Re-examining the Environmental Kuznets Curve Hypothesis in Nigeria: Recent Evidence from ARDL Model.

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Abstract

This study re-examines the Environmental Kuznets Curve (EKC) hypothesis in Nigeria over the 1980-2021 period. Applying the Autoregressive Distributed Lag (ARDL) model, the estimated result shows the long-run co-movement of the variables included in the model. However, the model fails to support the EKC inverted U-shaped hypothesis during the study period. The long-run estimates found that increase in Gross Domestic Income, Trade integration and GDP growth will significantly lead to reduction in CO_2 emissions. Meanwhile, increase in urbanization growth and population growth will significantly result to increase in CO_2 emissions in the long-run. The result of population growth on CO_2 emissions is quite alarming, thus, the study recommends for government intervention in collaboration with private sector to ensure smooth transition to a cleaner technology with a view to curb the environmental pollutants thereby achieving the sustainable development goal.

Keywords: *Carbon emissions, GDP growth, Trade integration, Environmental Kuznets Curve, Gross Domestic Income, Urbanization growth, Population growth*

I. Introduction.

One of the fundamental challenges affecting the global environment is persistent increase in carbon emissions. Carbon emissions induced climate change with its attendant consequences on environmental degradation and loss of biodiversity among others. Human-related factors, such as energy consumption, transportation and import and export of goods and services across international boundaries majorly account for environmental degradation (Oluwaseyi, Abdul-Rahim and Dankumo 2020; Zamir and Mujahid 2022). Also, human activities in agriculture, industrialisation, deforestation, and mining seriously affect the natural environment with an adverse effect on the planet earth (Nathaniel, Victor and Faizulayev, 2021; Wang, 2021). The United Nation had since considered the conservation of the natural environment as one of the key objectives of the sustainable development goals for 2030. Consequently, many developed and developing countries began to promote policies and programmes to control environmental degradation within their boundaries. All members of the United Nation during climate change conferences had recognised and pledged the promotion of renewable energy sources in addition to political will, efficient technology, among others (Sulaiman, Oluwaseyi and Abdul-Rahim, 2022).

Ever since, Nigeria hugely depends on non-renewable energy sources. Though, recently there has been slight shift on the use of renewable energy especially in solar powered energy. However, the high cost of transition to renewable energy technology is a major concern for policy makers in Nigeria. Also, not only that Nigeria depends majorly on fossil fuel as a source of energy, revenue from crude oil represent a major source of the country's foreign exchange earnings. However, the volatility in the prices of crude oil in the international market couple with the on-going campaign for paradigm shift to renewable energy sources continues to be of great challenge to an oil dependent economy like Nigeria. Interestingly, Nigeria has the vast potential to diversify the economy away from oil. Also, the country has the potential to harness and generate renewable energy especially solar powered energy due to its hot temperature/climate and vast land mass (Oluwaseyi, Abdul-Rahim and Dankumo, 2020).

The key contribution of this study to the existing literature, is that, it re-examined the Environmental Kuznets Curve (EKC) and unravelled the major area contributing to CO_2 emissions in Nigeria. This is particularly important because it helps to understand Nigeria's position in the United Nation 2030 SDG target with the view to advise the policy makers on the areas that need improvement. The study also, add to the body of existing literature on renewable energy and EKC. The first part of the study housed the introduction and the review of literature is in section two. The methodology is explained in section three while the result and discussions were presented in section four. Section five discussed the summary, conclusion and recommendation.

II. Literature Review

This study re-examines the Environmental Kuznets Curve hypothesis by unravelling the factor(s) attributing to CO_2 emissions for sustainable development in Nigeria. The theoretical literature underpinning this study is the Environmental Kuznets Curve (EKC) which hypothesised the inverted U-shaped relationship between economic growth and causes of environmental degradation. The EKC hypothesis posits that the level of country's carbon emission increases at the early stages of economic growth due to rise in per capita income. Though, the quality of environment improves over time with advancement in economic growth and development. The EKC theory was proposed by Simon Kuznets and later popularised by Grossman and Krueger

(1991) who revealed that an association between economic growth and CO_2 emissions will in the long run bring about reduction in environmental pollution. There are several factors determining environmental degradation in the literature such as economic growth; political will; foreign direct investment; international trade; technological progress; energy transition; energy efficiency; institutions; governance; population; globalisation and urbanization (Zubair, Samad and Dankumo, 2020; Radmehr, Henneberry and Shayanmehr, 2021; Sulaiman, Zubair and Abdul-Rahim, 2022; Zamir and Mujahid, 2022; Adebayo, et al. 2022; Akram, et al. 2020; Sadiqa at al. 2022; Amin and Song, 2023).

