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Environmental degradation, renewable energy consumption, fossil fuels, urbanization, and economic growth: Assessing the validity of EKC in Nigeria

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Abstract
This study empirically investigates the linkage among renewable energy consumption, fossil fuels, and urbanization and CO_2 emissions in Nigeria using Autoregressive Distributed Lags (ARDL) model ranging from 1990 to 2023. The Bounds Test shows that there exists a long run equilibrium relationship among the variables as the F-statistic value is greater than the upper bound critical values at 1% and 5% levels of significance. The findings validate the EKC hypothesis supports the existence of U-shaped relationship between CO_2 emissions and GDP per capita in both long run and short run. Unexpectedly, the fossil fuels use decreases the level of CO_2 emissions in Nigeria in the long run; but increases it in the short run. Not surprisingly, clean energy consumption significantly reduces environmental pollution in time dynamics of long and short run. As more people move from rural to urban centers, the economic activities increase; and our findings reveal a significant positive relationship between urbanization and CO_2 emissions in the long run. Based on the empirical results and findings, the study recommends that Nigeria's energy policy should, without restrictions, further encourage the use of clean and environmentally friendly energy source and further increase the awareness of the negative health deficit environmental pollution has on the people.
Keywords: ARDL, Carbon emissions, EKC Hypothesis, REC

1. Introduction

The unfavorable and unpalatable condition brought about by ecological footprints and ecosystems changes has a degrading effect on global populations and economic structures of future generations, which has called for an immediate and result-oriented global actions. Both emerging economies and highly industrialized ones are being affected immensely due to high level of emissions and environmental deterioration caused by the economic activities of human (Udeagha and Muchaponda, 2022). According to World Bank, (2021), green gas emissions (GHG hereafter) like environmental pollution caused by ecological footprints have increased dramatically in the last few years, rising about 34 billion tons, up from 22 billion tons in 1990 each year. Given that every country's precise and most cogent aim is to boost economic growth through higher output, maintain a low and stable inflation rate, raise living standards, and keep a positive balance of payments, environmental and climatic conditions still remains an unarguable key in achieving all of these macroeconomic goals. Human activities will always degrade and nosedive environmental sustainability and upsurge carbon and ecological footprints whilst unclean and fossil energy sources are in place. The goals as contained and detailed in Sustainable Development of the United Nations which, all things being equal, must be achieved by 2030 have given credence and legitimatize the need to immediately and holistically act for panacea to curb and forestall the deteriorating effect of addressing global warming by giving environmentally-friendly energy source, lasting economic prosperity, and modernized and technical advancement top priority through the smooth coming together of the tripartite of the socio-economic-environmental sustainability (Udeagha and Breitenbach, 2023).

Maintaining and striking a lasting balance between GDP-induced developmental growth and environmental sustainability has become an interesting debate among economists, environmentalists, and energy professionals. Among the most significant obstacles that policymakers, governments, and stakeholders face is achieving economic growth that is sustainable and environmentally-friendly. Nigeria, due to its dependent on fossil fuels usage, is bedeviled with severe environmental deterioration and economic growth that is not sustainable (Yusuf, 2023). On this wise, fostering sustainable economic growth that results in low carbon emissions should be the core of Nigeria's government and policymakers. Synergizing energy, economics and the environment in a country that is fossil fuels dependent like Nigeria and to curb the health deficit that the high carbon emissions cause remains a structural problem that requires a systemic and holistic economic approach. Over the years, foreign investors have seen Nigeria as a haven for polluting industries due to its weak and porous environmental laws and regulations (Nathaniel and Iheonu, 2019). In a chain effect, capital inflows from other countries into Nigeria bring about technological advancement, which will later translate into economic growth, and as the economy is growing, demand for energy use increases at first.

The motivation behind this paper is routed around the empirical testing whether EKC is valid or not in Nigeria, and some other reasons. One, to analytically investigate on how to sustainably accomplish economic growth by regulating greenhouse emissions, which advocates for a carbon-reduction productive system coupled with scanty empirical studies on the environmental effect of socioeconomic variables on Nigeria, and divergent views from extant research are what motivated the present study, hence, this study is poised to fill the gap and contribute to the existing empirical energy-environmental debate. Two, in November, 2021, the recent environmental regulations of Climate Change Act of 2021 that seeks to achieve low greenhouse gas emission, green and sustainable growth. With this newly passed environmental act, it cannot be said that carbon emissions in Nigeria have gone down (Okereke and Onuigbo, 2021). Thirdly, as one developing country with vast natural and mineral resources, more empirical studies need to be carried out to examine and investigate how environmental quality can be achieved while maintaining a sustainable level of growth. This study is further sectionalized into parts which are: reviews of the literature and hypotheses development, methodology used in the study, empirical results and discussions, and lastly, conclusion.

