Environmental Quality and Economic Growth: A Panel Analysis of the "U" in Kuznets

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Abstract

The primary motivation behind this study was to search for evidence of the link between environmental quality and economic growth so as to answer the relevant question of whether economic growth alone could serve as a long-run solution to environmental damage as implied by EKC hypothesis. Here we analyze the relationship using a panel of 47 countries over the period 1970 -2008. Using Random-effect estimation and two-stage least square, our results leads to the following conclusions: relying on a quadratic model can easily mislead researchers to ratify the existence of EKC; the EKC hypothesis ceased to hold whenever an alternative functional form (cubic) is employed. At best, the relationship between economic growth and environmental quality is shown to be typified by an N-shaped curve. The paper maintained that simply waiting for an automatic arrival of a delinking point for environmental damage given long-run growth will not be a feasible solution to environmental quality. A number of feasible policy menu and critical questions to guide selection of the best instrument capable of bringing about a downturn in environmental damage have been suggested in the paper.

Key-words: Economic growth, EKC hypothesis, Environmental quality, delinking

JEL Classification: C23, C33, Q5.

1. Introduction

The issue of environmental degradation constitutes one of the greatest concerns for policymakers especially in the less developed economies. Among other sources, the pollution problems associated with energy production and consumption has continued to attract global attention. Yet energy use is vital to economic growth of any nation. This apparent goal conflict poses serious policy dilemma: reducing environmental degradation or pollution may require reductions in the rate of economic growth. The solution to this problem seemed to have been found in the 1990s when some scholars (e.g. Grossman and Krueger, 1991; Shafik and Bandypadhyay, 1992; Panayotou, 1993) pointed out the existence of an inverted U-shaped relationship between environmental degradation and economic growth; a relationship which was latter coined by Panayotou (1993) as Environmental Kuznets Curve (EKC) because of its resemblance to Simon Kuznet's income distribution hypothesis. The EKC simply hypothesizes that pollution will first increase with the level of GDP per capita, reach a maximum and then decrease at higher levels of income. The policy implications of such findings are clear: economic growth is compatible with environmental improvements in the long-run as countries could eventually "grow themselves" out of their environmental problems (Akpan and Chuku, 2011). Stated differently, if EKC hypothesis holds, then policies that promote economic growth can be pursued with little or no regard for the corresponding consequences on the environment. In fact, in one of the earliest studies, Berkerman (1992) strongly submits that:

> *"…there is clear evidence that, although economic growth usually leads to environmental deterioration in the early stages of the process, in the end the best – and probably the only – way to attain a decent environment in most countries is to become rich"*

At the theoretical level, several intuitions have been put forward to justify the existence of an inverted U-shaped path for environmental damage in the long term. Usually, these arguments relates to (i) the expected structural changes in the composition of economic output as a nation develops, (ii) changing technology and input mix (iii)increased environmental awareness and willingness to pay for cleaner environment at higher income levels and (iv) development of stronger institutions and capacity to implement environmental laws at higher income level.

More succinctly, channels through which an inverted U-shaped path is expected to emerge for environmental quality and at higher levels of income per capita could be grouped into three: (i) the scale effect (ii) composition effect (iii) and the technique effect (Grossman and Krueger, 1991; Stern, 2004; Akpan and Chuku, 2011). It is argued that economic growth will initially aggravates environmental quality through the *scale effect* as production is increased at a given factor-input ratio, out-put mix and technology. However, as the structure of the economy changes (i.e. the output mix changes) from agriculture to more resource intensive manufacturing industries, pollution increases with growth. At the later stage of development, environmental quality is expected to improve as the structure of the economy moves towards service and light manufacturing industries which are supposed to generate lower emissions per unit of output. This is the *composition effect.* The *technique effect* captures the expected improvements in productivity and adaptation of cleaner technologies leading to improvement in environmental quality. A variant of the technique effect is the *input-mix effect* which simply underscores the possibility of substituting environmentally harmful inputs by less harmful inputs. An example includes substituting natural gas for coal.

Based on these arguments, one could have expected pollution to increase in less developed countries and reduce in more developed nations. But there is nothing automatic that these expectations would hold. On the one hand, a richer country is likely to use more resources, demand more energy and produce more waste and pollution than poor countries. On the other hand and in contrast to poor countries, richer countries may have higher capacity to invest in renewable energy infrastructure, developed and install state-of-the-art pollution control equipment and implement effective environmental policies.

Clearly, it is important to understand the nature of the relationship between environmental degradation and economic growth before advocating the use of EKC as a policy guide in solving environmental problems. Indeed, if EKC is empirically verified as true, it will simply imply that environmental damage is an inescapable consequence of growth and therefore structurally determined. This being the case, any attempt to overcome such damage at the early stage of development, might be seen as a futile exercise. Thus, given scare economic resources, the extent to which policy makers ought to allocate available resources in designing and implementing policies for sound environmental management can be seen to depend on the extent to which the driving forces underlying the EKC are susceptible to such policies (Munasinghe, 1999).

Given the importance of the presumed EKC for economic growth and environmental sustainability, a large span of research on the existence of EKC have emerged but with mixed empirical support. For instance, apart from those which have confirmed the existence of EKC (e.g. Heil and Selden, 2001; Holtz-Eakin and Selden, 1995; Berkerman, 1992; Grossman and Krueger, 1991; Panayotou, 1993), there are a plethora of others who have found no such evidence (e.g. Akpan and Chuku, 2011; Friedl and Getzner, 2003; He and Richard, 2010; Caviglia-Harris, Chambers and Kahn, 2009).

