Journal of Sustainable Energy & Environment

12 (2021) 53-57

Energy, economic growth and CO_2 emissions: New evidence of the Environmental Kuznets Curve in Nigeria

Emily E. Ikhide

National Institute for Legislative and Democratic Studies (NILDS), Maitama District, Abuja, Nigeria
emmyjay11@gmail.com; +234-8138461703

Abstract: Achieving economic development alongside environmental sustainability is a major priority of the global development agenda. This relationship between economic development and environmental quality is depicted by the Environmental Kuznets Curve hypothesis. Although there are several studies that have examined the validity or otherwise of the hypothesis, available evidence shows mixed and inconclusive results. In the case of Nigeria, there has also been no attempt to empirically estimate the turning point of the curve. Hence, this study examines the validity of the hypothesis in Nigeria, and estimates the turning point, based on yearly time series data from 1980 to 2016 and the Autoregressive Distributed Lag bound testing approach. The results confirm a long-run relationship between the series and provide evidence in support of the hypothesis in Nigeria. There is a positive sign between Gross Domestic Product (GDP) and CO_2 emissions, while a negative sign is found for the square of GDP. However, the linear term is bigger than the non-linear term, signifying that the environmental degradation effect of GDP growth is bigger than the environmental quality enhancement effect. Based on the results, the study recommends that the government develop policies to facilitate the transition from fossil-fuel and diversify the production base of the economy in order to mitigate the environmental effects of economic growth.

Keywords: Energy consumption, economic growth, CO_2 emissions, EKC, Nigeria.

1. Introduction

This paper examines the link between the economy, energy and environment in the context of the Environmental Kuznets Curve (EKC).

The EKC hypothesis, which emerged from the works of [1] and [2], establishes that there exist an inverted U-shape association between environmental degradation and income. Environmental pollution rises at the early stages of economic development and falls at the later stages. In the early stages, more inputs are required to maximise output and thus more natural resources are used up. There is limited attention to environmental protection. However, as the economy develops, the standard of living increases and the citizens begin to demand for environmental sustainability. In addition to this, there are also more resources and technology available for environmental protection. All these leads to an improvement in environmental quality.

Specifically, the validity of the EKC hypothesis is tested within the Nigerian context with a view to inferring policy implications for sustainable economic growth in Nigeria. However, the question remains of how this energy-intensive growth impacts the environment. This paper therefore extends the energy-growth nexus linkages to understanding how the growth affects environmental quality, forming the energy-growth-environment triad.

It is well-known that energy use is an effective driver of economic growth [3]. However, growth based on conventional energy has also been recognised to have a negative influence on the environment [4]. This discovery has now shaped intense public policy debates resulting from recent developments in global warming and climate change. In line with this, this paper seeks to explore the effects of energy use and economic growth on the environment.

Over the years, emerging literature has presented contradictory interests on the environment-growth relationship. While some have argued that depletion of the natural resource base places productive activities at high risk [5-6], several others have debated that the fastest route to environmental improvement is following the path of economic growth [7]. These issues have been explored in the literature using the EKC hypothesis. The hypothesis states that an inverted U-shaped relationship exists between economic growth and environmental degradation. However, various empirical studies have found mixed results to support EKC for different countries. This could in part be due to lack of sufficient empirical evidence that has fully addressed how environmental quality changes at different stages of economic growth, or due to the restrictive econometric techniques that have been employed.

This study advances existing studies on the validity of the EKC in Nigeria [8-10]. There are several studies on the EKC in Nigeria. Available studies on the EKC in Nigeria have not yielded conclusive and consistent results, and this is partly due to the varying methodologies adopted by these studies. This study is very important because it not only examines the validity or otherwise of the EKC in Nigeria as other studies have done, it goes further to calculate the threshold point. Therefore, the objective of this study is to examine validity of the EKC in Nigeria, and if valid, estimate the turning point.

The remainder of the paper is as follows. Section 2 presents the methodology and data employed in this study. The presentation and discussion of the results is the focus of Section 3 while Section 4 deals with the conclusion and recommendations.