2. Theoretical Framework and Hypotheses Development

2.1 Economic Growth and Carbon Emissions

In this study, Environmental Kuznets Curve was used as an underpinning theory to empirically explain the relationship between GDP per capita and carbon emissions as propounded by Simon Kuznets (1995).

In studying the connection and the linkage on the tripartite relationship among carbon footprints, economic growth and population growth, using ARDL econometric model, Singh et al., (2025) investigated the economic synergy among these variables in BRICS countries. The empirical results revealed significant impacts of population growth and GDP-induced growth on carbon footprints in South Africa, whilst in India, GDP-induced growth had effect on carbon and ecological footprints. On the flipside, Russia, Brazil and China did not have an empirical credence of co-integration in this study. The empirical findings are not applicable to Nigeria because of its economic peculiarities. Hence, the need for separate study on Nigeria.

In the same vein, Udo et al., (2024) unveiled the empirical relationship between economic growth and carbon footprints in MINT countries using panel nonlinear autoregressive distributed lags (PNARDL) from 1990 to 2023. The findings revealed that a nonlinear nexus stipulating that green energy sources dissipate carbon emissions. Also, it reduces environmental deterioration on the wings of clean energy as the empirical result validates the Environmental Kuznets Curve hypothesis in MINT countries. In South Africa, a study by Udeagha and Muchaponda, (2022) on the empirical nexus between carbon emissions and fiscal decentralization from 1960-2020, using dynamic ARDL simulation. The findings revealed that the different time dynamics in short run and long run financial development in South Africa improves environmental sustainability and ecological integrity. Also, in assessing the validity of EKC hypothesis, Kanli and Kucukefe, (2023) assessed the EKC hypothesis validity, using a global analysis for carbon emissions. It was found out that countries with high level of income has validity for EKC hypothesis, while in China, the EKC hypothesis is invalid.

Adebayo et al., (2021) linked economic growth, urban population, and environmental deterioration, asking an empirical question; what does the role of hydroelectricity consumption entail in China? The study used ARDL, analyzing the data from 1985-2019. It was found out that economic growth and urbanization increase environmental deterioration, signifying the empirical prevalence of EKC hypothesis in China.

H1: there is a significant relationship between economic growth and carbon emissions

2.2 Renewable Energy Consumption and Carbon Emissions

Yusuf, (2023) investigated the dynamic impact energy consumption, economic growth, foreign trade and urbanization has on environmental degradation in Nigeria from 1980-2020. Using ARDL with the presence of structural breaks, the empirical results revealed the presence of EKC hypothesis in Nigeria. In Nigeria, the relationship among urbanization, GDP-induced growth, carbon footprints, and energy consumption ranging from 1997 to 2017 was empirically examined by Akorede and Afroz (2020), using Granger Causality and ARDL econometric methodology. The findings revealed that EKC hypothesis is invalidated in Nigeria as economic growth has an unfavorable impact on carbon emissions both in the short run and in the long run time dynamics. Ganda (2019) investigated carbon emissions, diverse energy usage and economic growth in South Africa: investigating existence of the EKC hypothesis in South Africa, from 1980-2014, using ARDL and Johansen Co-integration. The results demonstrated that, over time, the EKC theory contradicts the environmental and GDP per capita income nexus in South Africa. Studying the economic interplay among ecological footprints, population growth and renewable energy in 46 African countries, Nguea, (2024) used a synthesis of some econometric methodologies such as IV-GMM and MMQR panel estimations. The empirical results revealed that carbon emissions is upsurge by urbanization, whilst the usage of clean and renewable energy enhances environmental sustainability.

H2: there is a significant relationship between renewable energy consumption and carbon emissions

2.3 Fossil fuels and Carbon Emissions

Hanif et.al., (2019) studied the impact of urbanization, fossil fuels consumption, and economic expansion on ecological footprints in sub-Saharan Africa between 1995 and 2015, the empirical findings of a panel of 34 emerging economies using GMM econometric analysis demonstrated that the use of solid and fossil fuels for cooking, as well as the expansion of metropolitan areas, are mostly responsible for carbon footprints. Fully Modified coupled with Dynamic OLS were used as econometric methodology to validate the EKC hypothesis in Japan starting from 1965 through to 2019, Adebayo et. al., (2021) found out fossil fuels and non-renewables increase the deterioration of the environment while giving credence to the validity of EKC theory in Japan. In Pakistan, environmental sustainability's reaction to sectoral carbon emissions was analyzed, ranging from 1971 to 2014 by Ali and Mujahid (2024), using STIRPAT methods and ARDL econometric technique to assess the nature of the linkage and connection, the findings revealed that independent variables are the main contributors to environmental pollution as a result of high consumption of fossil fuels. The validity of EKC hypothesis was not tested in the study.