More so, results of studies that have made claim for the existence of EKC have been disputed and questioned on several fronts. Some of such issues include that of omitted variable bias, simultaneity bias, and aggregation problem. Stern, *et al* (1996) has also criticized the tradition of including only high income countries in a given sample by some studies. Such inclusion ignores different trade patterns and the fact that high-income countries have higher emission reduction possibilities by outsourcing polluting industries to other countries through trade specialization or developing strong institutions to implement stringent environmental laws. On another front, the empirical robustness of the EKC relation remains an open issue (Grossman and Krueger, 1995). Most often, the reduced form equations in which environmental outcomes are related to economic growth of the individual countries and to other economic measures often ignore the feedback from environmental damage to economic activities. If the environmental damage is sufficiently strong, it is likely that economic activities will be negatively affected and therefore, ignoring this possibility may not provide a correct picture.

This paper makes robust attempt in addressing the above research gaps. First, we analyze the relationship using a panel of 47 countries over the period 1970 -2008. For comparative purpose, apart from pooled results where all the countries are lumped together, we further divide the sample into high income and low income countries. Second, we make an attempt to resolve the simultaneity problem by using the two-staged least square (2SLS) estimation technique to correct for the feedback effect. Third, we test for the validity and consistency of EKC hypothesis using two functional forms (quadratic and cubic) and controlled for other key variables that are germane in the environmental degradation – economic growth connection (e.g. energy prices, trade and population growth). Based on the empirical evidence, we draw up key policy implications for environmentally sustainable growth.

2. Methodology

2.1 Model and Data

Traditionally, the analysis of the relationship between some measure of environmental quality (*EQ*) and real income per capita (*RGDPpc*) usually takes the following polynomial approximation in the literature:

$$EQ_{it} = \beta_1 RGDPpc_{it} + \beta_2 {RGDPpc_{it}}^2 + \alpha_i + \eta_i + \varepsilon_{it}\ ;\ \varepsilon_{it} \sim i.i.d.(0, \sigma^2) \qquad (1)$$

Where$\alpha_i$andη_i capture country-specific and period specific effects respectively, and ε_{it} is the stochastic error term assumed to be normally distributed. From the above specification and given the statistical significance of the income terms, the EKC hypothesis is confirmed to exist if $\beta_1 > 0$ and $\beta_2 < 0$ and the turning point income at which per capita income is at their maximum level is easily derived as:

$$(RGDPpc)_{max} = exp\left(\frac{-\beta_1}{2\beta_2}\right) \qquad (2)$$

However, there are at least two critical specification issues arising from Eq. (1). First, such specification does not allowed for testing other possible functional forms of the environmental quality-economic growth relations. Second, estimating Eq. (1) may lead to bias and inconsistent inferences and parameter estimation owing to omitted variable bias. Specifically, Eq. (1) would be guilty of specification bias if indeed the true relation between the two variables is cubic rather than quadratic. To this end, we let the general model to take the following two forms:

$$EQ_{it} = \beta_1 RGDPpc_{it} + \beta_2 {RGDPpc_{it}}^2 + \beta_3 FFEC_{it} + \beta_3 \left(\frac{X}{GDP}\right)_{it} + \beta_4 \left(\frac{M}{GDP}\right)_{it} + \beta_5 POPg_{it} + \beta_6 EP_t + \eta_i + \varepsilon_{it} \qquad (3)$$

$$EQ_{it} = \beta_1 RGDPpc_{it} + \beta_2 {RGDPpc_{it}}^2 + \beta_3 {RGDPpc_{it}}^3 + \beta_4 FFEC_{it} + \beta_5 \left(\frac{X}{GDP}\right)_{it} + \beta_6 \left(\frac{M}{GDP}\right)_{it} + \beta_7 POPg_{it} + \beta_8 EP_t + \eta_i + \varepsilon_{it} \qquad (4)$$

Where *FFEC* is fossil fuel energy consumption, *X/GDP* and *M/GDP* respectively represent the ratio of exports of goods and services to domestic production and the ratio of imports of goods and services to domestic output, as used in Agras and Chapman (1999). *POPg* stands for population growth while *EP* is energy price[1]. We use per capita CO_2 emissions as a proxy for environmental quality (*EQ)*.

Given their statistical significance, the relationship between income per capita and environmental quality can be assessed through the signs of the associated beta (β_i) coefficients. For Eq. (3), EKC is confirmed if $\beta_1 > 0$ and $\beta_2 < 0$, but if $\beta_1 > 0$ and $\beta_2 = 0$, then a monotonically increasing relationship would be depicted. In the case of Eq. (4), EKC would equally be indicated provided $\beta_1 > 0$, $\beta_2 < 0$ and $\beta_3 = 0$. If this holds, then Eq. (2) reduces to augmenting Eq. (1) with only the control variables. There are other possibilities: $\beta_1 > 0$, $\beta_2 < 0$ and $\beta_3 > 0$ will reveals a cubic polynomial, representing an N-shaped relationship; $\beta_1 > 0$, and $\beta_2 = \beta_3 = 0$ will imply a monotonically increasing relationship;$\beta_1 < 0$, and $\beta_2 = \beta_3 = 0$ will indicate a monotonically decreasing relationship.

There are clear justifications for the inclusion of control variables in the models. For instance, fossil fuel energy consumption (*FFEC*) remains the chief culprit for global carbon dioxide (CO_2) emissions, accounting for about 80% of total greenhouse emissions (Akpan & Akpan, 2012). A priori therefore, this variable is expected to be positive in its coefficient. The inclusion of the trade variables (*X/GDP* and *M/*GDP) allow us to test for the effect of trade on the environment. Theoretically, following *the pollution heaven hypothesis,* it is argued that pollution-intensive or “dirty” industries would be “displaced” to less developed countries following the enforcement of strict environmental control laws in the more developed countries (Akpan & Chuku, 2011). Thus while we expect these variables to have negative relationship with environmental quality in high income countries, we expect the variables to have direct relationship with pollution in the case of low income countries.

