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Relationship between CO_2 Emissions and Economic Growth: A Panel Data Analysis across Countries over 2005-2010

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Abstract:
We know that CO_2 is one of the largest contributor to the greenhouse gas effect and is also a major source of pollutant and therefore harms the environment. It is therefore very important to study about the relationship between economic growth (GDP), foreign trade dependence and environmental pollution. It is also known that due to economic growth there are differences in CO_2 emission and a major determinant of CO_2 Emission is the level of energy consumption. We want to find out that if the environmental Kuznets curve (EKC) exists then where will a set of different (developed, developing) countries exist on it. In this paper we therefore, examine the relationship between CO_2 emission, energy consumption and economic growth for a set of different countries using annual data for the period 2005-2010.

1. Introduction

Today discharges from Carbon Dioxide (CO_2) have been more prominent than at any other time, expanding radically in the previous century because of human activities, chiefly by the utilization of fossil fuels with changes in area use practices, which are straightforwardly connected with economic development of nations and their economic progress. The causative relationship between economic growth and diverse of environmental value has been broadly investigated in the late years by the Environmental Kuznets Curve (EKC) models all around, locally or nation by a few authors. In 1991, the EKC theory was initially presented by Grossman and Krueger for diverse ecological indicators, including the carbon dioxide discharges too. The EKC theory indicated an inverted U-shape connection between different pointers of natural quality and per capita wage.

Enhancements in economy's development and welfare can influence the sorts of technological and fiscal openings which are used to evade and control for environmental issues. In this circumstance, it is fascinating to know whether the growth of economies and ecological conservation can match or not. Generally, environmental products and their quality are usually "good", indicating that expanded income from free market trade would lead to high environmental quality demand from individuals. In the initial stage of economic advancement, "a small portion of excess income is typically allocated for environmental problems, and thus, at this stage, the industrialization process is likely to be accompanied by environmental problems" (Choi, Heshmati , & Cho , 2010). At the point when GDP per capita rises and goes beyond a certain threshold, the level of pollution commonly diminishes. This consolidated impact can bring about a transformed U-shaped relationship between GDP per capita and the level of contamination.

2. Literature Review

"The EKC takes after the name Simon Kuznets who had famously hypothesized an inverted 'U' income-inequality relationship" (Mor & Jindal, 2012).According to He & Wang (2012), although pollution lessening instruments can differ in diverse areas, the ultimate level of pollution should be the outcomes of 'trade-offs between decreasing marginal utility of consumption and increasing disutility of pollution' which are linked to economic growth. As soon as the income touches a particular threshold level, the 'marginal disutility from pollution' will exceed the 'marginal utility from consumption', and then it becomes essential to devote further resources on pollution reduction to get maximum utility. From there onwards, a contradiction between environmental degradation and economic growth becomes imaginable. (He & Wang, 2012)

Grossman and Krueger (1993) were the first ones to point out an inverted-U relationship between pollutants (SO2 and smoke) and income per capita (Boopen & Vinesh, 2010).Whereas, De Bruyn, van den Bergh, & Opschoor (1998) believed that the inverted U shape will not hold in the very long run as it would be only an early phase of the connection between economic development and environmental degradation.

Al-Mulali, Saboori, & Ozturk (2015) explored the possibility of presence of the environmental Kuznets curve (EKC) hypothesis in Vietnam for the duration of 1981–2011. Based on the gotten results, the EKC hypothesis does not exist because the relationship between GDP and pollution is positive in both the short and long run.

Carbon dioxide (CO_2) explains the biggest portion of greenhouse gas productions and is a chief source of environmental issues (Choi, Heshmati , & Cho , 2010).Saboori, Sulaiman, & Mohd (2012) tried to establish a long-run as well as causal link between economic growth and carbon dioxide (CO_2) emissions for Malaysia. The empirical results suggest the existence of a long-run relationship between per capita CO_2 emissions and real per capita Gross Domestic Product (GDP) when the CO_2 emissions level is the dependent

variable. They found an inverted-U shape link between CO_2 emissions and GDP in both short and long-run, thus associated with the EKC hypothesis.

