REVISITING THE ENVIRONMENTAL KUZNETS RELATION IN NIGERIA: AN EMPIRICAL STUDY OF ECONOMIC AND ENVIRONMENTAL TRENDS

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ABSTRACT
This study reexamines the Environmental Kuznets Curve (EKC) in the context of Nigeria, exploring the relationship between economic growth and environmental degradation. The EKC hypothesis suggests that as an economy grows, environmental degradation worsens initially, but improves once a certain income threshold is reached. While some studies support this theory, others have produced mixed results, largely due to the oversimplification of the relationship between economic growth and environmental quality. The study specifically focuses on Nigeria, assessing the EKC hypothesis using indicators of environmental degradation such as CO_2 emissions, fossil fuel consumption, resource depletion, and erosion. The study aims to determine if a relationship exists between these environmental indicators and per capita GDP, whether the relationship follows the EKC pattern, and if Nigeria has reached the income threshold where economic growth begins to benefit the environment. Using time-series data from 1981 to 2023 sourced from the World Bank, the study employs threshold regression analysis to test the EKC. Results indicate that while some models support the EKC theory, the relationship is not consistent across all environmental indicators. The study concludes that for Nigeria to achieve sustainable and balanced growth, the government should implement green technologies, promote renewable energy, adopt circular economy models, and enforce stricter environmental regulations to mitigate pollution, preserve resources, and combat climate change. These measures could help Nigeria transition to a more environmentally sustainable growth trajectory.
Keywords: Economic growth, environmental sustainability, Environmental Kuznets Curve, sustainable development.
JEL Classification: Q01, Q56, Q58, O44

1. INTRODUCTION
The discovery of oil in Nigeria's Niger Delta region in 1956 marked a turning point in the nation's economic landscape but also initiated a trajectory of severe environmental degradation. Industrial activities, especially gas flaring, emit pollutants into the atmosphere, impacting air quality, contaminating water sources, and hindering agriculture in communities around the Niger Delta (Biala, 2019). With a growing population and intensifying industrial activity, Nigeria faces ongoing environmental challenges, with increased demands on its natural resources leading to deforestation, waste accumulation, air pollution, and water contamination. These issues have raised public health concerns, as pollutants from industrial activities are associated with respiratory illnesses, including asthma and lung cancer.

Nigeria's economic expansion has primarily been driven by oil revenues, which have led to urbanization, industrialization, and an increasing population density in urban areas. This development, while boosting the economy, has also accelerated environmental issues. Inadequate energy infrastructure has led to the extensive use of private generators, releasing carbon dioxide and other pollutants (Biala, 2019). Additionally, Nigeria's growing reliance on motor vehicles has resulted in a significant rise in carbon emissions, with transportation accounting for 74% of the country's total CO_2 emissions in recent years (Adeniyi, 2024). Between 1995 and 2019, the number of small passenger vehicles nearly doubled, contributing to worsening air quality. This pollution has disproportionately affected young children, with air pollution being a major cause of pneumonia-related deaths among children under five in Nigeria (Biala, 2022). The rapid increase in motorized vehicles has also brought about waste management issues, as vehicle disposal methods are often inadequate, adding further strain on the environment.

This backdrop of rapid economic growth coupled with environmental degradation poses a substantial challenge for Nigeria. While striving for economic development, Nigeria must address the adverse environmental impacts to ensure long-term sustainability. Nigeria's experience provides an interesting case study for the Environmental Kuznets Curve (EKC) hypothesis, a model that proposes an inverted U-shaped relationship between economic growth and environmental degradation. According to this theory, environmental degradation worsens in the early stages of economic growth but improves after reaching a certain income threshold as societies invest in cleaner technologies and adopt stronger environmental protections. In Nigeria's context, however, the validity of the EKC hypothesis remains contentious. Existing research on Nigeria has yielded mixed results, with some studies confirming the EKC hypothesis while others reject it. For instance, studies by Omisakin (2009), Olusegun (2009), Adeleye (2012), and Akpan and Chukwu (2011) did not find evidence supporting the EKC in Nigeria. Conversely, researchers like Drabo (2011) and Adeagbo (2022) identified patterns in line with the EKC. The inconsistencies across these findings are attributed to variations in methodologies, economic and environmental indicators, and omitted variables.

This study aims to re-evaluate the EKC hypothesis in Nigeria by incorporating more comprehensive data and addressing variables that previous studies may have overlooked. Specifically, the research includes factors such as foreign direct investment (FDI), fossil fuel consumption, resource depletion, and erosion, all of which play crucial roles in the complex relationship between economic growth and environmental quality. Furthermore, it employs threshold regression analysis, a statistical technique that captures nonlinear relationships and can identify income thresholds where environmental quality might improve.

The main objectives of this research include examining whether indicators of environmental degradation in Nigeria—such as CO_2 emissions, fossil fuel usage, resource depletion, and erosion—correlate with GDP per capita or real GDP growth. Additionally, the study aims to determine the income level at which economic growth might begin to have a positive impact on the environment. The study formulates specific hypotheses based on the EKC model: (1) environmental degradation in Nigeria increases with per capita GDP but decreases at higher income levels; (2) degradation increases with real GDP growth but decreases after surpassing a growth threshold; and (3) Nigeria has not yet reached the income level necessary for environmental quality improvements.