The possible effect of population on environmental quality is well documented in the literature. Higher population increases the demand for materials, energy and natural resources which in turn generates some negative environmental externalities. Thus, the expectation is that

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[1] The energy price variable used in the study is the real world oil price (in US$/b). Since we used the same series across all countries in the panel, including the country effects would create a near singular matrix. A similar approach was adopted by Agras and Chapman (1999)

the pressure of higher population would contribute positively to environmental degradation. The effect of energy prices in environmental pollution or carbon emission is very revealing. A rise in energy prices may generates changes in the rate of energy use as well as changes in the structure of capital and therefore emissions. For instance, consumers may drive less and try to conserve energy in the home by turning down thermostats. In the long-term, consumers may equally prefer more fuel efficient cars and make investments in insulation for their homes. In turn, lower energy prices encourage more fossil fuel consumption which drives environmental pollution. Thus we expect a negative relationship between energy price (*EP*) and environmental damage.

The sources of our data and its construction are shown in Table AI (at the appendix). Further, Table A2 (at the appendix) displays the summary statistics of the variables. A close examination of these descriptive statistics reveals that for most of the variables, the normally assumption cannot be rejected. In Table A3 (still at the appendix), the correlation matrix of the variables are presented. Of interest to note is the high and positive correlation (76.2%) between environmental damage and income per capita as well as with fossil fuel consumption (67.0%). In addition and as expected, energy price relates negatively with environmental quality (although the strength of such association is shown to be weak). As a preliminary exercise, we fit a quadratic curve to a scatter plot of environmental damage and income per capita. This preliminary result (as shown in Fig. A1, at the appendix) did not present much convincing evidence for the existence of an inverted U-shaped curve.

2.2 Econometric Procedure

2.2.1 Panel Unit Root and Cointegration Tests

To ensure reliable results, we first examine the stationarity properties of our data set. In this wise, we consider five sets of panel unit root tests. These include Levin, *et al* (2002), Breitung (2002), and Im, *et al.* (2003) tests as well as the ADF Fisher Chi-square test (Dickey and Fuller, 1979) and Phillips-Perron (PP) Fisher Chi-square (Phillips and Perron, 1988). These constitute a mix of first and second generations panel unit root tests respectively designed to handle cross-sectionally independent panels and cross-sectional correlation of one form or the other. While the Levin, *et al* (2002) and Breitung (2002) tests assume a common unit root process as their null hypotheses, the Im, *et al.* (2003), Hadri (2000), the ADF Fisher Chi-square and Phillips-Perron (PP) Fisher Chi-square tests assume the presence of individual unit root processes as their null hypotheses (Akpan and Ekong, 2013).

Specifically, for a brief exposition, the Im, *et al.* (2003) panel unit root test allows for heterogeneous autoregressive coefficients. It averages the augmented Dickey-Fuller (ADF) unit root tests of the respective variables while allowing for different orders of serial correlation, $\varepsilon_{it} = \sum_{j=1}^{p_i} \varphi_{ij}\, \varepsilon_{it-j} + u_{it}$, in the following:

$$y_{it} = \rho_i y_{it-1} + \sum_{j=1}^{p_i} \varphi_{ij}\, \varepsilon_{it-j} + \delta_i X_{it} + u_{it} \qquad (5)$$

Where i = 1,…, *N* for each country in the panel; *t* = 1,…, *T* refers to the time period;X_{it} represents the fixed effects or individual time trend in the model; ρ_i are the autoregressive coefficients; p_i represents the number of lags in the ADF regression; and ε_{it} are the error terms. If $\rho_i < 1$, y_{it} is considered weakly trend stationary whereas if $\rho_i = 1$, then y_{it} contains unit root. The null hypothesis is that each of the series in the panel contains a unit root, while the alternative is that at least one of the individual series in the panel is stationary.

On the other hand, the ADF Fisher Chi-square test combines the p-values of the test statistic for a unit root in each residual cross-sectional unit. The test is non-parametric and has a chi-square distribution with 2N degrees of freedom, where the *N* stands for the number of cross sectional units or countries in the panel. Using the addictive property of the chi-squared variable, the following test statistic can be derived:

$$\lambda = -2 \sum_{i=1}^{N} log_e\, \pi_i \qquad (6)$$

Were π_i represents the *p*-value of the test statistic for unit *i.* One of the main advantages of this test over Im, *et al.* (2003) is that it does not depend on different lag lengths in the individual ADF regression.

The Breitung panel unit root test has the following form:

$$y_{it} = \alpha_{it} + \sum_{k=1}^{p+1} \beta_{ik}\, X_{i,t-k} + \varepsilon_t \qquad (7)$$

Based on equation (7), the Breitung test statistic tests the null hypothesis that the process is difference stationary: that is, $H_0: \sum_{k=1}^{p+1} \beta_{ik} - 1 = 0;$ while the alternative hypothesis assumes that the panel series is stationary: $H_1: \sum_{k=1}^{p+1} \beta_{ik} - 1 < 0$ for all *i.* A detailed review of the other test procedures can be found in Choi (2001).

After testing for panel unit root, next is to examine whether there is a long-run relationship between the variables. While a number of cointegration tests are documented in the time series literature, there are few cointegration tests developed for panel data. Here, we used the Johansen Fisher panel cointegration test as proposed by Maddala and Wu (1999). Two kinds of Johansen-type test statistics have been developed: the Fisher test from the trace test and the Fisher test from the maximum eigen-value test.

2.2.2 Panel Long-Run Estimates

If a long-run cointegrating relationship between the variables is established, our models can safely be estimated through appropriate techniques. For robust analysis, we apply several estimation methods to the models. First, we run the pooled OLS regression on the models. The determination of the appropriate panel regression specification to use was done using the traditional Hausman specification test. This test enables us to determine whether to use the random effect model (REM) or the fixed effect model (FEM). The null hypothesis underlying the Hausman test is that the REM and FEM do not differ substantially (see Gujarati and Porter, 2009). If the null hypothesis is rejected, the conclusion is that the REM is not appropriate because the random effects are probably correlated with one or more repressors. In such instance, the FEM will be preferred to the REM.

