate is insignificant for OECD and Non-OECD country groups, but significant only for the world as a whole. Taking per capita accumulated emission as environmental (stock) degradation at the base year 1972 on the horizontal axis and the average growth rates on vertical axis, figure 1 shows the relationship between average growth rate of income and per capita environmental stock at 1972 for OECD, Non-OECD and the World.

Figure 1: Economic growth and environmental degradation.



Using non-parametric (Kernel) method, we try to find the actual shape or relationship between economic growth and environmental (stock) degradation. It should be noted that growth rate converges towards steady state from above in case of OECD (developed) country-group, while it moves towards steady state from below in case of Non-OECD (underdeveloped) country-group, and the World as a whole (See, fig. 1). Here, we observe that the steady state growth rate is approximately one percent. It should also be noted that the World is not yet reached at steady state, but it approaches towards equilibrium from below. From Fig.1, it is clear that few countries have already reached at steady state. Thus, figure 1 describes the relationship between economic growth and environmental degradation. The basic results remain unchanged. Thus, empirical findings also support our theoretical model. It should be also mentioned that the average growth rate declines as environment degrades/deteriorates more and more.

7. Conclusion

This study finds the evidence of the linking of economic growth and environment. This paper observes how economic growth is systematically linked to the economy and environment. The average growth rate of output is negatively related to the initial level of output and positively related to that of environment. We try to examine the model using some proxy of E data, viz.; cumulated per capita CO_2 emission, and per capita protected forest area for each country. The empirical findings of proxy E, namely cumulated emission and per capita protected forest area, suggest that environment is positively related to growth rate. In other word, environmental degradation reduces economic growth.

For the policy prescriptions, this paper suggests that in the national policy each less developed countries should protect and preserve their own natural resources. These natural resources would be the basis for their economic activities, which lead to future economic growth and development. Each individual country increases their protected area upto an optimum level (at least one-third of land). Thus, the highest priority should be given to the land-use and land conversions in their national policy.

In this context, following Kyoto protocol, CO_2 emission tradable permit policy (Jensen and Rasmussen (2000)) could be implemented at international level to arrest global warming. Developed countries should provide some incentives to countries of under developed world having facility and/or ability to increase protected forest area. That means developed countries are ready to negotiate and compensate under developed countries and/or provide some benefits to Less Developed Countries for not cutting trees or preserving forest that helps to reduce CO_2 emission. Otherwise LDC may opt for alternative uses of land instead of protect forest. If this preservation policy once implemented at international level, carbon absorption or sequestration increases and thereby atmospheric carbon dioxide concentration reduces. This whole system will be viable if and only if developed countries are ready to compensate less developed countries for protecting forest in terms of forgone development or alternative use of land.

Let us discuss the limitations of this study. In this study, we use proxy variable instead of actual E. Our choice of proxy of E may be biased or inappropriate. One can reexamine these results by using better proxy of E. The non-availability of actual data on E is the major limitation of this study. Since E is not measurable accurately, we can develop an index of environmental quality that could be a better measurement of E.

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