An Empirical Re-examination of the Output-Pollution Linkage in Nigeria

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Abstract

This study investigates the validity of the Environmental Kuznets Curve (EKC) hypothesis for carbon emissions (CO_2) in Nigeria for the period 1990 to 2016. The study revisited the Shen (2006) argument of increased explanatory variables in the income-pollution relation. Two additional variables were included: energy demand and the human development index. The study asked whether there is a feedback effect among the pollutant (CO_2), income and human welfare by setting up a simultaneous model of three equations for the pollutant, income and human welfare. It also sought to determine whether there is a significant difference between the result of the simultaneous model and the traditional polynomial EKC model. Despite increasing the variables, the result for the pollutant, CO_2, supports the EKC hypothesis in Nigeria and rejects the Shen (2006) argument. There was no significant difference between the single equation and the simultaneous model. Based on this result, the study recommends that provisions be made to factor in the simultaneity or endogeneity problem when conducting any study on EKC and policy makers should focus on policies that will enhance inclusive growth in order to have an improved environment.

Keywords: Environmental Kuznets curve, carbon dioxide (CO_2), simultaneous equation model, human development index

Introduction

In order to achieve higher economic growth and by extension higher economic development, countries of the world, Nigeria inclusive, are constantly striving to increase both output capacity and levels. Improvements in both capacity and levels of output come with their costs, in the form of air and water pollution, resource depletion and greenhouse gas emission (Alege and Ogundipe, 2013). These costs have raised great concerns among development economists on how to achieve optimum economic growth and development without obstructing the benefit of future generations and even the environment from which these resources are taken (Ajide and Oyinlola, 2010).

One extreme of the arguments is that an increased extraction of natural resources will lead to accumulation of waste and pollutants, which will overwhelm the environment and result in environmental degradation and a decline in human welfare though income may be rising (Omisakin, 2009). It is therefore necessary to deal with the question of sustainable green growth. However, on the other extreme is the argument that economic growth is the path that leads to environmental improvement. That is, with higher income comes increased willingness to pay for a clean environment, demand for goods and services that are less toxic to human health, and adoption of environmental protection measures (Ajide and Oyinlola, 2010). This theory has been extensively explained by Grossman and Krueger (1991) in the Environmental Kuznets Curve (EKC) hypothesis.

The Environmental Kuznets Curve shows the relationship between environmental pollution and economic growth. The inverted-U shape of the curve means that at the initial stage of production, industrialization or growth, the rate of environmental depletion or pollution would grow rapidly but as output and income rise to a certain threshold and beyond, environmental quality will be enhanced by higher income.

Several studies have been conducted on environmental pollution and output to establish the existence and applicability of the EKC hypothesis. While most of the early studies only tested for the relationship between pollution and income, Shen (2006) posits that, with a wider range of explanatory variables in the model, other than income, the EKC hypothesis fails. To address this problem, a number of studies have subsequently been conducted for Nigeria and Africa with no consensus in the findings (Orubu, Omotor and Awopegba, 2009; Sayed and Sek, 2013; Ajide and Oyinlola, 2010; Aduebe, 2013; Omisakin, 2009; Alege and Ogundipe, 2013; Ojewumi 2016). The reasons for the lack of consensus in the findings of these studies are not clear. This study, therefore revisits the Shen (2006) argument by including other welfare variables such as health, education, and population growth which, so far, has not been addressed by previous studies in Nigeria.

Whereas there is emerging theoretical evidence that pollution is both an input and by-product of output, studies on Nigeria have mainly based their estimation on a single polynomial equation which does not reflect the feedback from pollution to health, education and national growth. This therefore raises some fundamental questions. Does the EKC hypothesis hold when additional exogenous variables are added to the traditional EKC model? Is there a feedback effect between carbon dioxide ($CO_{2)}$, output, and the human development indicator (HDI)? Are there differences between the results of a single equation and simultaneous equation estimators?

It is in the light of these unanswered questions that this paper seeks to empirically verify the relationship between environmental degradation and economic growth in Nigeria. In essence, with the inclusion of additional variables such as energy consumption, population and HDI in the model, this study provides an explanation for the reaction of the EKC theory when there is a feedback from pollution to HDI and income in Nigeria. Furthermore, it examines the differences between the results of a single equation and simultaneous equation estimators.