Next, giving the likely simultaneity bias between economic growth and environmental quality, we applied the two-stage least squares (2SLS) method of estimation[2] and compared the results with those of the OLS.

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[2] The main problem with the use of instrumental variable (IV) method lies with the fact that it is difficult to find instruments that are both good at predicting the variable of interest and yet are not determinants of the dependent variable.

3. Results and Discussion

Table 1 presents the unit root test results for each of the variables. Since more than one panel unit root tests were conducted on the series, a simple majority criterion was employed to draw conclusion on the order of integration. Overall, as shown in Table 1, apart from population growth, which was found to be stationary at levels, the result shows that all other variables are stationary only at their first difference. The *I*(0) status of population growth is not surprising, since the variable is already measured in growth form.

The Johansen Fisher panel cointegration test results are also reported in Table 2. The tests are performed with one lag. The results show clearly that there is strong evidence of co-integration relationship between the variables included in the panel. The presence of co-integration vectors indicate that the EKC model can be safely estimated with variables in levels in our sample.

Table 1: Panel Unit Root Test Results

Variable	LLC	Breitung	IPS	ADFFC	PPFC	*Decision*
CO2pc	2.86(0.99)	-0.60(0.27)	2.94(0.99)	92.86(0.52)	128.46(0.01)***	
Δ*CO2pc*	-16.82(0.00)***	-14.96(0.00)***	-23.05(0.00)***	684.13(0.00)***	1292.2(0.00)***	*I*(1)
RGDPpc	5.73(1.00)	3.12(0.99)	10.40(1.00)	35.71(1.00)	62.34(0.99)	
Δ*RGDPpc*	-1.62(0.05)**	-8.55(0.00)***	-15.09(0.00)***	429.04(0.00)***	579.3(0.00)***	*I*(1)
FFEC	-3.28(0.00)***	1.16(0.88)	0.62(0.73)	10.54(0.57)	148.36(0.00)***	
Δ*FFEC*	-16.24(0.00)***	-15.73(0.00)***	-20.83(0.00)***	601.70(0.00)***	1081.5(0.00)***	*I*(1)
X/GDP	3.45(0.99)	-2.41(0.01)***	0.74(0.77)	110.31(0.12)	141.59(0.00)***	
Δ*X/GDP*	-17.92(0.00)***	-16.56(0.00)***	-22.77(0.00)***	664.65(0.00)***	1047.1(0.00)***	*I*(1)
M/GDP	2.47(0.99)	-5.66(0.00)***	1.70(0.96)	85.99(0.71)	102.57(0.26)	
Δ*M/GDP*	-20.73(0.00)***	-19.86(0.00)***	-24.63(0.00)***	1.96(0.99)	1119.6(0.00)***	*I*(1)
POPg	-8.19(0.00)***	-4.36(0.00)***	-13.10(0.00)***	409.27(0.00)***	146.47(0.00)***	
Δ*POPg*	-17.33(0.00)***	-7.05(0.00)***	-30.35(0.00)***	880.88(0.00)***	525.30(0.00)***	*I*(0)
EP	3.24(0.99)	-13.32(0.00)***	-0.63(0.26)	53.34(0.99)	70.32(0.97)	
Δ*EP*	-14.97(0.00)***	-25.95(0.00)***	-16.31(0.00)***	896.67(0.00)***	896.36(0.00)***	*I*(1)

Notes*: LLC = Levin, Lin and Chu test; IPS =Im, Pesaran and Shin W-stat; ADFFC = Augmented Dickey Fuller Fisher Chi-square test; PPFC = Philips and Perron Fisher Chi-square test; *, **, and *** denotes significance at 10%, 5% and 1% respectively. Values in bracket are the P-values. All tests include individual intercept.*

Table 2: Johansen Fisher Panel Cointegration Test
Trend assumption: Linear deterministic trend

Hypothesized No. of CE(s)	Fisher Stat.* (from trace test)	Prob.	Fisher Stat.* (from max-eigen test)	Prob.
None	2308.0***	0.0000	764.1***	0.0000
At most 1	1352.0***	0.0000	983.5***	0.0000
At most 2	1118.0***	0.0000	548.9***	0.0000
At most 3	721.0***	0.0000	390.5***	0.0000
At most 4	446.3***	0.0000	266.6***	0.0000
At most 5	248.7***	0.0000	191.6***	0.0000
At most 6	120.3***	0.0000	94.47***	0.0018
At most 7	115.4***	0.0000	115.4***	0.0000

Note: ** Probabilities are computed using asymptotic Chi-square distribution, *** denotes significance at 1% level.*

Table 3 shows the estimated results of the relationship between environmental quality and economic growth. The optimal model selection was guided by the Hausman's test statistic. The null hypothesis underlying the Hausman Test is that the random effect model is consistent, in favour of the fixed effects model. Usually, a low P-values count against the null, while a higher one counts in support of the null. As can be gleaned from the bottom of Table 3, especially from columns (3) – (6), we cannot reject the null at the conventional 5% level. Thus, the random effect model was selected as the optimal model estimation.