2. Method

Pesaran et al. [11] was among the first studies to have used the EKC hypothesis to explain the link between the numerous indicators of environmental pollution and income. According to them, at the early stages of economic growth, pollution increases, but to some certain level of income, which varies for different indicators and different countries, and after a while this relationship reverses, so that at very high-income levels, economic growth tends to lead to environmental improvement [6].

The long-run relationship between Gross Domestic Product (GDP) and CO_2 emission was established within an ARDL bounds testing approach advanced by [11] and [12] and is based on the following validations. First, the order of integration of the series does not matter as, unlike other conventional cointegration techniques, the ARDL does not enforce a limiting assumption that every variable in the regression must be integrated of the one order. Secondly, even though other cointegration methods may be sensitive to the sample size, the ARDL approach is more appropriate and appropriate for a small sample. Appropriate modification of the order of ARDL technique can also correct and provide impartial estimates of the long-run model and valid t-statistics even when some of the regressors are endogenous.

Given the specific objective of this study, the study followed the empirical study of [13] and [14] who employed the EKC method with the simple standard functions of levels of income using logarithmic dependent and independent variables. The model is specified as follows:

$$LNCO_2PC_t = \alpha_0 + \alpha_1 LNEPROD_t + \alpha_2 LNGDPPC_t + \alpha_3 LNGDPPC_t^2 + \varepsilon_t \ldots.. \quad (1)$$

Where CO_2PC denotes CO_2 emissions per capita, $EPROD$ stands for energy consumption, $GDPPC$ is gross domestic product per capita, and $GDPPC^2$ is the square of GDP per capita. $\alpha_0, \alpha_1, \alpha_2, \alpha_3$ are the coefficients to be estimated while $\varepsilon_t$is the error term. The LNindicates that the series are in log form.
The turning point (threshold) of the quadratic relationship between economic activity and the quality of environment is obtained from the partial derivate of Equation 2 as below:

$$\frac{\partial LNCO_2PC}{\partial LNGDPPC} = \alpha_{2,t} + 2(\alpha_{3,t}) LNGDPPC_t \ldots. \quad (2)$$

The turning point where the GDP effect switches from negative to positive and vice versa occurs where the slope is zero. Thus if we substitute this point and solve for GDP we obtain

$$LNGDPPC_t = \frac{-\alpha_{2,t}}{2(\alpha_{3,t})} \ldots\ldots\ldots\ldots \quad (3)$$

Equation 3 also confirms the shape of the relationship whether concave ($\alpha_{3,t}$ is negative) or convex ($\alpha_{3,t}$ is positive).

The ARDL representation of Equation 4 below in natural log form indicates that CO_2 tends to be influenced and explained by its past values, the past values of all the explanatory variables as well as the change in the past values of all the variables in the model.

$$\Delta LNCO_2PC_t = \alpha_0 + \alpha_1 LNCO_{2t-1} + \alpha_2 LNEPROD_{t-1} + \alpha_3 LNGDPPC_{t-1} + \alpha_4 LNGDPPC_{t-1}^2 + \sum_{t-1}^{n} \emptyset_1 \Delta LNCO_{2t-1} + \sum_{t-1}^{n} \emptyset_2 \Delta LNEPROD_{t-1} + \sum_{t-1}^{n} \emptyset_3 \Delta LNGDPPC_{t-1} + \sum_{t-1}^{n} \emptyset_4 \Delta LNGDPPC_{t-1}^2 + ECT_{t-1} + \varepsilon_t \quad (4)$$

Where α_0 is a constant term, $\alpha_1$to α_4 are long-run coefficients, $\emptyset_1$ to $\emptyset_4$ stand for the short-run coefficients, Δ is the lag operator, and all other variables are as defined above. The ECT is the error correction term, derived from residuals generated from the original function. It shows the adjustment process of the short- to long-run equilibrium relationship between economic growth, energy utilisation and other specified independent variables in Nigeria. As is standard, the coefficient of the ECT term is expected to be negative and statistically significant for there to be short-run adjustment to long-run equilibrium. The error term ε_t is expected to be normally distributed where each individual error term is centred on zero with the same spread so that an error drawn has no effect on another error drawn, meaning that errors are serially independent.