H3: there is a significant relationship between fossil fuels and carbon emissions

3. Methodology

Annual time series data from 1990-2023 are used in this study. Among the factors are carbon emissions (measured in metric tons from cement production and the incineration of fossil fuels), GDP per capita, the percentage of energy consumed by renewable sources, fossil fuels, urbanization, and trade openness. Data on all the variables were sourced from World Development Indicators (World Bank, 2023), CBN Statistical Bulletin, 2023 and National Bureau of Statistics, 2023. The basis of time frame was hinged on the availability of data.

Degradation of the environment is proportional to GDP and GDP squared is the conventional EKC hypothesis. The theoretical framework of this study is derived from the works of Hanif et al., (2019), Ahmed and Long (2012), Fodha and Zaghdoud (2010).

A modified version of environmental Kuznets curve theory is used to build the model, and its generalized functional form is as follows:

$$CO_2 = f(GDP, GDP^2, \omega) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

The EKC model's functional form can be transformed into an econometric model in the manner described below:

$$InCO_{2t} = \beta_0 + \beta_1 InGDP_t + \beta_2 InGDP_t^2 + \omega_k \pi_t + \mu_t \ldots\ldots\ldots\ldots. (2)$$

From equation 3.2, π_t is the group of extra variable under control, ω_k is the additional control variables' slope and μ_t is the error term and 't' is the time period. More so, the extended version of our model to empirically assess the validity of the EKC hypothesis in Nigeria, with log applied on both sides, can be expressed as follows:

$$InCO_{2t} = \beta_0 + \beta_1 InGDP_t + \beta_2 InGDP_t^2 + \beta_3 InTO_t + \beta_4 REC_t + \beta_5 FOS_t + \beta_6 URB_t + \mu_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where β_0 is the intercept and β_1 to β_6 are the coefficient to be estimated, and μ_t is the error term.

In the equation 3.3 above, Carbon emissions is employed as the dependent variable and, after reviewing all of the literature, as a proxy or indicator for environmental degradation. Whether or not the EKC hypothesis is true is indicated by the nature of the relationship between economic growth and CO_2 emissions. To validate the existence of EKC hypothesis in the carbon emission-economic growth nexus, the relationship must be positive; to invalidate it, it must be negative (Hanif et al., 2019; Acheampong et al., 2019). The theoretical justification of the inclusion of urbanization, trade openness and energy consumption is explained within the confines of EKC hypothesis. As economy grows and per capita income rises, people tend to settle for clean energy sources with zero or low carbon emissions. Influx of people into urban centers from rural areas causes increases in the infrastructural usage in the urban centers, and so increases economic activities which result in polluting the air and increases carbon emissions. A nation does not operate in isolation; it must interact with the rest of the world. Trade openness shows the degree of import to export in a small open economy like Nigeria.

3.1 ARDL Estimation

This study used an ARDL econometric model put forward by Pesaran et al., (2001). As specified in the (p,q) model, the econometric model is as follow:

$$Y_t = \varphi_0 + \sum_{i=1}^{p} \eta_i Y_{t-i} + \sum_{i=0}^{q} \delta'_i X_{t-i} + \varepsilon_t \dots\dots\dots\dots\dots\dots\dots\dots (4)$$

Where φ_0 represents the intercept, Y_t is the dependent variable, X_t is the explanatory variables' vector, η_i is a vector that is scalar, and δ'_i is a vector of coefficients while p and q represents the lag component of both dependent and independent variables' respective structure. The ε_t is the zero mean, finite variance error term.

The equation 4 which represents and the following details the error correction model's short and long term estimates:

$$\Delta Y_t = \varphi_0 + \zeta(Y_{t-1} - \varsigma') X_t) + \sum_{i=1}^{p-1} \eta_i \Delta Y_{t-i} + \sum_{i=0}^{q-1} \delta_i' \Delta X_{t-i} + \varepsilon_t \dots\dots\dots (5)$$

With $\zeta - (1 - \sum_{i-1}^{p} \eta_i)$, and κ = $\sum_{i-0}^{q} \delta_i \,/\, \zeta$, κ indicates long run estimate of the explanatory variables while δ_i^ represents the short-term estimates and ζ denotes the error correction mechanism effect. Δ is the difference operator. The overall form of the ARDL model in this study is as follows, and it is based on the model provided in equation 3:

$$InCO_{2t} = \beta_0 + \sum_{i=1}^{p} \alpha_1 In(CO_2) \quad {}_t + \sum_{i=0}^{q1} \beta_1\, InGDP_t + \sum_{i=0}^{q2} \beta_2 InGDP_t^2 + \sum_{i=0}^{q3} \beta_3\, InTO_t + \sum_{i=0}^{q4} \beta_4\, REC_t + \sum_{i=0}^{q5} \beta_5\, FOS_t + \sum_{i=0}^{q6} \beta_6\, URB_t + \mu_t \dots\dots\dots\dots\dots\dots\dots\dots (6)$$