Overall, a variety of interesting results emerged from Table 3. When the full sample is considered, our results in column (1) show that the relationship between environment and growth follows an inverted U-shape and therefore tends to confirm the EKC-hypothesis with a turning point at US$ 226596. However, when the cubic term of income per capita is added to the model, the EKC-hypothesis fails to hold (see column 2). Rather, the evidence shows that the relationship is described by an *N*-shaped curve, which exhibits the same pattern as the inverted U-curve initially, but become positive again after a certain income level. This indicates that de-linking environmental damage from income per capita is only a temporal phenomenon. Similar evidence have been confirmed in other studies (e.g. Galeotti and Lanza, 1999; Sengupta, 1996; Martinez-Zarzoso and Bengochea-Morancho, 2004). Given a possible explanation for an *N*-shaped relation between environmental damage and income, de Bruyn, *et al.* (1998) argued that once technological efficiency improvements in resource use or abatement opportunities have been exhausted, or have become too expensive, further income growth will result in net environmental damage.

Table 3: Environmental Quality and Economic Growth: Random Effects (GLS) Estimation

	Random Effects (GLS) Estimation Dependent Variable: *Carbon emissions per capita (CO_2pc)*					
Variable	Full Sample		High Income Countries		Low Income Countries	
	Quadratic (1)	*Cubic (2)*	*Quadratic (3)*	*Cubic (4)*	*Quadratic (5)*	*Cubic (6)*
Constant	-0.0861 (-0.20)	-1.1059** (-2.576)	-4.004*** (-4.174)	-5.334*** (-5.795)	0.050 (0.947)	-0.039 (-0.648)
RGDPpc	0.0005*** (23.94)	0.0012*** (27.46)	0.0006*** (19.95)	0.0013*** (21.42)	0.0004*** (5.837)	0.0007*** (5.241)
RGDPpc^2	-9.4e-09*** (-20.16)	-4.9e-08*** (-21.47)	9.9e-09*** (-16.26)	-4.9e-08*** (-16.00)	-4.7e-08* (-1.789)	-4.2e-07*** (-3.219)
RGDPpc^3	-	6.4e-013*** (17.72)	-	6.1e-013*** (12.96)	-	9.9e-011*** (2.914)
FFEC	0.0545*** (16.91)	0.0421*** (13.73)	0.1069*** (15.89)	0.089*** (14.01)	0.007*** (15.51)	0.0069*** (15.05)
X/GDP	3.6226 (1.06)	1.4e-011*** (4.25)	6.6e-012 (1.506)	1.6e-011*** (3.916)	0.0005 (0.5537)	0.0005 (0.582)
M/GDP	-0.0255*** (-9.54)	-0.0269** (-10.87)	-0.040*** (-8.015)	-0.045*** (-9.642)	0.0018** (2.215)	0.0018** (2.154)
POPg	-0.0948** (-2.28)	-0.0437 (-1.14)	-0.219*** (-3.338)	-0.1322** (-2.169)	-0.0352*** (-3.253)	-0.032*** (-2.937)
EP	0.0005 (0.09)	-0.0043 (-0.87)	0.219*** (-3.338)	-0.002 (-0.243)	0.0006 (0.441)	0.0006 (0.480)
No. of Obs.	1801	1801	966	966	798	798
No. of Contr.	47	47	25	25	22	22
Within Variance	0.840228	0.712059	1.35006	1.1412	0.0205	0.0207
Between Variance	5.7415	5.83328	10.7939	10.4755	0.0021	0.0217
Hausman Test	17.084 (0.0169)	17.148 (0.0286)	9.4629 (0.2211)	14.2351 (0.0758)	9.3815 (0.2264)	9.053 (0.3378)
Breusch-Pagan test	23455.6 (0.0000)	24036.7 (0.0000)	12059.1 (0.0000)	11557.3 (0.0000)	2784.33 (0.0000)	2851.23 (0.0000)
EKC	Yes	No	No	No	Yes	No
Turning Point (US$)	26595.74				4255.32	

Notes: *estimation is based on Robust (HAC) standard errors; *, **, and *** denotes significance at 10%, 5% and 1% respectively. Values in bracket for the estimated coefficient are the t-statistics while those for the F-stats, Hausman and Breusch-Pagan tests are the P-values*

When we divide the samples into low and high income countries, an inverted U-shaped relation was only confirmed for low income countries when the cubic income term was restricted from the model (see column 5). With similar restriction, high income countries exhibit an increasing linear trend. These results conflict sharply with theoretical prescriptions and called for a re-thinking of the EKC hypothesis. More so, the inclusion of the cubed-income term shows clearly that EKC is invalid for both high and low income countries. In both cases, the results returned an *N*-shaped curve rather than an inverted U-shape.

Going further, the results indicate that fossil fuel consumption is a major culprit in environmental damage. Expectedly, the impact is significant and much higher in high income countries than in low income countries. Surprisingly, population growth (though significant) does not conform to the priori expectations. In the same vain, energy price appears to have no significant impact on pollution which is inconsistent with theoretical expectations. Perhaps the unexpected result is because of the distortions in energy prices caused by widespread subsidies across countries. Given the wide variation in domestic energy prices, the use of one single measure for the variable may not have been appropriate.

The impact of the trade variables reveals that for the full sample, export is positively related with environmental damage while import is having the opposite effect. This result is similar in the case of high income countries. However, for low income countries, the result shows that both variables are positively related with environmental damage. Clearly, the results demonstrate that while high income countries are able to curtail environmental damage through imports, the opposite is the case in low income countries. By extension, it tends to confirm the pollution haven hypothesis. All else equal, by importing goods to substitute some manufactured goods that were earlier produced domestically by displaced pollution intensive industries, high income countries have not only reduce their energy requirements but environmental damage. A further explanation could be that high income countries are able to introduce new production process that replaces domestically produced inputs with imported ones.