2.1 Data source

The paper utilised yearly time series data for the period 1980 to 2016. The data was sourced from the World Development Indicators (WDI) of the World Bank and the U.S. and Energy Information Administration (EIA). The choice of time period was guided by the availability of data for all the variables of interest. Specifically, data on CO_2 emissions (metric tons per capita), is obtained from the World Development Indicator of the World Bank. It represents total CO_2 emissions from the combustion of fossil fuel. Although there are several indicators of environmental quality, CO_2 emissions are widely used in the literature due to the critical role of CO_2 emissions in climate change and global warming [15-16]. GDP per capita is used as a measure of economic growth in this study. This measure is more appropriate because it indicates the average standard of living of the population which is a main driver of environmental quality [17]. Energy consumption is also included in the model because it is a main driver of environmental quality. Recent evidence has shown that combustion of fossil fuel is the leading cause of man-made climate change, hence its inclusion in the model [18-19]. Energy consumption is measured as the total energy consumed from coal, natural gas, petroleum and other liquids, nuclear, renewable and others. The GDP data are in constant 2010 U.S. dollars.

3. Results and discussion

The results of the analysis are presented in this section. The results are further discussed in the light of the specific situation of Nigeria.

3.1 Stationarity test

The bounds testing approach to cointegration requires variables to be stationary at levels or at most at first difference, giving it an advantage over other methods such as Johansen that require all variables to be stationary at first difference. In this paper, the test for stationarity in all the variables is done with two popular tests: the Augmented Dickey-Fuller (ADF) test, and the Phillips- Perron (PP) test. The ADF tests the null hypothesis of the presence of unit root. The ADF statistics is expected to be negative, and the more negative it is, the stronger the rejection of the hypothesis that there is the presence of unit root. The PP test also examines the null hypothesis of a unit root in a data series. But it modifies the ADF statistic by incorporating autocorrelations and heteroscedasticity. However, it is non-parametric, as it does not require to select the level of serial correlation as in the ADF.

The results of the ADF and PP stationarity tests are presented in Table 1. The results show that all the variables are not stationary at levels for both tests. However, they become stationary after first differencing. When the intercept and trend are considered, only energy production is stationary at levels. However, all the other variables are stationary after first differencing. Both tests show mixed results of the stationarity of the variables. The differences in the order of integration among the variables provide strong justification for the bounds testing approach to cointegration.

Table 1. Augmented Dickey-Fuller and Phillips-Perron unit root tests.

Variables	ADF		PP		Decision
	Levels	1st Diff	Levels	1st Diff	
$LNCO_2PC$	-1.722758	-6.205237***	-1.778535	-6.248437***	I(1)
LNEPROD	-0.533434	-6.640630***	-0.580186	-10.83595***	I(1)
LNGDPPC	0.929579	-4.984696***	0.627129	-4.981328***	I(1)
$LNGDPPC^2$	0.953150	-4.971216***	0.645042	-4.967360***	I(1)
Intercept & Trend					
$LNCO_2PC$	-2.138497	-6.126482***	-2.200071	-6.170605***	I(1)
LNEPROD	-5.306692***		-5.101409***		I(0)
LNGDPPC	-3.006103	-5.099314***	-2.944547	-5.099314***	I(1)
$LNGDPPC^2$	-2.967649	-5.097776***	-2.907919	-5.097776***	I(1)

3.2 Cointegration analysis (bounds testing approach)

To determine the cointegration link between energy consumption, economic growth and environmental degradation in Nigeria, the unrestricted error correction model is estimated and an ARDL (3, 0, 6, 4) is chosen based on the Akaike Information Criteria for the lag length selection. Following this was the estimation of the restricted error correction model where the selection of the best economic and statistical properties is presented and discussed.

The test for long-run co-integration among the specified variables enables the identification of the short- and long-run relationship possibility under the bounds testing procedure. The error correction term, derived from the level form estimate of Equation 4, indicates the speed of adjustment of the short- to long-run equilibrium relation of growth and environment in Nigeria. Bounds testing requires a test of the combined significance of the variables in the model or an F- (Wald test) under the null hypothesis that all variables in the model are jointly insignificant. Consequently, a statistically significant F-statistic is compared with the upper bounds of the critical values provided in [11] for establishing a long-run relationship among stationary variables in the model. An F-statistic of 4.87 as shown in Table 2 is sufficient for the strong rejection of the null hypothesis of no long-run relationship between real output and the specified determinants in Nigeria as this exceeds the 5 per cent critical value for the upper bounds test critical values.