A significant aspect of this research is the use of threshold regression, a methodology that assumes a nonlinear relationship between variables, aligning with the EKC hypothesis, which posits that the relationship between income and environmental quality changes beyond a certain threshold. This study builds on previous work by Cole (2004) and Apergis et al. (2018), who utilized threshold regression to explore EKC validity in different contexts. Applying this methodology to Nigeria allows for a more nuanced understanding of how environmental degradation might respond to shifts in economic growth, especially in an emerging economy with unique resource dependencies and regulatory challenges.

By examining the relationship between economic growth and environmental degradation in Nigeria, this research aims to contribute empirical insights that may guide policy decisions. This study's findings have broader implications for sustainable development in Nigeria. By offering an in-depth analysis of the interplay between economic growth and environmental quality, it aims to provide a framework for balancing economic objectives with environmental sustainability. Policymakers can use these insights to devise strategies that promote green growth, reduce dependence on fossil fuels, and enhance the enforcement of environmental laws.

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With data covering 1981 to 2023, sourced primarily from the World Development Indicators, this study contributes to ongoing debates surrounding the sustainability of economic growth in emerging economies like Nigeria. As environmental challenges and climate concerns become increasingly urgent worldwide, understanding the dynamics of the EKC can assist policymakers in balancing economic growth with environmental preservation, both for Nigeria's long-term development and its role in global environmental sustainability efforts. Through its empirical investigation, the study ultimately aims to clarify the potential for sustainable economic growth in Nigeria while navigating the complex realities of environmental degradation.

2. LITERATURE REVIEW

The Environmental Kuznets Curve (EKC) hypothesis explores the link between economic growth and environmental degradation. It proposes that as an economy grows, environmental quality deteriorates initially but begins to improve once income surpasses a certain threshold, forming an inverted U-shaped relationship. This concept, adapted from Simon Kuznets' theory on income inequality, suggests that wealthier nations are better positioned to prioritize environmental protection. However, critics argue that economic growth alone is insufficient to guarantee environmental improvement without deliberate policy interventions. Since its introduction in the 1990s, the EKC hypothesis has sparked debates, with its relevance varying by region and pollutant type, emphasizing the need for tailored analyses and policies.

In Nigeria, studies have produced inconclusive results regarding the EKC hypothesis. Olusegun (2009) investigated the relationship between economic growth and CO_2 emissions from 1970 to 2005 using Ordinary Least Squares (OLS) and Granger causality. He found no long-term causal relationship, attributing the results to missing critical variables. Similarly, Omisakin (2009) observed a U-shaped relationship between income and emissions, contradicting the

EKC by suggesting that emissions declined initially with income but rose at higher income levels. This study's lack of period-specific analysis may have influenced its findings.

Akpan and Chukwu (2011) highlighted the role of poverty and traditional energy use in shaping environmental quality in rural Nigeria, indirectly linking socioeconomic factors to environmental degradation. While not testing the EKC directly, their work underscores the importance of considering broader social and economic dynamics. Drabo (2011) examined environmental degradation from 1986 to 2017 through the EKC framework, finding no significant relationship between income and emissions. Instead, factors like population growth, trade openness, and foreign direct investment (FDI) were significant contributors to environmental degradation, suggesting the need for broader analyses. Similarly, Adeleye (2012) rejected the EKC, citing increased degradation with minor economic growth improvements, while Alege and Ogundipe (2013) reported worsening environmental conditions during early development stages without any turning point for improvement.

Studies such as Aiyetan and Olomola (2015) supported the EKC in the long term, identifying a potential income threshold where emissions might decline. However, their use of autoregressive distributed lag (ARDL) models highlighted the need for methods better suited to capturing non-linear relationships. Ominiyi and Abu (2017) and Egbetokun et al. (2020) reinforced the importance of institutional quality and governance in shaping environmental outcomes, with some pollutants aligning with the EKC framework under specific conditions. Adeagbo (2022) examined the economic implications of environmental degradation in Nigeria, highlighting challenges like forest depletion and adverse exchange rate effects on growth. The study's limited variable integration left some findings open to interpretation within the EKC framework.

Overall, findings on the EKC hypothesis in Nigeria remain inconsistent. Economic growth alone is insufficient to mitigate environmental challenges, as factors like poverty, population growth, energy use, and governance play critical roles. The diverse methodologies employed—ranging from OLS to GMM—highlight the complexity of analyzing the EKC's non-linear nature.

3. METHODOLOGY

The theoretical framework for this study is Environmental Kuznets Curve (EKC), which analyzes the relationship between economic growth and environmental degradation. Unlike the energy ladder model, it provides a more comprehensive approach by considering factors like income, trade, foreign direct investment (FDI), and population growth. The EKC hypothesizes a non-linear relationship, where environmental degradation initially increases with economic growth but later decreases as higher income levels shift priorities toward environmental quality.

3.1 Model Specification

The EKC posits that environmental degradation depends on GDP and its square, commonly expressed in the equation

$$(ED)_t = \beta_0 + \beta_1(y)_t + \beta_2(y)_t^2 + \mu_t$$

where *ED* is represents environmental degradation, *y* stands for GDP per capita, and *u* stands for the error term. In this framework, environmental degradation initially rise with per capita income but eventually decline after reaching a turning point, represented by

$$y = \left(\frac{\beta_1}{2\beta_2}\right),$$

where the β coefficients indicate the growth phases of emissions.

Empirical studies have extended this theoretical model to include additional explanatory variables, such as trade openness, foreign direct investment (FDI), population growth, and resource use. Variations in these factors help explain the complexity of environmental outcomes across different regions and economies.