The study focuses on one major pollutant, carbon dioxide (CO_2) and spans the period 1990 to 2016, with data from the World Development Indicators (WDI) and the Human Development Report (HDR). The study is divided into 4 sections. The first section provides an introduction to EKC. The next section reviews the literature and the research methodology while the following sections present the empirical findings and the conclusion and recommendations.

Literature Review

Since the study is limited to a specific pollutant (CO_2), this review focuses its attention on recent studies on the pollutant (CO_2), the methodology used and the other independent variables used specifically in Nigeria and in Africa as a whole.

Orubu and Awopegba (2009) made use of the Pearson correlation coefficient between the periods 1975 to 2002 using five main pollutants. Their result conforms to the EKC inverted–U relationship between CO_2 per capita and per capita income. Moreover, study conducted by Ojewumi (2016) for sub-Saharan Africa countries between the period 1980 to 2012 with the use of fixed and random panel analysis discovers no EKC relationship between per capita CO_2 and per capita income.

Oshin (2013) examined the EKC for 15 West African countries with the use of a static panel analysis between the periods 1980 to 2012. In the same vein, Omojolaibi (2010) studied the relationship between carbon emission (CO_2) and economic growth in Nigeria, Ghana and Sierra Leone. The two studies found no existence of the EKC theory for CO_2 in these West African countries. On the other hand, Oshin (2013) conducted an EKC research on 16 West African countries with the use of a panel analysis for the period 1980 to 2012 with the inclusion of some other independent variables such as: literacy rate, trade openness and population density. His findings conform to the inverted U shape of the EKC hypothesis for CO_2.

In Nigeria, Aduebe (2013) introduces additional variables to the traditional polynomial equation of EKC such as: industrial share to GDP and energy consumption and discovered an EKC relationship between CO_2 and income. Omishakin (2009) got a U-shaped relationship between CO_2 and income for the period 1980 to 2012. Likewise, Usenobong and Agbai (2011) utilised the Auto Regressive Distributed Lag model to test the EKC hypothesis for Nigeria between 1960 and 2008 with additional independent variables such as: trade openness and shares of manufacturing in GDP. Their findings reveal no EKC relationship between CO_2 and per capita income.

Methodology

Model specification

To achieve the earlier stated objectives, the study employs a simultaneous estimation model (SEM), which enables the formulation of a feedback procedure through a three-equation simultaneous model. This model allows the measurement of the direct and indirect impacts of each endogenous variable in relation to pollution. The direct impact is captured in equation

(1) of the model which is the traditional EKC model of pollution equation, while the indirect impacts are represented in equations (2) and (3).

$$Co_t = \propto_0 + \propto_1 Y_t + \propto_2 (Y_t)^2 + \propto_3 PD_t + \propto_4 ED_t + \propto_5 HDI_t + T + \epsilon_t \quad (1)$$

$$Y_t = K_t^{\beta_1} L_t^{\beta_2} Co_t^{\beta_3} HDI_t^{\beta_4} \quad (2)$$

where: $\beta_1 + \beta_2 + \beta_3 + \beta_4 = 1$

$$HDI_t = \rho_0 + \rho_1 Y_t + \rho_2 Co_t + \rho_3 EL_t + \rho_4 LE_t + T + v_t \quad (3)$$

where:

Y	= per capita income
PD	= population density
ED	= energy demand
HDI	= human development index
K	= physical capital
L	= labour
CO_2	= carbon dioxide
EL	= education level
LE	= life expectancy rate
T	= time

Also, the error terms for equations (4), (5) and (6) are ϵ_t, μ_t, ν_t respectively.

Equation (1) is the pollution equation which is a function of per capita income, population density, energy demand and the human development index. If, $\alpha_1 > 0$ and $\alpha_2 > 0$, there is a U-shaped relationship between per capita CO_2 and per capita income. For an EKC relationship (inverted-U shape) to exist $\alpha_1 > 0$ and $\alpha_2 < 0$.