The quest to improve environmental quality remains one of the key policy target of governments across the globe. Such environmental concern had been the focal point of discussions by successive conferences of the United Nation (UN) where every nation proposes target commitment to reduce carbon emissions for achieving the 2030 sustainable development goals. For instance, EU has committed to reduce CO_2 emissions to at least 55% below 1990 levels by 2030. In light of these, matters relating to pollution, global warming and its attendant effects on the environment have continue to dominate the environmental economic literature especially as it relates to the role of renewable energy in mitigating the carbon emissions while achieving a sustained economic growth. Therefore, several studies had examined the validity or otherwise of the EKC hypothesis within the context of varied degree of explanatory variables. For instance, Sanu, (2020) evaluates the effect of GDP growth, coal consumption, financial advancement, and trade openness on CO_2 emissions in India from 1971-2017. The study employed Autoregressive Distributed Lag (ARDL) and Vector Error Correction Model (VECM). The results confirm a long-run relationship between the variables in the model. The study further revealed that GDP growth and coal consumption increase carbon emissions while trade openness and financial development improves environmental quality. The study also supports the validity of EKC hypothesis in India.

The study by Bekhet, Othman and Yasmin (2020) on the interaction between EKC Hypothesis and urban environment transition hypothesis employing data from 1971 to 2013 on ARDL methodology confirms the existence of an inverted U-shaped EKC hypothesis in Malaysia. The study also found the downward effect of urbanization on carbon emission attributing it to technical innovation and ecological modernization. Likewise, Oluwaseyi, Abdul-Rahim and Dankumo (2020) inquires whether Gross Domestic Income, trade openness, GDP and capital reduce CO_2 emissions in Nigeria. The study employed ARDL and Vector Autoregressive (VAR) approaches and using data span from 1980 to 2018. The findings reveal that increase in GDP and FDI reduce CO_2 emission thus, lending support to the validity of EKC hypothesis in Nigeria within the period studied. Also, the study shows the presence of cointegration between the variables under studied. Similarly, by using ARDL and NARDL approaches on data spanned from 1990 to 2020, Sreenu (2022) investigates the impact of foreign direct investment, crude oil price and economic growth on CO2 in India. The study found that economic growth reduces CO2 emission thus, supporting the EKC hypothesis between economic growth and CO2 emissions in India.

In contrary, Murad and Mazunder (2009) examined the EKC Hypothesis for selected environmental pollutants in Malaysia. The findings show no evidence of an inverted U-shaped EKC hypothesis for any of the six air and water pollutants in Malaysia. By using STIRPAT empirical model, panel cointegration and fully modified ordinary least square, Lin, (2016) examines between economic growth and environmental sustainability within the context of EKC framework on five African countries. The study fails to validate the existence of an inverted U-shaped in the countries studied. Similarly, Twerefou, Poku and Bekoe (2016) empirically examine the EKC Hypothesis for carbon dioxide emissions in Ghana using ARDL approach from 1970-2010. Major findings reveal a rather U-shaped relationship between per capita GDP and CO_2 emissions indicating the non-existence of EKC hypothesis for CO_2 emission in Ghana. The result reveals that increase in per capita income will rather increase carbon emissions in Ghana during the study period. Also, Kong'o, Saina and Ng'emo (2018) ascertained whether the EKC Hypothesis is valid for Kenya between the variables under study. The study did not support the existence of EKC Hypothesis in Kenya. The study further revealed that increase in economic activities would not leads to carbon emissions. The study recommended that sustainable development in Kenya could be achieved by using both environmental policies and development policies. In the same vein, Bese and Kalayci (2019) examine the EKC hypothesis in Egypt, Kenya and Turkey between period from 1971 to 2014 using VAR and VEC methodologies. The study invalidates the EKC hypothesis in the three countries studied. However, in Egypt and Kenya economic growth was found to have induced CO_2 emission but neutrality was reported in Turkey. Naz, et al. (2019) examine the moderating and mediating role of renewable energy consumption, FDI inflows and economic growth on CO_2 emissions in Pakistan using annual data from 1975 to 2016. Findings from the study invalidates the EKC hypothesis between per capita income and CO_2. However, the study lends support to the pollution haven hypothesis vindicating that FDI damaged the natural flora of Pakistan. In some different findings, Setyari and Kusuma examine the EKC hypothesis in 62 countries using annual data from 1992 to 2017. The study applied Error Correction Model (ECM) and result for the four sub-samples was found to be inconclusive vindicating a neutral (N-shaped) pattern between GDP per capita and CO_2. Similarly, Mitsis, (2021) investigates the income-pollution nexus in the context of the EKC hypothesis in 35 countries and the findings revealed an N-shaped pattern between income and CO_2 emission which implied inconclusiveness of the EKC framework. In light of the reviewed literature, it is quite evident that the validity or otherwise of the EKC hypothesis is still empirically debatable, thus creating an endless research gap to be explored. Meanwhile, most of the literature reviewed in this study for Nigeria support the EKC framework, but the uncertainty surrounding the empirical results across countries necessitate for the need to re-examine the EKC hypothesis in Nigeria by incorporating other determinants of environmental degradation to see whether the validity of the EKC hypothesis will still be upheld.