Table 2. ARDL bounds test.

Test Statistic	Value	K
F-statistic	4.869	3
Critical Value Bounds		
Significance	I(0) Bound	I(1) Bound
10%	2.618	3.532
5%	3.164	4.194
1%	4.428	5.816

Table 3 shows estimates of the long-run relationship and confirms that most parameters have the expected signs. The results suggest a positive effect of GDP per capita on CO_2 emissions per capita, and a negative effect of the squared term of GDP per capita on CO_2 emissions per capita. This result confirms the EKC hypothesis for Nigeria. It implies that economic growth increases environmental pollution to a level after which environment quality improves with further growth. As the economy begins to grow, there is less concern for the environment, and the main priority for policy makers is economic growth. During this period, CO_2 emissions will increase, leading to environmental degradation. However, after the government had achieved economic growth to some extent, it will start paying more attention to CO_2 emissions and environmental quality. The increase in income will help the government to invest in new and advanced technologies, including renewable energy, which will help to reduce CO_2 emissions. The coefficient of GDP per capita is large, and consistent with the results of other studies such as [17].

The EKC turning point is presented in Figure 1. From the elasticity coefficients one can infer that the linear and non-linear terms for GDP per capita and square are 143.90 and -21.99 respectively, and both are highly significant. This provides evidence that supports an EKC hypothesis in Nigeria. The turning point where the GDP effect switches from positive to negative is equal to the logged GDP per capita of 3.27. The antilog of 3.27 is $1,862. This implies that at the early stages of development, growth leads to an increase in carbon emission up to the threshold GDP per capita of $1,862, after which the effect of GDP per capita on CO_2 switches to negative and economic growth leads to decline in CO_2 emissions at the later stage of development. This means that after passing the threshold point of $1,862, GDP growth is achieved alongside environmental improvement. The linear term is bigger than the non-linear term, signifying that the environmental degradation effect of GDP growth is bigger than the environmental quality enhancement effect. This could mean that although the data validates the EKC for Nigeria, economic growth increases CO_2 emissions than it reduces it. This could not be unrelated with Nigeria's fossil-fuel dominated economy. Fossil fuel is a major sector of the Nigerian economy. Hence, it is expected as fossil-fuel drive economic growth, there will be negative environmental impacts.

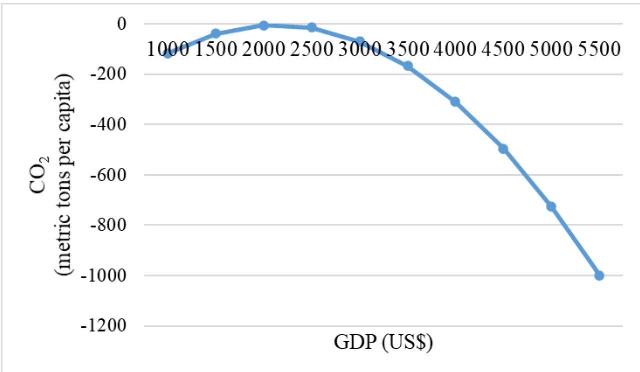

Figure 1. Plot of the EKC turning points.

Table 3. Cointegration equation (long-run model).

Variable	Coef.	Std. Error	T-Statistics	Prob.
LNEPROD	0.662	1.198	0.552	0.589
LNGDPPC	143.903	66.441	2.166	0.048
$LNGDPPC^2$	-21.999	10.221	-2.152	0.049
Turning Point (Threshold) Logged GDP per capita	3.27			
C	-238.6832	112.8222	-2.116	0.053
F-Statistic = 45.076 (0002) Durbin-Watson = 1.79 R-Squared = 0.834; Adjusted R-Squared= 0.724 Standard error of regression= 0.059				

Table 4. ARDL short-run model.