Further, researches emphases on the association of energy consumption and economic growth. This nexus touches for that more the economic growth more will be the energy consumption. Furthermore, more efficient energy use requires high levels of economic growth (Omri, 2013). Moreover, quality of human capital, as can be depicted by the level of secondary level enrolment, shows how awareness and sensitization programmes can improve the environmental quality of a nation (Boopen & Vinesh, 2010).

3. Objective

As we know, carbon dioxide (CO_2) can be considered as the largest contributor to greenhouse gas emissions and is a chief source of environmental issues, hence, it is important to examine the underlying relations between environmental pollution, foreign trade dependence (Choi, Heshmati , & Cho , 2010), and economic growth. Furthermore, many preceding studies have shown that economic progress would possibly show variations in CO_2 emissions. It has also been studied that energy consumption is generally a key determining factor of CO_2 emissions (Omri, 2013). The aim therefore is to see where do the countries in the groups, namely 'developed'[1], 'developing'[2] and 'all countries'[3] lie on the EKC (if it happens to exist).In other words, the objective of this paper is to analyse the interrelationship between CO_2 emissions, energy consumption and economic growth for different country groups using annual data over the period of 2005-2010[4]. Also, the paper aims to find how human capital affects environmental condition in developed as well as developing nations.

4. Methodology

This paper hence, tries to study the effect of gross domestic product (GDP) per capita, energy consumption (as a ratio of share of alternative fuels to share of fossil fuels), trade openness (as a ratio of total trade, i.e. sum of exports and imports, to GDP) and human capital (using net secondary school enrolment as a proxy[5]) for country groups on the carbon dioxide emissions (CO_2) for the year 2005-2010. The following represents the regression model for this analysis;

$$CO_{2t} = \beta_o + \beta_1 GDPPC_{it} + \beta_2 OPEN + \beta_3 FUEL_{it} + \beta_4 ENROL_{it} + \beta_5 (GDPPC_{it})^2 + \beta_2 (OPEN_{it})^2 + \mu_{it} \text{ , (Choi, Heshmati , \& Cho , 2010)} \textit{(1)}$$

CO_2 denotes Carbon Dioxide emissions per capita and is an endogenous variable representing better environmental quality when at low levels. The central exogenous variable is GDPPC which represents GDP per capita. The relationships are estimated as being conditional on FUEL representing Ratio of Alternative and Nuclear Energy and Fossil fuel energy consumption, the net secondary school enrolment ratio and OPEN representing trade openness or trade dependency on foreign countries.

"Decoupling carbon dioxide emissions from income growth is an important world issue today" (Fang & Chen, 2007). In general, decoupling is signified using the income elasticity's of carbon dioxide emissions. If the elasticity comes out to be positive and larger than or equivalent to +1, then the emissions are directly associated or coupled with economic growth hence, there exists no 'decoupling'. Comparative decoupling occurs if the elasticity is positive and a smaller amount of than +1.This implies that the proportionate growth of CO_2 emissions is less than the income growth. There is complete 'decoupling' when the income elasticity happens to be zero or less. "As income grows, CO_2 emissions will either stay at the same level or even decline" (Fang & Chen, 2007).

We will run the regression equation (1) for three sample sets, as mentioned before namely, 'all countries', 'developing' and 'developed' countries.

[1] 35 countries as classified by IMF, except San Marino, Taiwan (due to unavailability of data on CO_2 emissions for 2005-2010).

[2] 150 countries as classified by IMF, except Serbia, South Sudan, Tuvalu (due to unavailability of data on CO_2 emissions for 2005-2010).

[3] Here, we've taken the IMF classification of developed and developing nations. Countries not falling in any of the two categories are not taken into consideration (American Samoa, Andorra, Aruba, Bermuda, Cayman Islands, Channel Islands, Curacoo, Fareroe Islands, French Polynesia, Greenland, Guam, Isle of Man, Kosovo, Kuwait, Liechtenstein, Macao SAR, Monaco, New Caledonia, Northern Morians Islands, Puerto Rico, SintMaarter, St. Maartin, Turks & Caicos islands, Virgin Islands, and West Bank & Gaza).

[4]To consider a large set of countries (as classified by IMF under developed and developing) we'd to take a smaller time span. So, the study in consideration talks about short run impact of independent variable on the environmental quality.