III. Materials and Method

The linear models of this study follows the work of Oluwaseyi, Abdul-Rahim and Dankumo (2020) whose original model is as follows:

$$CO_{2t} = \beta o + \beta_1 I_t + \beta_2 lnTI_t + \beta_3 FDI_t + \beta_4 GDP_t + \beta_5 K_t + \mu_t \qquad (1)$$

Note that, CO_2 is the emission intensity, I refers to the gross domestic income, TI is the trade integration measured by the division between GDP percentage of total export and total import of goods and services, FDI is the foreign direct investment, GDP is the gross domestic product and K is the gross fixed capital formation. However, the models for this study differ in its explicit inclusion of urbanization (urban population growth, annual (%)) and population growth. The inclusion of urbanization growth is in the spirit of Bekhet, Othman and Yasmin., (2020). Therefore, the short-run and long-run model is expressed in equation 2.

$$CO_{2t} = \alpha_0 + \alpha_1 D(CO_2)t_{1-p} + \alpha_2 D(GDI)t_{1-p} + \alpha_3 D(TI)t_{1-p} + \alpha_4 D(GDPG)t_{1-p} + \alpha_5 D(URBG)t_{1-p} + \alpha_6 D(POPG)t_{1-p}\varepsilon_{it} + \beta_0 CO_{2t} + \beta_1 GDI_{t-1} + \beta_2 TI_{t-1} + \beta_3 GDPG_{t-1} + \beta_4 URBG_{t-1} + \beta_5 POPG_{t-1} + \varepsilon_t \quad (2)$$

Where CO_2 refers to the carbon intensity, *GDI* is the gross domestic income, GDPG is the GDP growth, *TI* is the trade integration, *URBG* is the urbanization growth, POPG is the population growth, t = period, α_0 *and* α_{ij} are the constant and parameters of the short-run respectively and β_0 *and* β_{ij} are the constant and parameters of the long-run respectively and ε_{ij} are error terms. The application of ARDL bound test for cointegration in this study was due to its superiority over other tests of cointegration. For example, the ARDL approach can be utilised whether or not the order of the variables are integrated of I(0) or I(1). Also, with ARDL the long run model will be unbiased. Furthermore, it can be efficiently and conveniently fit under a minute and finite sample data size. However, the shortcomings of ARDL model is that it cannot be used under I(2) or higher-order stationarity (Pesaran, Shin and Smith. 2001). Following the attainment of a long-run relationship between the variables included in the model, the Error Correction Term (ECT) that determines the short-run dynamics of the model has been applied as specified in the equation 3 and equation 4.

$$CO_{2t} = \alpha_0 + \alpha_1 D(CO_2)t_{1-p} + \alpha_2 D(GDI)t_{1-p} + \alpha_3 D(TI)t_{1-p} + \alpha_4 D(GDPG)t_{1-p} + \alpha_5 D(URBG)t_{1-p} + \alpha_6 D(POPG)t_{1-p} + \theta_1 (ECT_{t-1}) + \varepsilon_{it} \quad (3)$$

$$CO_{2t} = \beta_0 + \beta_1 D(CO_2)t_{1-p} + \beta_2 D(GDI)t_{1-p} + \beta_3 D(TI)t_{1-p} + \beta_4 D(GDPG)t_{1-p} + \beta_5 D(URBG)t_{1-p} + \beta_6 D(POPG)t_{1-p}\theta_2 (ECT_{t-1}) + \varepsilon_{it} \quad (4)$$