Table 4 contains the results based on two-stage least square estimation that controls for the feedback effect between income and environmental damage. It was difficult to find instruments that are both good at predicting the variable of interest and yet are not determinants of the dependent variable. However, to proceed, we used lagged values of the explanatory variables as instruments and test their validity using Sargan over-identification test. The null hypothesis here is that all the instruments are valid. A very low *P*-value counts against the null in favour of the alternative that they are invalid. Also, we used the Hausman’s test to judge if the OLS estimates are consistent or not. If they are consistent, it would imply that the estimation by

IV-method is not necessarily required. Again, a low *P*-value would counts against the null that OLS estimates are consistent while a high value will support the alternative hypothesis that they are not. Overall, the results of these diagnostic tests, as shown at the bottom of Table 4, indicate that the instruments used were valid and that the OLS estimates were inconsistent, except when the full sample was considered. Because of this, we choose to discuss only the results based on the sub-samples.

Table 4: Environmental Quality and Economic Growth: Two-Stage Least Square (2SLS) Estimation

	2SLS Estimation Dependent Variable: *Carbon emissions per capita (CO_2pc)*					
Variable	Full Sample		High Income Countries		Low Income Countries	
	Quadratic *(1)*	*Cubic* *(2)*	*Quadratic* *(3)*	*Cubic* *(4)*	*Quadratic* *(5)*	*Cubic* *(6)*
Constant	-7.688** (-2.32)	7.790** (2.08)	-4.188*** (0.35)	-4.298*** (-5.615)	0.092** (2.137)	0.0013 (0.02)
RGDPpc	0.001*** (6.93)	0.002** (2.15)	0.0006*** (15.32)	0.0007* (1.698)	0.0004*** (2.883)	0.0008*** (3.009)
RGDPpc^2	-3.9e-08*** (-6.00)	-3.3e-08 (-0.46)	-8.8e-09*** (-8.65)	-1.8e-08 (-0.642)	-8.0e-08 (-1.415)	-4.6e-07** (-2.272)
RGDPpc^3	-	-6.9e-013 (-0.53)	-	1.5e-013 (0.322)	-	1.0e-010** (2.127)
FFEC	0.083*** (3.44)	-0.032 (-1.28)	0.087*** (12.95)	0.084*** (6.89)	0.009*** (16.23)	0.009*** (14.59)
X/GDP	-4.1e-011*** (-4.32)	-6.5e-011*** (-2.59)	-2.5e-011*** (-3.51)	-2.4e-011*** (-2.95)	-0.001 (-0.183)	-0.003 (-0.566)
M/GDP	-0.027*** (-5.50)	-0.014 (-1.51)	-0.013*** (-3.45)	-0.013*** (-3.45)	0.001 (0.271)	0.0029 (0.646)
POPg	1.6079*** (9.26)	1.539*** (5.43)	0.951*** (8.19)	0.955*** (8.142)	-0.036*** (3.067)	-0.032*** (-2.630)
EP	0.0037 (0.01)	-1.395*** (-2.84)	-0.039 (-1.23)	-0.047 (-1.259)	-0.002 (-0.789)	-0.0025 (-0.973)
No. of Obs.	1733	1708	841	841	790	790
No. of Contr.	47	47	25	25	22	22
Adj. R-sqd.	0.645	0.292	0.454	0.448	0.641	0.628
F-test	447.166 (0.0000)	88.106 (0.0000)	101.407 (0.0000)	87.849 (0.0000)	203.866 (0.0000)	172.42 (0.0000)
Hausman Test	42798 (0.0000)	308.697 (0.0000)	6.929 (0.4363)	7.215 (0.5136)	7.853 (0.3457)	8.875 (0.3530)
Sargent test	0.7385 (0.3902)	7.1188 (0.1297)	18.4986 (0.9129)	18.2296 (0.8963)	6.8399 (0.2328)	4.823 (0.4379)
EKC	Yes	No	Yes	No	No	No
Turning Point	12820.51		34090.91			

Notes: *estimation is based on Robust (HAC) standard errors; *, **, and *** denotes significance at 10%, 5% and 1% respectively. Values in bracket for the estimated coefficient are the t-statistics while those for the F-stats, Hausman and Sargent tests are the P-values*

Generally, in all the estimations, the results show that the presumed EKC ceased to hold whenever the cubic income term is included in the model. Specifically, we found that without the cubic term, EKC can be confirmed for high income countries with a turning point at about US$34091. This closely mirrors what has been found by Cole (2004) who reports a turning point of US$34880 after controlling for other variables. However, looking at the R-squared, the relatively low fit of the model (45.4%) portrays that the evidence is (at best) weak. In the case of the cubic estimation, the EKC typed relationship tends to fade away. These results demonstrate that relying on a cubic model to validate EKC can generates misleading results and conclusion.

Moving to the low income sample, we found that the entire evidence does not lend strong supports to the EKC typed relationship. The squared income term in the quadratic model was insignificant (even though it is negative). The inclusion of the cubic income term confirms the existence of an *N*-shaped curve which agrees with the Random effect results in Table 3. In effect, these results tend to demonstrate that decoupling economic growth from environmental damage is only temporal. It appears that unless cogent measures are taken to protect the environment, unfettered growth objective would not automatically resolve environmental damage.

Interestingly, most of the control variables conform to their theoretical expectations. For instance, in almost all the estimations, the impact of fossil fuel consumption on environmental damage remains positive and significant. As expected, the impact is relatively higher in the high income sample than in the low income sample. Also, energy prices bear a negative relationship with environmental damage (though by our results, such impacts are largely insignificant). This result supports the fact that reforming harmful energy subsidies can contribute (to some extent) in solving environmental damage. The impact of trade (especially imports) and population growth shows mixed evidence for high and low income countries. Specifically, for the high income sample, higher population growth leads significantly to higher CO_2 emissions (and therefore environmental damage) while the reverse is the case in low income countries. For one, the result could be attributed to energy poverty problem that characterized low income countries. Energy poverty is a lack of access to modern energy services. Globally over 1.3 billion people are without access to electricity (IAE, 2013). More than 95% of these people are either in sub-Saharan African or developing Asia and 84% are in rural areas. Low access translates to low consumption and therefore low emissions.