Variables	Coefficient	t-statistics	Prob.
C	-117.3314	-2.228844	0.0427
$LNCO_2PC(-1)$*	-0.491578	-3.102563	0.0078
LNEPROD**	0.325419	0.624702	0.5422
LNGDPPC(-1)	70.73997	2.216102	0.0438
LNGDPPC_2(-1)	-10.81458	-2.205711	0.0446
$D(LNCO_2PC(-1))$	0.300164	1.382947	0.1883
$D(LNCO_2PC(-2))$	0.225926	1.450219	0.1690
D(LNGDPPC)	78.53742	2.407002	0.0305
D(LNGDPPC(-1))	-111.6434	-3.459014	0.0038
D(LNGDPPC(-2))	68.24043	1.876238	0.0816
D(LNGDPPC(-3))	35.50579	1.000555	0.3340
D(LNGDPPC(-4))	-0.641076	-1.034630	0.3184
D(LNGDPPC(-5))	-2.104339	-4.330309	0.0007
D(LNGDPPC_2)	-12.13531	-2.382144	0.0319
D(LNGDPPC_2(-1))	17.20545	3.396034	0.0043
D(LNGDPPC_2(-2))	-10.88248	-1.892678	0.0793
D(LNGDPPC_2(-3))	-5.802355	-1.037552	0.3171
ECT(-1)	-0.491578	-5.594958	0.0001

Note: * P-value incompatible with t-Bounds distribution, ** Variable interpreted as Z = Z(-1) + D(Z).

Table 4 shows the parsimonious short-run estimates or the dynamic relationship between growth and the environment in the short run. The continuous switch in signs of both the linear and non-linear terms in the difference lagged terms confirm the dynamism in the relationship between the environment and economic activity. The coefficients of linear and non-linear terms of GDP per capita and GDP per capita squared also confirms the EKC relationship, but they are smaller than the long-run coefficient. The finding that the long-run income elasticity for CO_2 emissions is less than the short-run elasticity emphasises the long-run evidence in support of EKC in Nigeria [12]. Impact of energy production is very small and insignificant in the short run. A 1% increase in energy consumption is expected to raise emissions by 0.32%. This is lower than the long-run result, and could mean the polluters obey the rules in the short run but tend to evade the laws in the long run. The parameter which corrects for the error correction term (ECT-1) has the appropriate sign and is statistically significant. This suggests a 49 per cent adjustment speed of disequilibrium in the short-run to long-run equilibrium.

Table 5. Diagnostic statistics.

Serial Correlation	0.6759(0.0.8576)
Heteroscedasticity (Breusch-Pagan)	0.6686(0.8079)
Normality	6.9132(0.0315)
Durbin-Watson	1.78
ARCH	0.9078(0.09117)
CUSUM at 5%	Stable
Adjusted R^2	0.7941

Values in parenthesis are *p*-values

The diagnostic tests (Table 5) show that the model is robust. The errors are serially independent with the LM test statistic of 0.68 and a probability value of 0.86, leading to the acceptance of the null hypothesis of serial independence of errors. The errors are homoscedastic. Other diagnostic tests including the Jarque-Bera Normality confirm the reliability of the model.

4. Conclusion and recommendations

The paper evaluated the link between economic growth and CO_2 emissions in Nigeria. The study employed annual time series data from 1980-2016, using an ARDL bound testing approach to examine the long-run relationship among energy consumption, economic growth and CO_2 emissions in Nigeria. Using the ARDL estimates we also calculated the threshold point for Nigeria for policy implications. The ADF unit root tests check for stationarity, and the ARDL approach to cointegration was employed for the EKC relation. The results confirm a long-run relationship among the series and provide evidence in support of EKC in Nigeria.

This result confirms the EKC hypothesis for Nigeria. Specifically, as economic growth increases it worsens the quality of the environment up to a level where improvements in environmental quality begin to occur with further growth. Overall results show that the net effect on the environment may be negative as the environmental degradation effect of growth is larger than the environmental quality enhancement effect. A unique feature of this paper is the computation of the threshold effect. The calculated threshold point of GDP per capita of $1,862 implies that at the early stages of development, economic growth leads to an increase in carbon emission up to a threshold of $1,862 after which the effect of GDP per capita on CO_2 switches to negative and economic growth leads to a decline in CO_2 emissions at the later stage of development.