Equation (2) is a Cobb-Douglas equation of physical capital, labour, pollutant (CO_2) and the human development index. Equation (3) is the human development index equation which is a function of per capita income, the pollutant, education level and life expectancy.

The log forms of equations (1), (2), and (3) are then taken to linearize them to construct a simultaneous equation model (SEM), with the extended Cobb-Douglas production function, and to correct the distribution of variables in equation (1) with positive skewness (Shen, 2006). These then become:

$$lnCo_t = \propto_0 + \propto_1 lnY_t + \propto_2 (lnY_t)^2 + \propto_3 lnPD_t + \propto_4 lnED_t + \propto_5 lnHDI_t + T + \epsilon_t \quad (4)$$

$$lnY_t = \beta_0 + \beta_1 lnK_t + \beta_2 lnL_t + \beta_3 lnCo_t + \beta_4 lnHDI_t + T + \mu_t \quad (5)$$

$$lnHDI_t = \rho_0 + \rho_1 lnY_t + \rho_2 lnCo_t + \rho_3 lnEL_t + \rho_4 lnLE_t + T + v_t \quad (6)$$

Table 1: A priori expectations

Equation 1		Equation 2		Equation 3	
Explanatory Variable	Sign	Explanatory Variable	Sign	Explanatory Variable	Sign
Y_t	+	K	+	Y_t	+
Y_t^2	-	L	+	Co_t	-
PD	+/-	Co	+/-	EL	+
ED	+	HDI	+	LE	+
HDI	+				

Table 1 presents the *apriori* expectation of the explanatory variables that are used in this model. From Equation (1), the coefficient of per capita income(Y_t) is expected to be positive while the quadratic term of per capita income (Y_t^2) is expected to be negative for the EKC relationship of an inverted–U shape to exist (i.e. $\alpha_1 > 0$ and $\alpha_2 < 0$).

The relationship of the pollutant to population density could either be positive or negative. According to Shen (2006), an increase in population leads to an increase in emission generation which will yield a positive relationship. On other hand, Selden and Song (1994) theorize that a high-density population is more concerned about reducing per capita emission more than a low-density area. Therefore, we considered population to either be positive or negative.

The coefficient of energy demand is expected to be positively related to pollution, since an increase in energy demand will lead to an increase in per capita CO_2, as a result of increased energy output from non-renewable sources.

The human development index coefficients in both equations (1) and (2) are expected to be positively related with pollution and output. Improved well-being of the people makes them more active at work, and contributes more to the degradation of the environment through increased use of the available natural resources.

From equation (2), the coefficients of capital and labour are expected to yield a positive relationship with output or income. While the pollutant is expected to have a negative relationship with income since it reduces the well-being of labour. It is also possible for the coefficient of the pollutant to be positive if the production process is more capital intensive than labour intensive, since the pollutant has little or no effect on capital.

The HDI equation is a function of level of education, health and national income. The pollutant is included since it could have either a positive or negative effect on HDI, while all the coefficients of these variables are expected to be positively related to human well-being, except the pollutant.

Empirical Result

Using the Augmented Dicky Fuller (ADF) and Phillips-Perron (PP) tests, all the variables were subjected to stationarity test since the study is a time series analysis. These tests are important to determine the stationarity of the variables used and to determine the lag length that is necessary for each variable in the estimation (Pesaran and Shin, 1997).

Table 2 shows that almost all the variables are stationary at first difference except for life expectancy and population density under the ADF unit-root test. Therefore, we lagged our entire variable by one period except for life expectancy and population density.

Table 2: Stationarity Test

	Augmented Dickey Fuller (ADF)			Phillips-Perron (PP)		
Variables	Levels	First Difference	I(d)	Levels	First Difference	I(d)
CO_2	-1.9412[b]	-4.3264**[b]	I(1)	-2.0783[b]	-4.3304**[b]	I(1)
Y	-2.298[b]	-3.9222**[b]	I(1)	0.2871[a]	-3.9222**[b]	I(1)
Y^2	0.5296[a]	-3.9539**[b]	I(1)	0.3279[a]		I(1)
HDI	-2.5378[b]	-4.3935**[b]	I(1)	-2.5941[b]	-3.9539**[a] -4.3878**[b]	I(1)