However, this present study modifies the foundational work of Grossman and Krueger (1991) by specifying the model

$$lnEDI_t = \beta_0 + \beta_1 lny_t + \beta_2 lny_t^2 + \beta_3 (y_t - \tau) + \beta_4 POPGRT_t + \beta_5 lnTRO_t + \beta_6 lnFDI_t + \mu_t$$

where environmental degradation indicators (EDI)—carbon dioxide emissions (COE), fossil fuel consumption (FOS), resource depletion (RED), and erosion (ERO)—are employed alternately as dependent variables. The y represents GDP per capita, τ stands for threshold income level, FDI is foreign direct investment, POPGRT is population growth rate, and TRO is trade openness. β_0, β_1, β_2, β_3, β_4, β_5, and β_6 are the regression parameters while μ represents the error term.

The explanatory variables included in the model are informed by theoretical and empirical literature:

1. **Per Capita Income (y):** Reflecting economic growth, this variable is central to testing the EKC hypothesis. Empirical evidence often supports an inverted U-shaped relationship, indicating reduced degradation at higher income levels. It is widely studied for its dual impact on environmental degradation—aggravating it initially but mitigating it at higher income levels.
2. **Population Growth (POPGRT):** POPGRT is hypothesized to correlate positively with environmental pressure due to higher waste generation and resource demand. Represents demographic pressures, where higher population growth often leads to increased resource consumption and waste generation.
3. **Trade Openness (TRO):** This represents economic integration, which may either exacerbate or mitigate environmental harm depending on energy use and technological advancements. Facilitates economic growth and technological exchange but may also increase emissions through energy-intensive production and import of polluting technologies.
4. **Foreign Direct Investment (FDI):** FDI examines the environmental implications of international investments, which can transfer cleaner technologies or increase pollution depending on the host country's regulations. While generally associated with technological advancement and economic benefits, FDI can also increase pollution, aligning with the pollution-haven hypothesis in weaker regulatory environments.

The coefficients of the explanatory variables were expected to take the following signs: $\beta_0 = 0$, $\beta_1 > 0$, $\beta_2 < 0$, $\beta_3 > 0$, $\beta_4 > 0$, $\beta_5 > 0$, and $\beta_6 > 0$. The expected signs of the coefficients reflect various theoretical scenarios described above. We described the relationship that was expected to hold between GDP per capita and environmental degradation with varying signs of β: If $\beta_1 > 0$, and $\beta_2 = 0$, we would have the linear case where the relationship between economic development and environmental degradation is monotonically increasing. If $\beta_1 > 0$ and $\beta_2 < 0$, then there would be an inverted-U shaped relationship between emissions and GDP per capita. Finally, if $\beta_1 > 0$, $\beta_2 < 0$ and $\beta_3 > 0$, then an N-shaped relationship between emissions per capita and output per capita would be observed. These configurations help capture the nuances of environmental-economic interactions, illustrating how different variables influence the trajectory of environmental quality.

Table 1 depicts the measurement and sources of data used for the study, which spans from 1981 to 2023. All the data were obtained from World Bank's World Development Indicator (WDI) in 2023.

Table 1 Measurement and Sources of Data

	Variable	**Measurement**
1.	COE	Carbon dioxide emissions measured in metric tons per capita
2.	FOS	Consumption of petroleum measured in percentage of total energy consumption
3.	RED	Natural resource depletion measured in percentage of gross national income.
4.	ERO	Erosion measured in millimeters per year
6.	Y	Per capita income measured by real GDP divided by population
7.	POPGRT	Population growth rate measured as annual percentage change in population.
8.	TRO	Trade openness measured as the ratio of the sum of exports and imports to GDP
9.	FDI	Foreign direct investment measured in current U.S. dollars

4. RESULTS AND DISCUSSION

Descriptive statistics for each variable used in the study are presented in Table 4.1. These statistics include the mean, median, maximum, minimum, standard deviation, skewness, and kurtosis.

Table 4.1: Descriptive Statistics

Variables	**Mean**	**Min.**	**Max**	**Overall Std.**	**Skewness**	**Kurtosis**	**Coeffv.**
COE	0.621761	0.093119	0.916618	0.182079	-0.906840	4.017723	0.292844
ERO	83341.78	-9670.000	126060.0	33699.44	-1.283315	3.897530	0.404352
FOS	19.75084	15.85414	22.84479	1.508469	-0.134227	2.774739	0.076375
RED	6.448670	0.835361	17.72443	4.051964	0.684803	1.426979	0.628341
Y	1912.749	1388.535	2688.267	473.7247	0.325526	1.426979	1.405449
POPGT	2.577475	2.488785	2.709843	0.065115	0.266480	1.833608	0.025263
TRO	32.58685	9.135846	53.27796	11.83397	-0.455237	2.493556	0.363152
FDI	2.45E+09	-1.87E+08	8.84E+09	2.51E+09	1.198086	3.328820	1.024489

Source: *Authors' computation*, 2024.