Where p represents the lag of the dependent variable; q1-q6 specifies the lag of the regressors; β_0 is the intercept, and α_1, β_1 to β_6 are the variables that need to be calculated.
Consequently, with the following unrestricted error correction model, ARDL technique is used to differentiate short-and long term estimates

$$\Delta InCO_{2t} = \beta_0 + \sum_{i=1}^{r0} \phi_0 \Delta In(CO_2) \quad {}_t + \sum_{i=0}^{r1} \phi_1\, \Delta InGDP_t + \sum_{i=0}^{r2} \phi_2\, \Delta InGDP_t^2 + \sum_{i=0}^{r3} \phi_3\, \Delta InTO_t + \sum_{i=0}^{r4} \phi_4\, \Delta REC_t + \sum_{i=0}^{r5} \phi_5\, \Delta FOS_t + \sum_{i=0}^{r6} \phi_6\, \Delta URB_t + \varphi_0 InCO_{2t-i} + \varphi_1 InGDP_t + \varphi_2 InGDP_t^2 + \varphi_3 InTO_t + \varphi_4 REC_t + \varphi_5 FOS_t + \varphi_6 URB_t + \phi_7 ECM_{t-i} + \mu_t \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots. (7)$$

Where β_0 is the intercept; r_0 to r_6 $refer$ to the optimal lag length selected based on Akaike Information Criterion (AIC), ϕ_0 to $\phi_6 represnts\ the\ short\ ru\ ncoefficents$ to be estimated while φ_0 to $\varphi_6 represents\ the\ long\ ru\ ncoefficients$ to be estimated and (ECM_{t-1}) signifies the rate at which the short-term equilibrium path is adjusted to the long-term phase. To be reliable, it must be statistically significant and negative.

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4. Results and Discussion

4.1 Unit Root Test

In the words of (Nelson and Plosser, 1982), it is econometrically correct to firstly evaluate the variables' random-walk hypothesis because most of the macroeconomic time series are recognized to be non-stationary in nature.

Empirical results generated from the estimated model's non-stationary variables produce erroneous findings that are unsuitable for drawing conclusions.

The Augmented Dickey Fuller and Phillips Perron were the unit root tests used in this study. Using the ADF and PP tests for unit root in the following equation:

ADF Model: $\Delta Y_t = C_t + \vartheta Y_{t-1} + C_{2t} + \sum_{k-1}^{p} d_k \Delta Y_{t-k} + V_t;\ H_0: \vartheta = 0; H_1: b > 0 \dots\dots (8)$

PP Model: $\Delta Y_t = \varphi_t + \mathrm{p}Y_{t-1} + \varepsilon_t;\ H_0: \mathrm{p} = 0;\ H_1: \mathrm{p} > 0 \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (9)$

Y represents the time series data
Δ represents an operator for first difference;
t a linear trend
and V_t *and* ε_t *represents the eror terms*

Table 1. Unit root test

	Level		First Difference		Comment
Variables	ADF	PP	ADF	PP	
$InCO_2$	1.918	-1.896	-6.488***	0.000***	I(1)
InTO	-4.653***	-5.679***	-6.192***	-18.809**	I(0)
InGDP	-0.960	-0.654	-3.011**	2.987**	I(1)
$InGDP^2$	-2.238	-2.273***	-0.545	-2.716	I(0)
REC	-1.588	-1.554	-6.268***	-6.285***	I(1)
FOS	-3.914***	-6.289***	-2.751	-6.507	I(0)
URB	-0.591	-1.647***	2.523	-1.651	I(0)

*Note: For $InCO_2$, InGDP, $InGDP^2$, InTO, the line plots of the series indicate that trend and intercept should be included at levels while for their first differences, line graph indicates only intercepts can be included; for FOS and REC the plots of the series suggest that only constant term should be included at levels neither trend nor constant term should be included in the test equations for their first differences; *, ** and *** represents 10%, 5% and 1% respectively.*

4.2 Descriptive statistics

In Table 2, the variables are analyzed descriptively. Typically, the amount of carbon dioxide released in Nigeria is 18.4056 which is greater than what is available in certain African nations like Ghana, Mali, Ivory Coast, Benin, Congo DR (see World Bank, 2024). According to World Bank, 2024, comparatively speaking, Nigeria's average GDP per capita share of 7.58% is low when compared to the average GDP per capita shares of South Africa, Egypt, and Algeria. It was demonstrated by the Jarque Bera that every variable had a normal distribution.