[5] Secondary School Enrolment (% net) is taken as a proxy for human capital because it lays down foundation of lifelong learnings (The World Bank , 2013).

4.1. Variables and Data Sources

Variable Name	Definition	Source
CO_2: CO_2 emissions (metric tons per capita)	Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring	WORLD BANK
GDPPC: GDP Per Capita (constant 2005, US$)	GDP per capita is gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of products.	WORLD BANK
OPEN: Trade openness (Choi, Heshmati , & Cho , 2010)	It represents trade openness or trade dependence of a country on foreign countries. It is calculated as total trade in a given time period divided by GDP of that period.	WORLD BANK (data taken for (a)GDP(constant 2005, US$), (b)Exports and Imports (BoP, current US$)
FUEL: Ratio of Alternative and Nuclear Energy and Fossil fuel energy consumption (Fang & Chen, 2007)	Alternative and Nuclear Energy (% of total energy use): Clean energy is no-carbohydrate energy that does not produce carbon dioxide when generated. It includes hydropower and nuclear, geothermal, and solar power, among others. Fossil fuel energy consumption (% of total): Fossil fuel comprises coal, oil, petroleum and natural gas products	WORLD BANK
School enrolment, secondary (% Net)	Net enrolment rate is the ratio of children of official school age who are enrolled in school to the population of the corresponding official school age. Secondary education completes the provision of basic education that began at the primary level, and aims at laying the foundations for lifelong learning and human development, by offering more subject- or skill-oriented instruction using more specialized teachers.	WORLD BANK

Table 1
Source: worldbank.org

5. Results and Discussions

Using Hausman test, we test if random effects (RE) is ideal than fixed effect model (FE); we reject the null (H_o: RE Better than FE) when we take 'all countries' category and have the indication that FE model is better than RE. The fixed effect model takes into account the fact that individual heterogeneity is reflected by the intercept term. This means every individual here country gets its own intercept β_o (level of CO2 emissions) while the slope coefficients are the same. Whereas, the random effects model assumes in some sense that the individual effects are captured by the intercept and a random component μi. Further, a joint significant test for all years taken as dummies gave insignificant results implying absence of time variant variables in this model. Hence, FE is the best fitted model for a case we take 'all countries' and we consider the result of it over RE and Time Fixed Effects (TFE). (See Appendix Table: A1 for a comparison between RE, FE and TFE results for 'all countries').

We again used the Hausman's test, and found that RE is the best fitted for 'developing' and 'developed' countries categories as we fail to reject the Null this time. Hence, RE model is validated in these two cases.

VARIABLES	(2) Fixed Effects
Gdppc	-0.00125
	(0.00233)
Gdppcsq	1.21e-06
	(2.12e-06)
Open	0.410**
	(0.162)
Opensq	-0.0380***
	(0.00911)
Fuel	-0.929***
	(0.275)
Enrol	0.00258
	(0.0162)
Constant	5.594***
	(1.215)
Observations	384
R-squared	0.040
Number of country	87

Table2: Fixed Effects model for 'All Countries'
Robust standard errors in parentheses
**** p<0.01, ** p<0.05, * p<0.1*

When we take into account all the countries we see that Gross Domestic Product per capita is negatively correlated to the CO2 emissions. But it is highly insignificant i.e. insignificant at 10% significance level. Further we see that the variable OPEN positively and significantly (significant at 5% and 10% significance levels only) affects CO2 emissions, implying a positive correlation between trade openness of countries and the CO2 emission levels. We further observe the regression coefficients of squares of OPEN are negative and highly significant. This implies that as international trade increases the CO2 levels in countries increases but at a falling rate. Further, the regression coefficient of FUEL is negative and highly significant. This strongly recommends that as countries consume more alternative and nuclear energy than fossil fuel energy consumption the CO2 level falls.