Based on the findings of this study, Nigeria's fossil-fuel reliant economy will worsen environmental quality, more than it enhances the environment. Therefore, it is recommended that the government develop policies to facilitate the transition from fossil-fuel and diversify the production base of the economy. This will help to achieve economic growth without damaging the environment.

References

[1] Hussen, A. 2004. *Principles of Environmental Economics*. Second edition. Routledge, London, UK.

[2] Callan, S.J. and Thomas, J.M. 2013. *Environmental Economics and Management: Theory, Policy, and Applications*. Sixth edition. Cengage Learning, USA.

[3] Stern, D.I. 2003. *International Society for Ecological Economics Internet Encyclopedia of Ecological Economics*. The Environmental Kuznets Curve. Troy, NY: Department of Economics, Rensselaer Polytechnic Institute.

[4] Newman, P., Birrell, R., Holmes, D., Mathers, C., Newton, P., Oakley, G., O'Connor, A., Walker, B., Spessa, A. and Tait, D. 1996. Human settlements (Chapter 3). In: Taylor, R. (ed.): *Australia State of the Environment 1996*. An independent report presented to the Commonwealth Minister for the Environment by the State of the Environment Advisory Council.

[5] Mishan, E.J. 1967. *The Costs of Economic Growth (Revised Edition)*. Westport, CT: Greenwood Press.

[6] Panayotou, T. 2003. Economic growth and the environment, *Economic Survey of Europe*, 2, 45-63.

[7] Beckerman, W. 1992. Economic growth and environment: whose growth? Whose environment?, *World Development*, 20(4), 481-496.

[8] Olusegun, O.A. 2009. Energy consumption and economic growth in Nigeria: A bounds testing co-integrative approach, *Journal of Economic Theory*, 2, 118-123.

[9] Akpan, U.F. and Chuku, A. 2011. Economic growth and environmental degradation in Nigeria: beyond the environmental Kuznets curve. In: *Proceedings of 2011 Annual Conference of NAEE, Abuja*.

[10] Alege, P.O. and Ogundipe, A.A. 2013. Environmental quality and economic growth in Nigeria: a fractional co-integration analysis, *International Journal of Development and Sustainability*, 30(4), 1882-1908.

[11] Pesaran, M., Shin, Y. and Smith, R. 2001. Bounds testing approaches to the analysis of level relationships, *Journal of Applied Econometrics*, 16(3), 289-326.

[12] Narayan, P.K. and Narayan, S. 2010. Carbon dioxide emissions and economic growth: panel data evidence from developing countries, *Energy Policy*, 38(1), 661-666.

[13] Stern, D.I. 2004. The rise and fall of the environmental Kuznets curve, *World Development*, 32, 1419-1439.

[14] Shahbaz, M., Ozturk, I., Afza, T. and Ali, A. 2013. Revisiting the environmental Kuznets curve in a global economy, *Renewable and Sustainable Energy Review*, 25, 494-502.

[15] Wolde, E.T. 2015. Economic growth and environmental degradation in Ethiopia: An environmental Kuznets curve analysis approach, *Journal of Economics and International Finance*, *7*(4), 72-79.

[16] Apergis, N. and Payne, J.E. 2010. Renewable energy, output, CO_2 emissions, and fossil fuel prices in Central America: evidence from a nonlinear panel smooth transition vector error correction model, *Energy Economics*, 42, 226-232.

[17] Agras, J. and Chapman, D. 1999. A dynamic approach to the Environmental Kuznets Curve hypothesis, *Ecological Economics*, 28, 267-277.

[18] Al-Mulali, U., Saboori, B. and Ozturk, I. 2015. Investigating the environmental Kuznets curve hypothesis in Vietnam, *Energy Policy*, 76, 123-131.

[19] Schmalensee, R. 2012. From "green growth" to sound policies: an overview, *Energy Economics*, 34(Supplement 1), S2-S6.

[20] Figueroa, E. and Pasten, R. 2009. Country-specific environmental Kuznets curves: a random coefficient approach applied to high-income countries, *Economic Studies*, 36(1), 5-32.