The standard deviation results showed that all of the variables' values are less erratic than the corresponding mean value.

Table 2. Descriptive statistics of the variables

	$InCO_2$	InGDP	$InGDP^2$	InTO	FOS	REC	URB
Mean	18.406	7.589	14.344	3.169	19.272	84.379	40.959
Median	18.421	7.626	14.434	3.177	18.899	84.500	40.381
Maximum	18.634	7.893	14.901	3.584	22.845	88.600	54.283
Minimum	18.125	7.265	14.399	2.606	15.854	79.900	29.680
Std. Dev	0.143	0.235	1.342	0.219	1.534	2.694	7.806
Jarque Bera	1.314	4.020	8.129	0.315	1.262	2.440	2.590
Probability	0.476	0.134	0.232	0.815	0.532	0.281	0.274
Observation	34	34	34	34	34	34	34

Source: Authors' computation using e-view 10

4.3 ARDL Bounds Co-integration Test Results

The F-statistic (6.0391) is greater than the upper bound critical value at the 5% significance level (3.38), based on ARDL co-integration estimated results as depicted in the Table 3. Consequently, variables have a co-integration connection in long-term time dynamics.

Table 3. Co-integration Test Results

MODEL	F-Statistic	K	CRITICAL VALUES		
$InCO_2 = f(InGDP, InGDP^2, InTO, REC, FOS, URB)$			%	Lower Bound I(0)	Upper Bound I(1)
	6.0391		10%	2.08	3
		6	5%	2.39	3.38
			2.5%	2.7	3.73
			1%	3.06	4.15

Note: The actual sample size is 30; the finite sample is 30 and the p-values for 10%, 5% and 1% (both upper and lower critical values) are -1 all through. Reject H_0 and Accept H_1: Co-integration exists because the F-statistic is greater than the upper bound I (1) critical value at 5%

4.3 Autoregressive distributed lag estimation results

Since it was found that the variables have a co-integration connection, and over time estimates of gross domestic product per capita, urbanization, trade openness, consumption of renewable energy, and gross domestic product per capita squared were further estimated. Table 4 presents the long run estimate results.

The results showed that Nigeria's GDP per capita had a significant negative effect on carbon emissions. Holding all other factors constant, a 1% rise in GDP per capita will lower carbon dioxide emissions by around 0.56%. This result validates the EKC hypothesis in Nigeria as there is a negative significant relationship between GDP per capita and carbon emissions. The economic implication of this is that, as people's income rises, they become more aware about the health deficit of air pollution and opt for a clean and environmentally-friendly energy source. In addition, there is a sensitization about the health imbalance of having a robust economy at the expense of environmental well-being and sustainability. The empirical findings corroborate with the findings of Yusuf, (2023), Adebayo et al., (2021), Li & Haneklaus, (2022); Hanif, (2019); but the result conversed that of Dritsaki and Dritsaki, (2024), Kanli and Kucukefe, (2023), Akorede and Afroz, (2020), Ganda (2019). The Nigeria government should uphold still the sensitization of creating health awareness of the danger of using and advocating non-renewable energy consumption. Going forward, Nigeria government should keep at the recently enacted environmental regulation of 2021 that disincentive people for demanding for energy-intensive products.

Holding all other variables constant, a 1% increase in trade openness will result in a notable 0.28% reduction in carbon emissions. The findings corroborate the studies of Wang and Zhang (2021) and Sun et al., (2020). This implies that there is some level of protection for local industries to thrive, and consequently reducing the influx of polluting foreign industries. The Nigeria government should hold on to the environmental regulations on protectionism to constantly improve environmental quality.

Expectedly, the empirical result revealed a significant unfavorable connection which exists in the integration of carbon emissions and clean energy consumption. Holding all other factors constant, a 1% rise in renewable energy consumption will reduce carbon emissions by 0.05%. The empirical result is in tandem with that of Sharif et al., (2019). The implication of this is that people are more aware about the health benefits of environmental quality, and the sustainability of renewable energy source. In the same vein, fossil fuels increase the prevalence in the level of carbon emissions. Holding all other factors constant, a 1% increase in fossil fuels will increase carbon emissions by 0.02% and it is statistically significant. This perhaps further connotes that residents are strongly involve in the excessive use of non-renewables such as gas, oil, coal for domestic, industrial & commercial reasons. Urbanization has an insignificant positive relationship with carbon emissions in Nigeria as expected. Holding all other factors constant, a 1% increase in urbanization increases the level of carbon emissions by 0.008%. This empirical result supports the finding of Yusuf, (2023). The economic implication is that as more people mover from rural areas to urban areas, economic activities increase and this in turn increases the carbon emissions. Nigeria government and policymakers should establish an institution saddled with giving mouthwatering incentives to rural dwellers and make social amenities available in rural areas to discourage them from migrating into the urban centers.