VARIABLES	CO_2 (Random Effects)
Gdppc	-0.00216
	(0.00202)
Gdppcsq	1.41e-06
	(1.86e-06)
Open	0.489
	(0.961)
Opensq	-0.0228
	(0.279)
Fuel	-1.097**
	(0.430)
Enrol	0.0660*** (0.0147)
Constant	-0.432
	(1.085)
Observations	232
R-squared	
Number of country	58

Table 3: Random Effects model for 'Developing Countries'
Robust standard errors in parentheses
**** p<0.01, ** p<0.05, * p<0.1*

A sample of only Developing countries shows a negative impact of a unit change in GDP (per capita) on the CO2 emissions but it is insignificant. The possible reason for this could be the shorter time period taken. The reason for selecting such time period was mainly

the unavailability of various variable data for all countries for many years. The ENROL coefficients are positive and highly significant. One can assume an inverted U-shaped curve for effect of human capita on environmental degradation in the long run, implying that, at initial development stage as the quality of human capital increases in countries there is an increase in Co2 emissions (due to increase in productivity and production), but eventually, in the long run, due to further improvement in human capital CO2 emissions decreases on account of awareness about the environment and technological advancements. Hence, in the case of developing countries we can say that as net secondary school enrolment ratio (proxy of quality of human capital) increases, the CO2 levels rise too due to more production (in the early stage of development).

Lastly, the regression coefficient of FUEL is negative and significant at 5% and 10%mlevels of significance. This acclaims that as countries consume more alternative and nuclear energy than fossil fuel energy consumption the CO2 level falls. Whereas, the results of the FE model show that FUEL is highly an insignificant factor in impacting CO2. Also, ENROL which is highly significant in our RE model is shown to be weekly significant in FE (See Appendix: Table A2).

VARIABLES	**CO_2 Random Effects**
Gdppc	0.00312
	(0.00450)
Gdppcsq	-2.43e-06
	(4.40e-06)
Open	0.251
	(0.198)
Opensq	-0.0254***
	(0.00909)
Fuel	-1.020***
	(0.376)
Enrol	-0.0822*
	(0.0492)
Constant	15.97***
	(5.274)
Observations	152
R-squared	
Number of country	29

Table 4: Random Effects model for 'Developed Countries'
Robust standard errors in parentheses
**** p<0.01, ** p<0.05, * p<0.1*

In a sample of developed countries per capita GDP is positively related to CO2 hence, conforming to the EKC theory of higher the economic growth lesser the environmental degradation for economically advanced economies. However the results are highly insignificant. Further we see that the variable OPEN is positive but insignificant, implying no major correlation between trade openness of countries and the CO2 emission levels. However, the squares of OPEN are negative and highly significant. But, since there is no good relation between OPEN and CO2, we can say not much about the rate of change in CO2 with changes in trade openness. The regression coefficient of FUEL is negative and significant at all significance levels. This strongly recommends that as developed countries consume more alternative and nuclear energy than fossil fuel energy consumption the CO2 level falls. ENROL is positive and weakly significant. We assumed before that initially when quality of human capital increases in a country production increases too which leads to increase in Co2 emissions, but eventually, in the long run, due to better human capital and hence awareness about the environment, improvement in the quality of human capital should lead to decrease in Co2 emissions. Here, we can say that for advanced countries, which unlike the developing countries are in the later stage of economic growth (long term scenario) as human capital builds up, the CO2 emissions fall, reflecting higher environmental awareness and technological advancements.

When we compare the RE and FE models, we observe that FUEL has a negative and highly significant impact on CO2 in this RE model but a weekly significant negative impact in FE model. ENROL which is weekly significant here, is totally insignificant in the FE model (See Appendix Table: A3).

6. Conclusion

Generally, environmental products and their quality are usually "good", indicating that expanded income from free market trade would lead to high environmental quality demand from individuals. According to the famous inverted U-shaped income-inequality curve introduced by Simon, in the initial stage of economic advancement, "a small portion of excess income is typically allocated for environmental problems, and thus, at this stage, the industrialization process is likely to be accompanied by environmental problems" (Choi, Heshmati , & Cho , 2010). At the point when GDP per capita rises and goes beyond a certain threshold, the level of pollution

commonly diminishes. This consolidated impact can bring about a transformed inverted U-shaped relationship between GDP per capita and the level of contamination.

Our study, conversely showed contrasting outcomes for the link between GDP per capita and CO2 emissions for the two groups namely 'developing countries' and 'developed countries'. We can say that technological up-gradation in developing countries in the period of 2005-2010 could be the reason of negative link between CO2 emissions and higher economic growth, whereas for developing countries who have been using the better technologies for a long time now showed a positive link between CO2 and per capita GDP. One should note that these results do not hold much relevance as they end up being insignificant, which could be on account of the short time period taken into consideration.