Carbon dioxide emission in metric tons per capita has an average value of 0.623 with a standard deviation of 0.182, which shows that emission in metric ton per capita differs across the years that were considered in this study. The minimum value of carbon emission in metric ton per capita is 0.093, while the maximum value is 0.916. Amount of erosion has an average value of 83341.78 with a standard deviation of 33699.44, which shows that there is fluctuation in erosion in Nigeria over the years. The minimum value of erosion is -9670, while the maximum value of erosion is 126060. Fossil fuel as a percentage of total energy consumption on petroleum has an average value of 19.751 with a standard deviation of 1.508, which showed that there is significant difference in the value of fossil fuel over the years. The minimum value of fossil fuel is 15.854, while the maximum value of fossil fuel is 22.844. Resource depletion has an average value of 6.449, with a standard deviation of 4.052, which shows that there is minimal difference in resource depletion. The minimum value of resource depletion is 0.835, while the maximum value of resource depletion is 17.724.

Per capita income has average value of ₦1912.749 billion with a standard deviation of ₦473.72 billion, which suggests that there is wide variance in average standard of living in Nigeria within the considered period. The minimum value of per capita income is ₦1388.535 billion, while the maximum value of per capita income is ₦2688.267 billion. Population growth has an average value of 2.577 percent with a standard deviation 0.065 percent, which indicates minimal difference percentage growth of total population. The minimum value of total population is 2.488 percent, while the maximum value of total population is 2.709 percent. This shows that there has been steady population growth in Nigeria over years with the timeframe considered.

Trade openness as percentage of GDP has an average value of 32.587 percent with a standard deviation of 11.834, which implies that the values of trade openness do not deviate significantly from the mean value. The minimum value of trade openness is 9.135 percent, while the maximum value of trade openness 53.277 percent. Foreign direct investment has average value of -₦2.12 billion with a standard deviation of ₦2.13 billion, which suggests that there is wide variance in foreign direct investment in Nigeria within the considered period. The minimum value of foreign direct investment is -₦8.02 billion, while the maximum value of foreign direct investment is ₦751,578.

4.1 Correlation Analysis

Table 4.2 shows the correlation between every pair of the variables. The p-values of the correlation coefficient in Table 4.2 indicate the statistical significance of the correlation between each pair of the variables. The magnitude of the correlation coefficients (the highest being 0.66) and their corresponding p-values show that the explanatory variables are correlated but not perfectly correlated. Hence, the results obtained in this study were not affected by multicollinearity problem.

Table 4.2: Correlation Matrix

Correlation Probability	COE	ERO	FOS	RED	y	POPGT	TRO	FDI
COE	1.000							

ERO	0.663	1.000						
	(0.000)	-----						
FOS	-0.077	-0.157	1.000					
	(0.621)	(0.312)	-----					
RED	0.611	0.077	0.041	1.000				
	(0.000)	(0.622)	(0.789)	-----				
y	-0.176	0.563	-0.128	-0.415	1.000			
	(0.257)	(0.000)	(0.413)	(0.005)	-----			
POPGT	-0.501	-0.160	-0.203	-0.222	0.561	1.000		
	(0.000)	(0.305)	(0.191)	(0.151)	(0.000)	-----		
TRO	0.651	0.659	-0.215	0.398	0.169	-0.160	1.000	
	(0.000)	(0.000)	(0.165)	(0.008)	(0.276)	(0.304)	-----	
FDI	0.031	-0.277	0.389	-0.117	-0.544	-0.599	-0.406	1.000
	(0.842)	(0.071)	(0.009)	(0.452)	(0.000)	(0.000)	(0.006)	-----

Source: *Authors' computation, 2024*

4.2 Results of Diagnostic Tests

Table 3 reports the Augmented Dickey Fuller unit root test, which reveals that trade openness (TRO), foreign direct investment (FDI), carbon emission in metric tons per capita (COE), fossil fuel consumption (FOS), resource depletion (RED), amount of erosion (ERO), per capital income (y) and percentage of total population (POPGRT) follows the I(1) processes. This means that they are all stationary at first difference at 1% level of significance. This implies that they are non-stationary series. The results of the Augmented Dickey Fuller indicates that the order of integration of the variables follows I(1) series which is the short-term dynamics or the rate of change rather than the absolute levels of the variable. Therefore, the study proceeded to test for the presence of cointegrating relationship among the underlying variables. As a result, the co-integration test was conducted using the threshold co-integration to assess the possibility of a long-run relationship in the model.

Table 4.3: Results of the Augmented Dickey-Fuller Unit Root Test (ADF-URT)

Variables	Unit Root at Level		Unit Root at First Difference		
	Test statistic	***p*-value**	**Test Statistic**	***p*-value**	**I(*d*)**
COE	-2.971807	*p>0.1*	*-4-558869*	*P<0.01****	I(1)
ERO	-2.758165	*p>0.05*	-5.773313	*P<0.01****	I(1)
FOS	-2.810891	*p>0.05*	-6.627115	*p<0.05****	I(1)
RED	-2.534194	*p>0.05*	-8.367274	*p<0.01****	I(1)
y	-2.220312	*p<0.5*	-3.727035	*p<0.05****	I(1)
POPGT	-0.961445	*p>0.5*	-4.753455	*p<0.01****	I(1)
TRO	-2.489402	*p>0.5*	-7.863688	*p<0.01****	I(1)
FDI	-1.751144	*p>0.5*	-8.349656	*p<0.01****	I(1)

Notes: ***and ** denote the rejection of null hypothesis at $p < 0.01$ and $p < 0.05$ significance level, respectively.

Source: Authors' computation, 2024.