Both serial correlation and heteroscedasticity were eliminated by the diagnostic tests, and the errors are regularly distributed, as demonstrated by the Jarque-Bera normality. In Figure 1 below, there are no structural fractures, cumulative sum (CUSUM) validates the model's stability, and the Ramsey test indicates that the model has no misspecification issues.

Table 4. ARDL long run results

Dependent Variable: InCO$_2$		
	Coefficients	P-Value
InGDP	-0.568***	0.002
InGDP^2	-0.435	0.557
InTO	-0.281***	0.021
REC	-0.060***	0.000
FOS	0.020***	0.042
URB	0.009^{n}	0.079
Constant	28.526***	0.000
Adjusted R^2	0.965	
Diagnostic Test		
	Chi-Square	Prob
Serial Correlation LM	0.257	0.562
Heteroscedasticity ARCH	0.296	0.999

Jarque Bera	0.554	0.758
Ramsey Reset	0.315	0.584
CUSUM	Stable	
CUSUMQ	No Structural breaks	

*Note: ***, **, and * show significant levels of 1%, 5%, and 10%, respectively. The autoregressive conditional heteroscedasticity (ARCH) test, the Ramsey Reset test, the Jarque-Bera test, and the serial correlation LM test all have orders of 1. The optimal lags are selected based on Akaike Information criterion. CUSUM denotes cumulative sum while CUSUMSQ stands for cumulative sum of squares.*

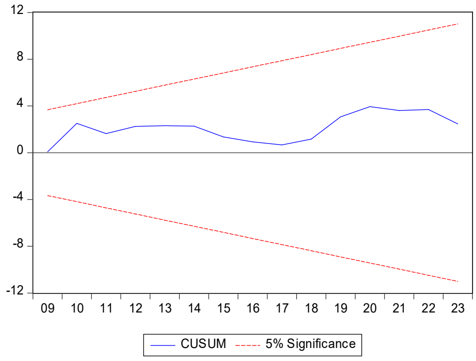
Table 5 below displayed the ARDL results from short run estimates. According to the empirical findings, there is a statistically significant negative relationship between GDP per capita and carbon emissions. In addition, the EKC's significant negative coefficient (-0.6996) attests to the variables' long run relationship. Economically speaking, this means that after a shock or distortion, the model must adjust at a rate of 69.96% to return to the long run equilibrium. Going by Narayan and Narayan (2010), it can be deduced from the long run and short run estimations that EKC hypothesis is valid in Nigeria due to GDP per capita's lower short run elasticity (-0.7756) compared to its long run elasticity (-0.5678). This indicates that as individual income levels have increased, environmental deterioration has decreased over time. At the early stage of EKC hypothesis, environmental quality decreases, thereby, increasing emissions over time, but it will get up until a point at which rising income levels will offset rising carbon emissions. In supporting the EKC hypothesis' viability in Nigeria, a few developing nations like Pakistan (Rahman et al., 2019); (Solarin et al., 2017 studies in Ghana) and (Budiono, 2023 studies in Indonesia) also confirmed the validity of EKC hypothesis.

Table 5. ARDL short run results

Dependent Variable: $\Delta InCO_2$		
	Coefficients	P-Value
ΔInGDP	-0.776^{***}	0.000
ΔInGDP(-1)	0.016	0.916
$\Delta InGDP^2$	-0.002	0.078
$\Delta InGDP^2$(-1)	0.109^{***}	0.013
ΔInTO	-0.053^{***}	0.017
ΔInTO(-1)	0.133^{***}	0.000
ΔREC	-0.052^{***}	0.000
ΔREC(-1)	-0.048	0.699
ΔFOS	0.009	0.111
ΔFOS(-1)	-0.000	0.937
ΔURB	-0.024	0.772
ΔURB(-1)	0.209^{***}	0.021
ECM (-1)	-0.699^{***}	0.000
Adjusted R^2	0.928	

*Note: Δ indicates the first difference operator. The asterisks ***, ** and * indicate significance levels at 1%, 5%, and 10% respectively*