4. Conclusion and Policy Options

The primary motivation behind empirical studies on EKC hypothesis is to search for evidence of the link between environmental degradation and economic growth so as to answer the relevant question of whether economic growth alone could serve as a long-run solution to environmental damage. Similar motivation drives the present study. Here we analyze the relationship using a panel of 47 countries over the period 1970 -2008. For comparative purpose, apart from pooled results where all the countries are lumped together, we further divide the sample into high and low income countries. To resolve the likely simultaneity problem between growth and environment, we used the two-staged least square (2SLS) estimation technique to correct for the feedback effect. We tested for the validity and consistency of EKC hypothesis using two functional forms (quadratic and cubic) and controlled for other key variables that could impact on environmental quality.

Overall, our findings do not lend strong support to the presumed EKC-typed relationship. Generally, our result shows clearly that relying on a quadratic model is capable of misleading researchers to readily ratify the existence of EKC. Further, findings show that EKC hypothesis ceased to hold whenever an alternative functional form (cubic) is employed. At best the relationship between economic growth and environmental quality is shown to be typified by an *N*-shaped curve - indicating that any delinking of economic growth from environmental quality is temporal. An important policy issue arising from here is that as nations (especially developing countries) continue to demand more energy to drive their growth process, adequate concern should be giving to environmental impacts of such process. The evidence in this paper suggests that it would be misleading to follow the policy of polluting first and cleaning later as espoused by proponents of EKC. It does not make much sense to “do nothing” and wait for the magic-wand of economic growth to cure environmental problems. Proactive policies and measures are required to mitigate the problem.

There are a number of policy instruments for controlling environmental quality. Some of these include fiscal instruments (e.g. taxes), charge systems (fees), financial instruments (e.g. subsidies), etc. Alternatively, the state can also use its coercive power to regulate polluter behavior and limits emissions below a prescribed policy target. A good example here is setting *industrial emission standards* where the maximum limits of pollution from industrial activities are specified (for each type of activity and pollutant) as well as *fuel quality standards* where the minimum quality of fuels that could be used in production or energy generation purposes may be specified. In addition, demand-side management options to reduce excessive energy demand may also be considered (e.g. reforming harmful energy subsidies especially on fossil fuel)

However, the choice of appropriate policy instrument should be considered with respect to the specific characteristics and conditions of the country as well as the type of environmental pollutant. In dealing with these issues, policy makers may be guided by the following set of questions (as in Panayotou, 1994; Bhattacharyya, 2011):

- *Environmental effectiveness:* Will the chosen instrument achieve the environmental objective within specified time span and what degree of certainty can be expected?
- *Cost effectiveness:* Will the instrument achieve the environmental objective at the minimum possible cost[3] to the society?
- *Flexibility:* Is the instrument flexible enough to changes in technology, the resource scarcity and market conditions?
- *Dynamic efficiency:* Does the instrument provide incentive to technological innovation? Does it promote environmentally sound infrastructure?
- *Equity:* Will the costs and benefits of the instruments be equitably distributed?[4]
- *Ease of introduction:* Is the instrument consistent with the country's legal framework? Does it require new legislation? If so, is it feasible? Does the regulatory body have the requisite administrative capacity to administer the new instrument?
- *Ease of monitoring and enforcement:* How difficult or costly will monitoring and enforcement of the instrument be?
- *Predictability:* The relevant question here is does the instrument combine predictability and flexibility? Effectiveness of a given policy instrument can be assessed if it remains in force in the long-run and thus imposes predictable costs on polluters.
- *Acceptability:* This issue is very important in opting for a particular policy instrument. The question that needs to be asked here is whether the selected instrument is understandable by the public, acceptable to the industry and politically saleable.

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[3] In considering costs to the society, a much wider view should be taken to incorporate those related to compliance, monitoring and enforcement (i.e. administrative cost), as well as any other costs induced by distortions.

[4] This consideration is important because the poor will usually have much lower willingness to pay for environmental benefits. But being more vulnerable, they may gain more from environmental protection

Summing up, evolving a practical solution to the problem of environmental quality requires a critical assessment of certain issues that relates, amongst others, to its practicability and effectiveness. While no single instrument may satisfy all the conditions stated above, a combination of different approaches, specific to the type of pollutant and the circumstances of the country can be used to ensure that the overall objective of improved environmental quality is obtained, irrespective of the level of economic growth.

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Appendix

Table A1: Data Construction and Sources

Variable	Definition/Measurement	Source
CO2pc	Carbon-dioxide emissions (measured in metric tons per capita) 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.	WDI/GDI database, 2012
RGDPpc	Real GDP per capita (measured in constant 2000 US$)	WDI/GDI database, 2012
FFEC	Fossil fuel consumption (measured as a % of total fuel consumption)comprises consumption of coal, oil, petroleum, and natural gas products.	WDI/GDI database, 2012
EP	Real World Oil Price based on OPEC Reference Basket (i.e. Nominal Oil Price Adjusted for Exchange Rates and Inflation), using 1973 as the base year. The variable is measured in US dollars per barrel (US$/b)	OPEC database, 2012
POPg	Annual population growth rate	WDI/GDI database, 2012
X/GDP	Exports of goods and services represent the value of all goods and other market services provided to the rest of the world. The variable is expressed in percentage of GDP	WDI/GDI database, 2012
M/GDP	Imports of goods and services represent the value of all goods and other market services received from the rest of the world. The variable is measured as a percentage of GDP	WDI/GDI database, 2012