We also see that trade openness is positive and significantly affecting the CO2 emissions but only for the group 'all countries' for the time period 2005-2010. Further, the regression coefficient of FUEL is negative and highly significant for 'all countries' group and 'developed countries group and weakly significant for 'developing' group of countries. This strongly recommends that as countries consume more alternative and nuclear energy than fossil fuel energy consumption the CO2 level falls. Here, we can draw a policy implication which could encourage countries to switch to alternative and nuclear energy consumption.

Lastly, we can say that there may also exist an inverted U-shaped curve for effect of human capita on environmental degradation in the long run since, net secondary school enrolment ratio is positively related to CO2 for developing countries and negatively related with CO2 for developed countries. Thus implying that at initial development stage as the quality of human capital increases in countries there is an increase in Co2 emissions, but eventually, in the long run, due to better human capital quality (on account of awareness about the environment and advanced technologies), CO2 emissions decreases.

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APPENDIX

	(1)	(2)	(3)
VARIABLES	Random Effects	Fixed Effects	Time Fixed Effects
gdppc	0.000447	-0.00125	-0.00184
	(0.00204)	(0.00233)	(0.00228)
gdppcsq	-6.13e-07	1.21e-06	1.72e-06
	(1.93e-06)	(2.12e-06)	(2.09e-06)
Open	0.464**	0.410**	0.423**
	(0.232)	(0.162)	(0.205)
opensq	-0.0331***	-0.0380***	-0.0383***
	(0.0111)	(0.00911)	(0.0103)
Fuel	-0.934***	-0.929***	-0.873***
	(0.346)	(0.275)	(0.328)
enrol	0.0770***	0.00258	0.0177
	(0.0121)	(0.0162)	(0.0151)
2006.year			-0.0571
			(0.0828)
2007.year			0.113
			(0.240)
2008.year			-0.0772
			(0.195)
2009.year			-0.227
			(0.240)
2010.year			-0.220
			(0.220)
Constant	-0.543	5.594***	4.602***
	(0.848)	(1.215)	(1.223)
Observations	384	384	384
R-squared		0.040	0.063
Number of country	87	87	87

Table A1: Comparison of FE, RE and TFE regression Results for 'All countries'
Robust standard errors in parentheses
**** p<0.01, ** p<0.05, * p<0.1*

	CO_2	CO_2
VARIABLES	Random Effects	Fixed Effects
Gdppc	-0.00216	-0.00350
	(0.00202)	(0.00267)
Gdppcsq	1.41e-06	2.95e-06
	(1.86e-06)	(2.33e-06)
Open	0.489	0.929
	(0.961)	(1.063)
Opensq	-0.0228	-0.143
	(0.279)	(0.282)
Fuel	-1.097**	-0.240
	(0.430)	(0.537)
Enrol	0.0660***	0.0186*
	(0.0147)	(0.0103)
Constant	-0.432	2.056*
	(1.085)	(1.095)
Observations	232	232
R-squared		0.025
Number of country	58	58

Table A2: Comparison of RE and FE Regression Results for 'Developing Countries'
Robust standard errors in parentheses
**** p<0.01, ** p<0.05, * p<0.1*

	CO_2	CO_2
VARIABLES	Random Effects	Fixed Effects
Gdppc	0.00312	0.00414
	(0.00450)	(0.00576)
Gdppcsq	-2.43e-06	-3.57e-06
	(4.40e-06)	(5.31e-06)
Open	0.251	0.226
	(0.198)	(0.153)
Opensq	-0.0254***	-0.0271***
	(0.00909)	(0.00833)
Fuel	-1.020***	-0.974**
	(0.376)	(0.359)
Enrol	-0.0822*	-0.0842
	(0.0492)	(0.0496)
Constant	15.97***	16.29***
	(5.274)	(4.998)
Observations	152	152
R-squared		0.160
Number of country	29	29

Table A3: Comparison of RE and FE Regression Results for 'Developed countries'
Robust standard errors in parentheses
**** p<0.01, ** p<0.05, * p<0.1*