4.4 Diagnostic Tests



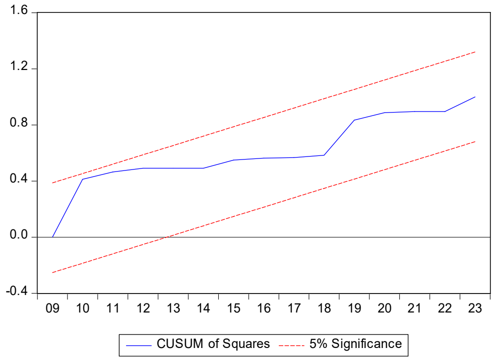


Figure 2: Normality Test

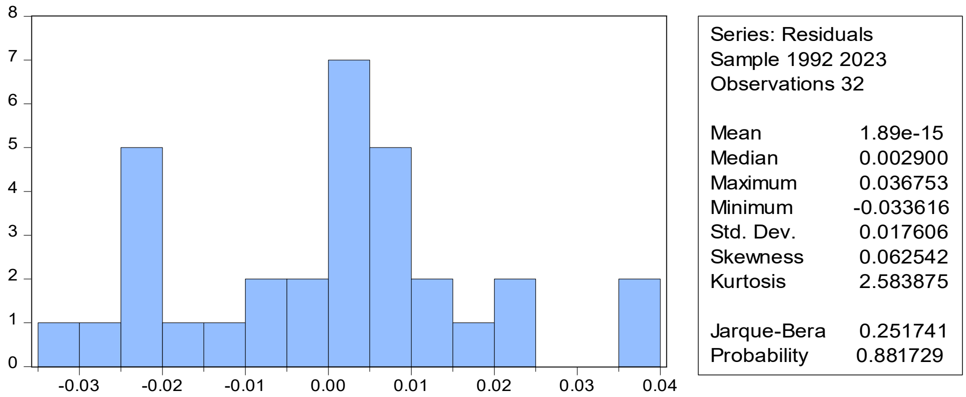


Figure 1: Plots of CUSUM and CUSUMQ

5. Conclusion

The empirical findings showed that variables have a co-integration nexus and relationship. More so, the empirical findings supported whether the EKC hypothesis is valid in Nigeria as elasticity of negative value of GDP per capita in short run is less than the elasticity of the negative value of an average GDP per capita across time. In sum, the results of the study have policy ramifications for government officials, scholars studying renewable energy, possible investors, and scientific communities. The feedback effect between

GDP per capita and environmental degradation suggests that Nigeria is on the precipice of EKC hypothesis, meaning that the nation has crossed to increase in GDP per capita which has caused more health awareness on the environmental benefits of using clean and renewable energy source for economic activities. Nigeria makes extensive usage of fossil fuels, which are detrimental to human health and welfare. Fossil fuels are naturally created, but because they are rapidly consumed and have a limited degree of replenishment, they will soon run out.

References

Acheampong, A., Adams, S., and Boateng E (2019) Do globalization and renewable energy contribute to carbon emissions mitigation in Sub-Saharan Africa? Sci Total Environ 677:436 446. https://doi.org/10.1016/j.scitotenv.2019.04.353

Adebayo, T., Awosusi, A., Oladipupo, S., Agyekum, E., Jayakumar, A., and Kumar, N. (2021). Dominance of fossil fuels in Japan's national energy mix and implications for environmental sustainability, International Journal of. Enviromental Research and Public Health 18 (1) 73–93, https://doi.org/ 10.3390/ijerph18147347

Adebayo, T., Agboola, M., Rjoub, H., Adeshola, I., Agyekum, E., and Kumar, N. (2021). Linking economic growth, urbanization, and environmental degradation in China: what is the role of hydroelectricity consumption? Int. J. Environ. Res. Publ. Health 18 (2021) (2021) 69–75, https://doi.org/10.3390/ijerph18136975.

Ahmed, K. and Long, W. (2012). Environmental Kuznets Curve and Pakistan: An Empirical Analysis. Procedia Economics and Finance, 1, 4-13. https://doi.org/10.1016/S2212-5671 (12)00003-2

Akorede, Y., and Afroz, R. (2020). The Relationship between Urbanization, CO2 Emissions, Economic Growth and Energy Consumption in Nigeria. *International Journal of Energy Economics and Policy*, *10*(6), 491–501

Ali, S., and Mujahid, N. (2024). Sectoral carbon dioxide emissions and environmental sustainability in Pakistan. Environmental and Sustainability Indicators. https://doi.org/10.1016/j.indic.2024.100448

Budiono, A, (2023). Is the Environmental Kuznets Curve (EKC) hypothesis valid on CO_2 emissions in Indonesia? International Journal of Environmental Studies, 80(1), 20-31, 2023

Climate Change Act (2021)

Dritsaki, M and Dritsaki, C. (2024). The Relationship between Health Expenditure, Carbon emissions, and economic growth in G7: Evidence from Heterogeneous Panel Data. Journal of the Knowledge Economy 15(1), 4886-4911

Fodha, M., and Zaghdoud, O. (2010). Economic growth and pollutant emissions in Tunisia: An empirical analysis of the EKC. Energy Policy, Elsevier, Vol. 38(2), pages 1150-1156

Ganda, F. (2019). Carbon emissions, diverse energy usage and economic growth in South Africa: Investigating existence of EKC Hypothesis. Environmental Progress and Sustainable Energy. 38(1), 30-46

Hanif, I., Raza S., Gago-de-Santos P., and Abbas Q. (2019) Fossils fuels, foreign direct investment, and economic growth have triggered CO2 emissions in emerging Asian economies: some empirical evidence. Energy 171:493–501. https://doi.org/10.1016/j.energy.2019.01.011

Kanli, N., and Kucukefe, B. (2023) Is the environmental Kuznets curve hypothesis valid? A global analysis for carbon emissions. Environment, Development and Sustainability, 25(3), 2339-2367, 2023.