Θ_1 *and* Θ_2 Signifies the magnitude of error corrected each time. Thus, for a long run equilibrium to be obtained, the coefficient of ECT is required to be negative and statistically significant. The ECT primarily measures the speed of adjustment from short-run disequilibrium to long-run equilibrium. The diagnostic tests of serial correlation, heteroscedasticity, normality test, specification test and stability test has been carried out to ensure the healthiness of the model.

Annual time series data spanning from 1980 to 2021 were utilised on the data. The data were sourced from the World Bank Database and International Financial Statistics.

IV. Results and Discussion

The results from both Augmented Dickey Fuller (ADF) and Phillip Peron (PP) tests show that the variables are integrated of either I(0) or I(1) as shown in table 1.

Table 1. Unit root test results

	Augmented Dickey Fuller (ADF)		Phillips-Peron (PP)	
	Level	**First Difference**	**Level**	**First Difference**
CO_2	-4.37***	-	-4.28***	-
GDI	-2.78	-5.96***	-2.79	-5.95***
TI	-4.46***	-	-4.27***	-

GDPG	-2.59	-12.08***	-4.24***	-
URBG	-6.55***	-	-2.17	-716***
POPG	-3.26*	-	-3.09	-5.24***

Note that, *, **, *** represent 10%, 5% and 1% significance levels respectively

Given that the variables are integrated of either I(0) or I(1), justified the application of ARDL model (Pesaran, et al. 2001. The result of the ARDL bound test for cointegration which examines whether or not the variables co-move in the long-run was presented in table 3.

Table 3. ARDL bound test result.

Estimated model	**F-statistics**	**Critical value**	
		I (0)	**I**
(1)			
F(CO_2/GDI,TI,GDPG,URBG,POPG)	5.63***	3.06	4.15

*Note that, *** implies 1% significance level.*

The ARDL bound test results in table 3 signifies that the F-statistics value of 5.63 exceeds the critical upper bound value of 4.15 at K=3, at 1% significance level. Impliedly, the alternative hypothesis of the existence of a long-run relationship between the variables in the model will be accepted and conclude that cointegration exist in the model. The base line results for the long-run estimate of the model is presented in table 4 where it indicates the direct long-run relationship between CO_2 and the set of explanatory variables used in the model.

Table 4. Long-run Estimates

Regressors	***ARDL* Model**
Constant	0.137 (0.425)
GDI	-8.65E-15*** (-10.90)
TI	-0.125*** (-2.958)
GDPG	-0.029*** (-6.024)
URBG	0.083*** (4.568)
POPG	0.393** (2.728)

*The t-statistics are reported in parenthesis. *, **, *** implies 10%, 5% and 1% significance levels.*