4.2.2 Threshold Testing Approach to Cointegration

This study adopts the threshold cointegration tests, which allows for combining linear and non-linearity adjustment and cointegration to long-run equilibrium. The study tested for the presence of threshold effect (the null of linearity). The result of Threshold Boswijk (BO) cointegration test is presented in Table 4.4.

Table 4.4: Threshold Cointegration

	F-statics	P-value
Equation 1	13.9780	0.0000
Equation 2	7.3929	0.0066
Equation 3	11.3322	0.0000
Equation 4	27.2520	0.0000

Source: Authors' computation, 2024.

Table 4.4 presents the cointegration results for the two models specified for this study. Each of the models was estimated for four equations. It reveals long-run relationship between carbon dioxide emission in metric tons per capita, fossil fuel consumption, resource depletion, amount of erosion and the independent variables, which were divided into two (linear and non-linear variables). The non-linear variable are y and GRGDP while all other variables are linear.

The F-statistics of the threshold cointegration in COE equation is 13.9780 with associated p-value of 0.0000 which indicates that there is presence of long-run relationship between carbon dioxide emission in metric tons per capita and the independent variables. For the FOS equation, the F-statistics of the threshold cointegration is 7.3929 with associated p-value of 0.0066. The implication of this is that fossil fuel consumption and the independent variables have long-run relationship as indicated by the test statistic. The RED equation showed that the F-statistics of the threshold cointegration is 11.3322 with associated p-value of 0.0000. This indicates that there exists a long-run relationship between resource depletion and the independent variables. Lastly, the ERO Equation showed that the F-statistics of the threshold cointegration is 27.2520 with associated p-value of 0.0000, which implies that there is presence of long-run relationship between amount of erosion and the independent variables.

Based on this outcome, the study proceeded to estimating the model using threshold regression, results of which are presented next.

4.3 Estimation Results

Presented in Table 4.5 are the results estimated for Carbon emissions (COE), fossil fuel consumption (FOS), resource depletion (RED), and amount of erosion (ERO) with the same set of independent variables of per capital income, growth rate of real GDP, population growth, trade openness and foreign direct investment.

4.3.1 Results Estimated from the COE Equation

As it can be seen from Table 4.5, the R-squared in the carbon emission in metric tons per capita in equation 1 in model 1 is 0.7055, which implies that 70.55 percent variation in carbon emission in metric tons per capita is explained by the independent variables (per capita income, population growth rate, trade openness, foreign direct investment). The F-statistics is 13.978 with an associated p-value of 0.000. This indicates the overall statistical significance of the equation, with the model indicating high goodness of fit or explanatory power. With regards to the normality of the data, the JarqueBera test was employed to test whether data are normally distributed. The statistic value of 2.2891 with an associated p-value of 0.1025 indicates normality of data, which makes the study concludes that the variables are normally distributed. In terms of presence or absence of autocorrelation of the residuals, the study carried out Breusch-Godfrey Serial Correlation LM test. The statistic value of 5.983 with an associated p-value of 0.0575 led to the conclusion that there is absence of autocorrelation in the carbon dioxide emission in metric tons per capita equation. Furthermore, concerning the presence or absence of heteroskedasticity of the residuals, the study carried out the Breusch-Pagan-Godfrey Heteroskedasticity test. The statistical value of 0.7092 with an associated p-value of 0.7294 implies that we accept the null hypothesis that heteroskedasticity is present in the model. Hence, it was concluded that heteroskedasticity does not exists in the equation.

Having just evaluated the overall diagnostic statistics of the equation, the study now proceeds to examine the performance of the explanatory variables in the equation.

Table 4.5: Threshold Regression Results

Variables	**ENVIRONMENTAL INDICATORS** **Equation 1**	**Equation 2**	**Equation 3**	**Equation 4**
	Carbon emission in metric tons per capita	Fossil fuel consumption	Resource depletion	Amount of erosion
	Threshold Variables			
	lny < 7.413535	lny < 7.285005	lny < 1.794254	lny< 1.794254
lny t-statistics p-values	0.000537 (0.484) [0.6312]	0.000325 (1.370) [0.0134]***	-0.0015 (-5.158) [0.0000]***	0.000588 (3.916) [0.0004]***
	7.413535 < lny	7.285005 < lny	1.794524 < lny	1.794524 < lny
lny t-statistics p-values	0.000425 (2.362) [0.0239]***	-0.124 (-1.875) [0.0275]***	0.098 (0.387) [0.3170]	0.002881 (2.3829) [0.0022]***
	Non-Threshold Variables			
POPGRT t-statistics p-values	-2.617641 (-2.956) [0.0056]***	-0.611 (-3.037) [0.0045]	2.461 (1.367) [0.1800]	-1.325 (-1.223) [0.2296]
lnTRO t-statistics p-values	0.167140 (2.3318) [0.0256]***	-0.076 (-2.821) [0.0078]***	0.762 (3.135) [0.0034]***	0.825 (6.299) [0.0000]***
lnFDI t-statistics p-values	0.402047 (3.235) [0.0027]***	-0.016 (-1.069) [0.2925]	0.269 (1.868) [0.0696]***	-0.0571 (-0.7089) [0.4831]
C t-statistics p-values	0.190177 (0.084) [0.9336]	5.257 (10.538) [0.0000]***	-2.913 (-2.128) [0.0281]***	10.9023 (2.2120) [0.0001]***
R-squared F-Statistic (p-value) Normality (p-value) Serial Correlation Heteroskedasticity Test	0.7055 13.978 (0.000) 2.2891 (0.1025) 5.9829 (0.0575) 0.7092 (0.7294)	0.5589 7.3929 (0.0000) 0.6495 (0.7226) 1.3225 (0.2845) 1.6232 (0.1437)	0.5506 11.3322 (0.000) 0.8546 (0.6522) 3.4206 (0.0486) 2.7277 (0.0148)	0.7569 27.252 (0.0000) 1.3651 (0.5053) 0.8698 (0.4313) 1.2049 (0.3291)