	Augmented Dickey Fuller (ADF)			Phillips-Perron (PP)		
Variables	Levels	First Difference	I(d)	Levels	First Difference	I(d)
ED	-2.4592[b]	-5.0173***[a]	I(1)	-2.5121[b]	-5.2470***[b]	I(1)
GFI	-2.5288[b]	-6.1469***[b]	I(1)	-1.9532[b]	-5.2460***[b]	I(1)
LF	-2.7031[b]	-3.7720***[a]	I(1)	-1.7805[b]	-4.8751***[a]	I(1)
LEI	-3.6419**[b]		I(0)	-2.4336[b]	-1.5725[b]	-
EI	-2.1437[b]	-4.4811***[a]	I(1)	-2.1437[b]	-4.4661***[a]	I(1)
PD	-5.6574***[b]	-	I(0)	5.6269[a]	-2.1725[b]	-

Notes: **a** = without constant **b**= with constant and trend. Respectively ***, **, * denotes 1%, 5% and 10% significance.

The results of the earlier stated models are presented in the Table 3. The relationship between the pollutant and income indicates that a 1% increase in income or output leads to a 53% increase in environmental degradation, but in the long-run, with increased output, a 1% increase in output will lead to about 4% increase in environmental quality as shown by the coefficient of Y and Y^2 respectively. This suggests that pollution is a problem to address in Nigeria but with increased growth, improved environmental quality will be achieved. This shall be discussed further in answering the major questions later.

Furthermore, all the explanatory variables conform to a priori expectations except for per capita pollutant in the HDI equation and labour which is even significant in the income equation. Some of the reasons why these could be possible include: One, if there is an increase in pollution as a result of an increase in output, both CO_2 and HDI will increase at the same time. Two, if labour does not contribute significantly to the production process, it is possible for the welfare level to increase even as per capita pollutant increases. Finally, since labour is negatively related to production in equation (2), the negative effect of pollution on labour will not be significant since it has enough income to outweigh the effect of pollution

The Nigerian economy is mainly dependent on crude oil, and its proceeds remain the major source of revenue for government. The exploration of crude oil is usually capital intensive with minimal labour which comprises only administrators. A large proportion of the proceeds from the sale of crude oil is used to offset recurrent expenditure while the rest is shared among the different tiers of government that have no contribution to its production. This could be responsible for the negative relationship between labour and output in Nigeria and also for the positive relationship between the pollutant and human welfare.

Table 3 : Estimated results for pollution (CO_2)

Explanatory variables	Single polynomial equation Eq.(1) ($lnCO_2$)	Simultaneous equation Eq.(1) ($lnCO_2$)	Simultaneous equation Eq.(2) (lnY)	Simultaneous equation Eq.(3) (lnHDI)
Constant	0	0	-269.275**	-2.039
			(-1.32)	(-0.89)
$lnCO_2$			-0.129	0.011
			(-0.96)	(1.00)
lnY	53.116***	53.812***		0.108**
	(3.98)	(3.97)		(2.27)
lnY^2	-3.631***	-3.677***		
	(-4.04)	(-4.03)		
lnHDI	1.075	0.963	0.283	
	(1.12)	(0.98)	(0.52)	
lnED	5.755***	5.767***		
	(3.83)	(3.78)		
lnPD	5.448***	5.556***		
	(0.50)	(3.87)		
lnK			0.309***	
			(5.35)	
lnL			-7.534**	
			(-2.38)	
lnLE				0.336*
				(4.81)
lnEL				0.279***
				(16.66)
T	-0.129***	-0.131***	0.201**	0.005
	(-4.61)	(-4.60)	(2.52)	(0.50)
R^2	0.759	0.759	0.937	0.994
Over identification test		15.431***		
Hausman test for endogeneity		-0.33		
Sample	27	27	27	27

Notes: ***, ** & * denotes significance at 1%, 5% and 10% respectively (t-statistics is in parentheses)

The next section provides answers to the three major questions raised at the beginning of the study.

Q1: Does the EKC hypothesis hold or not?