Kuznets, S. (1955). Economic growth and income inequality, Am. Econ. Rev. (45) 1–28.

Li, B., and Haneklaus, N. (2022). The potential of India's net-zero carbon emissions: analyzing the effect of clean energy, coal, urbanization, and trade openness, Energy Rep. 8 (2022) 724–733.

Narayan, P., and Narayan, S. (2010). Carbon dioxide emissions and economic growth: Panel data evidence from developing countries. Energy Policy, Vol. 38, Issue 1, 661-666.

Nathaniel, S., and Iheonu, C. (2019). Carbon dioxide abatement in Africa: the role of renewable and non-renewable energy consumption. Sci. Total Environ. 679, 337e345.

Nelson C. R., and Plosser C. R (1982) Trends and random walks in macroeconomic time series: some evidence and implications. J Monet Econ 10(2):139–162

Nguea, S.M (2024) Combining the role of urbanization and renewable energy in sustainable development: testing the EKC hypothesis for Africa. *Environ Sci Pollut Res* 31, 29595–29609. https://doi.org/10.1007/s11356-024-33175-3

Okereke, C. and Onuigbo, M. (2021). Key Features and Significance of Nigeria's Climate Change Initiative. Business Day November 21, 2021.

Pesaran, M., Shin, Y. and Smith, R. (2001). Bounds Testing Approaches to the Analysis of Level Relationships. Journal of Applied Econometrics, 16, 289-326. https://doi.org/10.1002/jae.616

Rahman Z., Chongbo W, and Ahmad M (2019). An asymmetric analysis of the pollution haven hypothesis in the context of Pakistan: a nonlinear approach. Carbon Management 10(3):227–239. https://doi.org/10.1080/17583004.2019.1577179

Sharif, A., Raza, A., Ozturk, I., and Afshan, S. (2019). The dynamic relationship of renewable and nonrenewable energy consumption with carbon emission: A global study with the application of heterogeneous panel estimations. Renewable Energy. Vol. 133, Pages 685-691.

Singh, G., Singh, P., and Lal, P (2025). Dynamic Approach to Study Relationship among Carbon Dioxide Emissions, Urbanization, and Economic Growth in BRICS Countries. *J Knowl Econ* **16**, 3386–3403. https://doi.org/10.1007/s13132-024-01964-3

Solarin, S., Al-Mulali U, Musah, I., and Ozturk I (2017) Investigating the pollution haven hypothesis in Ghana: an empirical investigation. Energy 124:706–719. https://doi.org/10.1016/j.energy.2017.02.089

Sun, H., Enna, L., Monney, A., Tran, D and Rasoulinezhad, E., (2020). The long run effects of trade openness on carbon emissions in sub-Sahara African countries. Energies 13(20), 52-95

Udeagha, M., and Breitenbach, M. (2023). Revisiting the nexus between fiscal decentralization and CO2 emissions in South Africa: fresh policy insights, Financial Innovation 9 (50) 1–46, https://doi.org/10.1186/s40854-023-00453

Udeagha, M., and Muchapondwa, E. (2022). Investigating the moderating role of economic policy uncertainty in environmental Kuznets curve for South Africa: evidence from the novel dynamic ARDL simulations approach, Environ. Sci. Pollut. Control Ser. 29 (2022) (2022), 77199, https://doi.org/10.1007/s11356-022-21107-y, 77237

Udo, E., Jack, A., Inim, V., Agama, E., Ugar, O., and James, S. (2024). Unveiling the Transformative Nexus of Energy Efficiency, Renewable Energy, and Economic Growth on CO2 Emission in MINT Countries, *Journal of Renewable Energy and Environment (JREE)*, 11(2), 138- 150. https://doi.org/10.30501/JREE.2024.430213.1770.

World Bank (2021). World Development Indicators. Washington

World Bank (2023). World Development Indicators. Washington

World Bank (2024). World Development Indicators. Washington

Yusuf, A. (2023) Dynamic effects of energy consumption, economic growth, international trade and urbanization on environmental degradation in Nigeria. Energy Strategy Reviews 50 (101-228)

Zhang, F. (2021). The effects of trade openness on decoupling carbon emissions from economic growth: evidence from 182 countries. Journal of Cleaner Production, 279, 123838, 2021