Source: Authors' computation, 2024.

a) Per capital income (y): This is the threshold variable with the threshold value obtained being 7.4135. The coefficient of per capita income when less than threshold value of 7.41 is not statistically significant, while it is positive and statistically significant when greater than the threshold value. Thus, this implies that a percentage point increase in per capita income would lead to a percentage increase in carbon emission in metric tons per capita beyond the threshold level of 7.41. This result is in line with the a priori expectation postulated in Chapter three, where a positive relationship is posited. This conform to the findings of Grossman and Krueger (1991), Olusegun (2009) and Hassan, et al. (2011).

b) Annual Percentage of Total Population (POPGRT): As it can be seen from the Table 4.5, the coefficient of POPGRT is -2.618 with an associated p-value of 0.0056. This indicates that the coefficients of population growth is negative and statistically significant. The implication of this is that a percentage point increase in population growth will bring about a 2.618 percentage decrease in carbon dioxide emission in metric tons per capita. The study concludes that population growth have significant effect on carbon emission in metric tons per capita in Nigeria. Thus, this findings is not in line and conformity with the a priori expectation as well as the findings reported by Aiyetan and Olomola (2015) who reported that population growth had a positive effect on carbon emission. However, it is seen that a percentage growth in population leads to increased urbanization in Nigeria as urban areas tend to have more concentrated and efficient infrastructure, reducing the need for extensive energy use compared to sparsely populated area. Urbanization promote public transportation, energy-efficient buildings, and centralized services, contributing to lower carbon dioxide emissions per capita. This also shows that when there is better access to education and information, this lead to higher levels of environmental awareness. This awareness can drive individuals to adopt more sustainable practices and support policies that reduce carbon dioxide emission.

c) Trade Openness (TRO): It could be seen in the Table 4.5 above that the coefficient of TRO is 0.167 with an associated p-value of 0.0044. This indicates that the coefficient of TRO is positive and statistically significant. The implication of this is that a percentage point increase in TRO will lead to a 0.167 percentage increase in carbon dioxide emission in metric tons per capita. The study concludes that TRO have significant effect on carbon dioxide emission in metric tons per capita in Nigeria. This result is in line with the a priori expectation postulated in Chapter three, where a positive relationship is posited. This conforms to the findings of Chandran and Tang (2013), Karssalari, (2014) and Muftau, et al. (2014).

d) Foreign Direct Investment (FDI): Table 4.5 shows that FDI had a positive coefficient of 2.71 with an associated p-value of 0.0256. It implies that FDI is statistically significant. The logical explanation of this is that a percentage point increase in FDI will lead to a 2.71 percentage increase in carbon dioxide emission in metric tons per capita. This result is in line with the a priori expectation postulated in Chapter three, where a positive relationship is posited. This conforms to the findings of Chandran and Tang (2013), Karssalari, (2014) and Muftau, et al. (2014).

4.3.2 Results Estimated from the FOS Equation

As it can be seen from Table 4.5, the R-squared in the fossil fuel Consumption in equation 2 in model 1 is 0.5589, which implies that 55.89 percent variation in fossil fuel consumption is explained by the independent variables (per capita income, population growth, trade openness and foreign direct investment. The F-statistics is 7.3929 with an associated p-value of 0.0000. This indicates the overall statistical significance of the equation, with the model indicating high goodness of fit or explanatory power. With regards to the normality of the residual, the JarqueBera test was employed to test of the data are normally distributed. The statistic value of 0.6495 with an associated p-value of 0.7226 indicates normality of residual, which makes the study concludes that the variables are normally distributed. In terms of presence or absence of autocorrelation of the residuals, the study carried out Breusch-Godfrey Serial Correlation LM test. The statistic value of 1.3225 with an associated p-value of 0.2845 led to the conclusion that there is absence of autocorrelation in the fossil fuel consumption equation. Furthermore, concerning the presence or absence of heteroskedasticity of the residuals, the study carried out the Breusch-Pagan-Godfrey Heteroskedasticity test. The statistical value of 1.6232 with an associated p-value of 0.1437 implies that we accept the null hypothesis that heteroskedasticity is present in the model. Hence, it was concluded that heteroscedasticity does not exists in the equation.

a) Per capital income (y): This is the threshold variable with the threshold value obtained being 27.2850. The coefficient of per capita income when less than threshold value of 7.285 is statistically significant, while it is negative and statistically significant when greater than the threshold value. Thus, this implies that a percentage increase in per capita income would lead to a percentage decrease in fossil fuel consumption beyond the threshold level of 7.285 because this suggests that at the early stages of economic progress, environmental degradation and pollution increases with increment in per capita income, but after some level of per capita income, there exists reversal in the trend and environmental degradation thus reduce with increases in per capita income. This result is in line with the a priori expectation postulated in Chapter three, where a positive relationship is posited. This conforms to the findings of Grossman and Krueger (1991), Olusegun (2009), Omojolabi (2010) and Hassan et al. (2011).