With additional exogenous variables of population density and energy demand, both the single polynomial equation model and the simultaneous model yielded an EKC relationship since the coefficient of per capita GDP and its quadratic term are positive and negative respectively, i.e. $\alpha_1>0$ and $\alpha_2<0$. This proves that the Shen (2006) argument that with increased exogenous variables the EKC hypothesis will not hold is not true for Nigeria.

Both per capita income and its quadratic terms are significant. The single polynomial equation indicates that a 1% increase in income will lead to 53.116% increase in per capita CO_2 emission while the simultaneous model indicates 53.812% increase in per capita CO_2 emission. The quadratic term for both models are negative and significant, which lends credence to the earlier argument in support of the EKC hypothesis in Nigeria.

Q2: Is there a feedback effect?

In order to achieve a feedback effect, two major conditions must be met: one, the null hypothesis of no endogenous variable must be rejected and two, the model must also pass the over-identification test, otherwise the error term will be correlated with the instrumental variables.

The null hypothesis of the Hausman test for endogeneity is rejected. This means there is presence of endogenous variable(s) in the traditional EKC model of equation (1) and the variables CO_2, Y_t and HDI, which are assumed to be endogenous are truly endogenous variables. Also, the over-identification test is statistically significant at 1% with a value of 15.431. Therefore, the null hypothesis for over-identification holds. This justifies the use of the 2SLS method for the model to give a consistent and efficient estimate. We therefore conclude that there is a feedback effect among per capita pollutant (CO_2), per capita income and human welfare.

Q3: Is there any difference between the single and the simultaneous equation estimators?

From Table 3, the estimated values of the variables from a single polynomial equation and that of the simultaneous equation (equation 1) may look very similar. The 2SLS estimation allows the measurement of both the direct and indirect impacts of the endogenous variables. The direct impact is presented in the third column of Table 3. However, based on the theoretical fact earlier established through the simultaneous model specification, it is obvious the direct impact is not the true (total) impact. The total impact therefore is the addition of both the direct and indirect impact.

For instance, the impact of HDI on per capita pollution indicates that a 1% increase in human welfare (HDI) leads to a 1.075% increase in per capita pollution for the single equation model. The indirect impact of the HDI which is reflective in the income equation indicates that a 1% increase in welfare leads to a 0.108% increase in income. Since this does not directly relate to per capita pollution, the share of HDI in income is multiplied with the direct impact of income on per capita pollution in equation (1) (i.e. 53.813 * 0.108)= 15.229. Since per capita income is positively related to per capita pollution, the total impact is the sum of the direct and the indirect impact (i.e. 0.963 + 15.229) = 16.192. Therefore, instead of 1.075% increase in per capital pollution as a result of a 1% increase in human welfare, the simultaneous equation model gave a total impact, which indicates a 16.192% increase in per capita pollution as a result of a 1% increase in welfare. This is also applicable to per capita income. Table 4 presents the total impact of both HDI and per capita income.

Table 4: Impact of income and human well-being on per capita pollution

Variables	Direct impact	Indirect impact	Total impact
lnYt	53.812	0.104	53.915
lnHDI	0.963	15.229	16.192

Note: This table shows the Total impact of Y_t and HDI on per capita pollution.

From the above discussion, the difference between the single equation model and the simultaneous equation model has been established. Thus, it is necessary to consider the endogeneity problem or the simultaneous implication of EKC before explaining the relationship between income and pollution in Nigeria.

Conclusion and Recommendations

Labour as a factor of production was found to be insignificant to the production equation which implies that the contribution of labour in Nigerian is insignificant. Also, all the variables in the model conform to the theoretical expectation with the exception of CO_2 which is positive and significant in the HDI equation. The implication is that a measure of human welfare without the inclusion of the pollutant CO_2 is incomplete. This could mean that the Nigerian economy is still in the infant stage of production, as postulated by the EKC theory, hence unaffected yet by pollution.

Based on these findings, it is recommended that policy formulation in Nigeria should be directed towards raising the level of growth coupled with some regulations to reduce pollution. These policies should be inclusive in nature to make labour more active and efficient in the production process. Also, researchers should be more concerned about the endogeneity or simultaneity problem when addressing the relationship between carbon dioxide, income and human welfare. Finally, the measure of human welfare will be incomplete if it does not include the quality of the environment in which people live.

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