Note: WDI/GDI = World Development Indicators/Global Development Finance

Table A2: Summary Statistics of the Variables

	CO2pc	RGDPpc	FFEC	X/GDP	M/GDP	POPg	EP
Mean	4.9339	8418.4	60.248	1.2e+009	33.759	1.7075	7.9088
Median	2.5969	2498.7	63.072	27.352	29.640	1.7471	6.6430
Minimum	0.0294	82.672	2.7067	2.6097	2.7045	-1.6096	2.3960
Maximum	22.511	41904	100.25	1.7e+011	219.07	6.3610	16.125
Std. Dev.	5.2314	10108	30.403	1.1e+010	24.193	1.1754	4.1214
Skewness	1.0027	1.1336	-0.24919	10.793	3.9305	0.2987	0.6856
Kurtosis	3.24830	3.28039	1.6000	133.59	23.656	2.9128	2.2707
C.V.	1.0603	1.2007	0.50463	8.5398	0.7167	0.6884	0.5211
Obs.	1831	1828	1806	1828	1828	1833	1833

Table A3: Correlation Matrix of the Variables

	CO2pc	RGDPpc	FFEC	EP	POPg	X/GDP	M/GDP
CO2pc	1.0000						
RGDPpc	0.7616	1.0000					
FFEC	0.6704	0.4405	1.0000				
EP	-0.0173	0.0069	-0.0070	1.0000			
POPg	-0.4239	-0.5206	-0.4479	0.0217	1.0000		
X/GDP	0.0674	0.1593	0.0683	0.0151	-0.1320	1.0000	
M/GDP	0.0941	0.0551	0.1498	0.0834	0.0414	0.0420	1.0000

Table A4: **Countries included in the sample**

High Income Countries	**Low Income Countries**
Norway, Korea Republic, Japan, Australia, Portuguese Republic, Italy, Austria, Saudi Arabia, Canada, Hungary, Iceland, Portuguese Republic, Chile, China, Cyprus, Denmark, Finland, French Republic, Hellenic Republic, Israel, Singapore, South Africa, Sweden, United Kingdom and United States	Philippians, Nigeria, Bangladesh, Benin, Bolivia, Cameroon, Democratic Republic of the Congo, Republic of Congo, Côte d'Ivoire, El Salvador, Ghana, Honduras, India, Indonesia, Kenya, Morocco, Pakistan, Paraguay, Senegal, Sri Lanka, Sudan and Togo

- Classification based on WDI-GDF (2012)

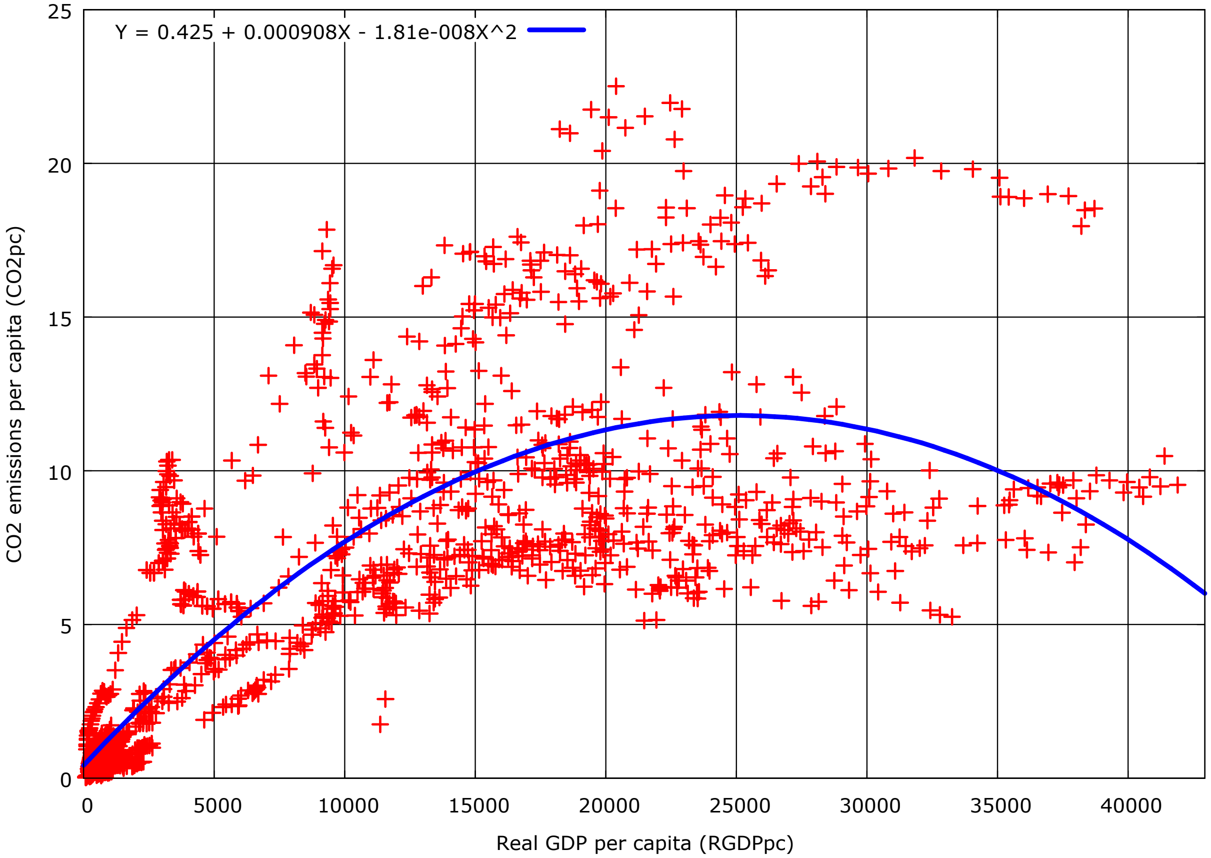

Fig. AI: CO2 emissions per capita (CO2pc) versus Real GDP per capita (RGDPpc) (with quadratic fit)