b) Annual Percentage of Total Population (POPGRT): As it can be seen from the Table 4.5, the coefficient of POPGRT is -0.611 with an associated p-value of 0.0045. This indicates that the coefficients of population growth is negative and statistically significant. The implication of this is that a percentage point increase in population growth will bring about a 0.611 percentage decrease in fossil fuel consumption. The study concludes that population growth have significant effect on fossil fuel consumption in Nigeria. Thus, this findings is not in line and conformity with the a priori expectation as well as the findings reported by Aiyetan and Olomola (2015) who reported that population growth had a positive effect on carbon dioxide emission.

c) Trade Openness (TRO): The coefficient of TRO is -0.076 with an associated p-value of 0.0078. This indicates that the coefficient of TRO is negative and statistically significant. The implication of this is that a percentage increase in TRO will lead to 0.076 percentage increase in fossil fuel consumption. The study concludes that TRO have significant effect on fossil fuel consumption in Nigeria. This result is in line with the a priori expectation postulated in Chapter three, where a positive relationship is posited. This conform to the findings of Chandran and Tang (2013), Karssalari, (2014) and Muftau, et al. (2014).

d) Foreign Direct Investment (FDI): Table 4.5 shows that FDI had a positive coefficient of 5.257 with an associated p-value of 0.0000. It implies that FDI is statistically significant. The logical explanation of this is that a percentage point increase in FDI will lead to a 2.71 percentage increase in fossil fuel consumption. This result is in line with the a priori expectation postulated in Chapter three, where a positive relationship is posited. This conforms to the findings of Chandran and Tang (2013), Karssalari, (2014) and Muftau, et al. (2014).

4.3.3 Results Estimated from the RED Equation

As it can be seen from Table 4.5, the R-squared in the resource depletion in equation 3 in model 1 is 0.5506, which implies that 55.06 percent variation in resource depletion is explained by the independent variables (per capita income, population growth, trade openness and foreign direct investment. The F-statistics is 11.33 with an associated p-value of 0.000. This indicates the overall statistical significance of the equation, with the model indicating high goodness of fit or explanatory power. With regards to the normality of the residual, the JarqueBera test was employed to test of the data are normally distributed. The statistic value of 0.8546 with an associated p-value of 0.6522 indicates normality of residual, which makes the study concludes that the variables are normally distributed. In terms of presence or absence of autocorrelation of the residuals, the study carried out Breusch-Godfrey Serial Correlation LM test. The statistic value of 3.4206 with an associated p-value of 0.0486 led to the conclusion that there is presence of autocorrelation in the resource depletion equation. Furthermore, concerning the presence or absence of heteroskedasticity of the residuals, the study carried out the Breusch-Pagan-Godfrey Heteroskedasticity test. The statistical value of 2.7277 with an associated p-value of 0.0148 implies that we reject the null hypothesis that heteroskedasticity is absent in the model. Hence, it was concluded that heteroscedasticity exists in the equation.

Having just evaluated the overall diagnostic statistics of the equation, the study now proceeds to examine the performance of the explanatory variables in the equation.

a) Per capita income (y): This is the threshold variable with the threshold value obtained being 1.79. The coefficient of per capita income when less than threshold value of 1.79 is statistically significant, while it is also positive and statistically significant when greater than the threshold value. It implies that a percentage point increase in per capita income would lead to percentage decrease in resource depletion above the threshold level of 1.79. This result is in line with the a priori expectation postulated in Chapter three, where a positive relationship is posited. This conforms to the findings of Grossman and Krueger (1991), Olusegun (2009) and Hassan, et al. (2011).

b) Annual Percentage of Total Population (POPGRT): As it can be seen from the Table 4.5, the coefficient of POPGRT is 2.461 with an associated p-value of 0.1800. This indicates that the coefficients of POPGRT is positive but not statistically significant. This is not in line with priori expectation which postulated a negative relationship between resource depletion and economic growth and not in line with the previous studies as Borhana et al. (2012) and Saidi and Hammami (2017) have reported.

c) Trade Openness (TRO): It could be seen in Table 4.5 above that the coefficient of TRO is 0.762 with an associated p-value of 0.0034. This indicates that the coefficient of TRO is positive and statistically significant. The implication of this is that a percentage increase in TRO will lead to 0.762 percentage increase in resource depletion. The study concludes that TRO have significant effect on resource depletion in Nigeria. This result is in line with the a priori expectation postulated in Chapter three, where a positive relationship is posited. This conform to the findings of Chandran and Tang (2013), Karssalari, (2014) and Muftau, et al. (2014).

d) Foreign Direct Investment (FDI): Table 4.5 shows that FDI has a positive coefficient of 0.269 with an associated p-value of 0.0696. It implies that FDI is statistically significant. The logical explanation of this is that a percentage point increase in FDI will lead to a 0.269 percentage increase in resource depletion. Thus, this findings is in line and conformity with the a priori expectation as well as the findings reported by Chandran and Tang (2013), Karssalari, (2014) and Muftau, et al. (2014) who reported that foreign direct investment had a positive effect on carbon emission.

4.3.4 Results Estimated from ERO Equation

As it can be seen from Table 4.5, the R-squared in the amount of erosion model in equation 4 in model 1 is 0.7569, which implies that 75.69 percent variation in amount of erosion is explained by the independent variables (per capita income, population growth, trade openness, and foreign direct investment). The F-statistics is 27.252 with an associated p-value of 0.000 which indicates the overall statistical significance of the equation, with the model indicating high goodness of fit or explanatory power. With regards to the normality of the data, the Jarque-Bera test was employed to test if the data are normally distributed. The statistic value of 1.3651 with an associated p-value of 0.5053 indicates normality of data, which makes the study concludes that the variables are normally distributed. In terms of presence or absence of autocorrelation of the residuals, the study carried out Breusch-Godfrey Serial Correlation LM test. The statistic value of 0.8698 with an associated p-value of 0.4313 led to the conclusion that there is absence of autocorrelation in the amount of erosion equation. Furthermore, concerning the presence or absence of heteroskedasticity of the residuals, the study carried out the Breusch-Pagan-Godfrey Heteroskedasticity test. The statistical value of 1.2049 with an associated p-value of 0.3291 implies that we accept the null hypothesis that heteroskedasticity is present in the model. Hence, it was concluded that heteroskedasticity does not exists in the equation. Having just evaluated the overall diagnostic statistics of the equation, the study now proceeds to examine the performance of the explanatory variables in the equation.

a) Per capita Income (y): Per capita income was found to be significant when it is less than the threshold value of 1.794, and statistically significant when greater than the threshold level. Therefore, it was concluded that a percentage increase in per capita income will lead to 0.0005 percentage increase in amount of erosion below the threshold level value of 1.794. This result is in line with the a priori expectation postulated in Chapter three, where a positive relationship is posited. This conform to the findings of Grossman and Krueger (1991), Olusegun (2009) and Hassan et al. (2011).

b) Annual Percent of Total Population (POPGRT): As it can be seen from the Table, the coefficient of population growth is -1.325 with an associated p-value of 0.0296. This indicates that the coefficient of POPGRT is negative and statistically significant. The implication of this is that a percentage point increase in POPGRT will bring about a percentage decrease in amount of erosion by 118385.2. The study concludes that POPGRT have significant effect on amount of erosion in Nigeria. Thus, this findings is not in line and conformity with the a priori expectation as well as the findings reported by Aiyetan and Olomola (2015) who reported that population growth had a positive effect on amount of erosion. As the population increases, there is often a greater demand for land to support housing, agriculture, and infrastructure. Increased agricultural activities, especially if not managed sustainably, can lead to deforestation, overgrazing, and the conversion of natural landscapes into cultivated areas. These practices expose the soil to erosion by removing vegetation that helps bind the soil together.

c) Trade Openness (TRO): It could be seen in the Table that the coefficient of TRO is 0.825 with an associated p-value of 0.000. This indicates that the coefficient of TRO is positive and statistically significant. The implication of this is that a percentage increase in TRO will lead to a percentage increase in Amount of erosion by 0.825. The study concludes that TRO have significant effect on Amount of erosion in Nigeria. This result is in line with the a priori expectation postulated in Chapter three, where a positive relationship between trade openness and amount of erosion is posited. This conforms to the findings of Chandran and Tang (2013), Karssalari, (2014) and Muftau, et al. (2014).

d) Foreign Direct Investment (FDI): Table 4.5 shows that FDI has a negative coefficient of -0.0571 with an associated p-value of 0.4831. It implies that FDI is not statistically significant and this result is not in line with the a priori expectation postulated in Chapter three, where a positive relationship is posited. However, this does not also conform to the findings of Chandran and Tang (2013), Karssalari, (2014) and Muftau, et al. (2014).

5. CONCLUSION

The study examines the intricate relationship between economic growth and environmental degradation in Nigeria, focusing on testing the Environmental Kuznets Curve (EKC) hypothesis. Empirical findings reveal that per capita income exhibits threshold effects on environmental indicators, including resource depletion, carbon dioxide emissions, and erosion. While per capita income aligns with the EKC assumption in specific cases, inconsistencies are observed across other indicators, underscoring the complexity of the economic-environmental nexus. Trade openness and foreign direct investment also significantly contribute to environmental degradation, particularly in carbon emissions and resource depletion.

Population growth, intriguingly, shows a negative effect on certain environmental degradation indicators, suggesting that sustainable consumption patterns, technological advancements, and conservation efforts can mitigate environmental harm. However, trade openness amplifies degradation, emphasizing the need for responsible supply chain practices and sustainable trade policies. Similarly, while foreign direct investment spurs economic activity, its environmental impact necessitates fostering green innovations and eco-friendly practices.

The study concludes that context-specific strategies, such as adopting green technologies, enforcing stringent regulations, and promoting circular economies, are critical for achieving sustainable economic growth. It also highlights the potential of sustainable population policies and environmentally conscious investments to address environmental challenges effectively. Despite these insights, the study recognizes limitations, including data scarcity, regional diversity, and socio-political complexities, which affect the reliability of conclusions.

The EKC framework underscores the dual potential of economic growth to exacerbate and alleviate environmental degradation, emphasizing the importance of localized methodologies and future research. Expanding the scope to Sub-Saharan Africa or comparing findings across diverse economies could provide broader perspectives. Additionally, incorporating alternative environmental indicators, such as air and water pollution, and leveraging micro-level or cross-sectional data could refine understanding and inform more targeted policy interventions. Future research should focus on integrating broader variables and advanced models to understand the EKC in Nigeria more fully. Such research could provide a foundation for policies that balance economic growth with environmental sustainability, guiding Nigeria toward sustainable development and improved environmental quality.

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