The results in table 4 show the estimated long-run results between CO_2 emission intensity and its regressors from 1980 to 2021 in Nigeria. The model shows that 1% increase in Gross Domestic Income (GDI) will significantly decrease CO_2 Emissions by 8.7E-15. This result though quite negligible but its coefficient does not support the preposition of the Environmental Kuznets Curve (EKC) which hypothesised the inverted U-shaped relationship between the level of country's CO_2 emission and economic growth. This result is also consistent with the findings reported by Murad and Mazunder, 2009; Twerefou, Poku and Bekoe, 2016; Bese and Kalayci, 2019. Trade integration in our model shows a significance negative relationship with CO_2 emissions in Nigeria. This result implies that 1% increase in trade integration will decrease CO_2 emissions by 12.5% at 1% significance level. With advancement in her trade integration drive in manufacturing, agriculture and mining couple with the use of cleaner and environmentally friendly technology, Nigeria like other countries expect to see a decline in the level of CO_2 emissions. This result further shows that the commitment made toward climate change mitigation strategy has begun to manifest in Nigeria. Similar result was also reported by Adam, (2015) whose findings show that trade integration reduces carbon intensity in Nigeria. The model also shows that 1% increase in GDP growth will decrease CO_2 emission by 2.9% in Nigeria. This value though negligible indicates that Nigeria is on track toward ensuring that increase in economic activities leads to a monumental decline in the level of CO_2 emissions. This was possible by switching from a high carbon emissions technology to a lower carbon emission technology. This finding corresponds to that of Oluwaseyi, Abdul-Rahim and Dankumo, (2020) whose finding reveals that increase in economic growth led to decline in carbon emissions in Nigeria. The result further shows that increase in urbanization growth leads to a rise in CO_2 emissions in Nigeria. Impliedly, 1% increase in urbanization growth significantly increase CO_2 emissions by 8.3%. This result is expected especially in developing countries because urbanization comes with high demand for goods and services which necessitates industries to increase their production drive thereby resulting to higher carbon emissions. The result is in line with the findings reported by Abbas, Kouser and Pervaaiz (2021) and Sun, et al. (2022). However, this result does not coincide with the findings by Bekhet, Othman and Yasmin (2020) who reported the negative effect of urbanization on carbon emissions in Malaysia. The model also shows the positive effect of population growth on CO_2 emissions in Nigeria. From the baseline result, 1% increase in population growth will increase carbon emissions by 39.3% at 5% significance level. This result is quite alarming and policy makers in Nigeria should promulgate policies and programmes to address this challenge since the large chunk of carbon emission attributed to increase in population growth. This result is in line with findings by Shan, et al. (2021) and Abbas, Kouser and Pervaaiz (2021) whose findings show an increasing effect of population growth on carbon emissions.

The results of short-run estimates in table 5 shows that 1% increase in CO_2 emissions in the previous year significantly increase the CO_2 emissions in the current year by 86.6%. A point increase in the GDI in the previous year significantly increase the CO_2 emissions in the current period by 3.16E-14 point. Furthermore, 1% increase in TI and GDPG in the current year decrease the CO_2 emissions in the current year by 10.1% and 1.0% respectively at 5% significance levels. In the same vein, 1% increase in URBG in the previous year significantly decrease the CO_2 emissions in the current year by 15.1%. Similarly, 1% rise in POPG in the current year significantly decrease CO_2 emissions in the current period by 93.7%. The error correction coefficient of the short-run model is -2.23. The higher ECT suggests a shorter adjustment time for the disequilibrium. The ECT coefficient shows that the short-run disequilibrium will be corrected at the speed of 5 months only (1/2.23=0.45).

Table 5. Short-run Estimates

Regressors	ARDL Model
$\Delta CO_2(-1)$	0.866*** (4.263)
ΔGDI(-1)	3.16E-14*** (5.301)
ΔTI	-0.101** (-3.648)
ΔGDPG	-0.01** (-2.32)
ΔURB(-1)	-0.151** (-2.164)
ΔPOPG	-0.937*** (-2.545)
ΔECT	-2.230*** (-7.357)

*The t-statistics are reported in parenthesis. *, **, *** implies 10%, 5% and 1% significance levels.*

The diagnostic checks were carried out on the long-run model to ensure the healthiness of the model and its validity for analysis and policy implications. The result of the diagnostic checks is reported in table 6.

Table 6. Diagnostic test results.

	Statistics
Serial correlation (LM test)	3.166 (0.073)
Hetroskedasticity (BPG test)	0.539 (0.908)
Normality test	4.330 (0.115)
Ramsey Reset test	0.916 (0.354)

The F-statistics are reported and the P-values are in parenthesis.

The Breusch-Godfrey serial correlation (LM) test result in table 6 shows evidence of autocorrelation as we could reject the null hypothesis at 10% significance level, signifying that the residuals of the model is not independently distributed. However, the existence of the serial correlation in the model has been corrected using the HAC. Also, there is non-existence of heteroscedasticity as we did not reject the null hypothesis at 10% significance level, indicating that the residual of the model has constant variance. In addition, the normality test shows that the residual of the model is normally distributed since we could not reject the null hypothesis at 10% level of significance. Ramsey Reset test shows that the model was correctly specified as we did not reject the null hypothesis at 10% significance level. Succinctly, the model is healthy enough to be relied upon for analysis and policy recommendations. Also, the model was subjected to Cusum and Cusum Square tests in figure 1 and figure 2 respectively to find out whether or not the model is stable over a long-run. The result from Cusum and Cusum Square tests of parameter stability shows satisfactory plot lying between the critical bound at 5% significance levels implying that, the model was stable over a long period.

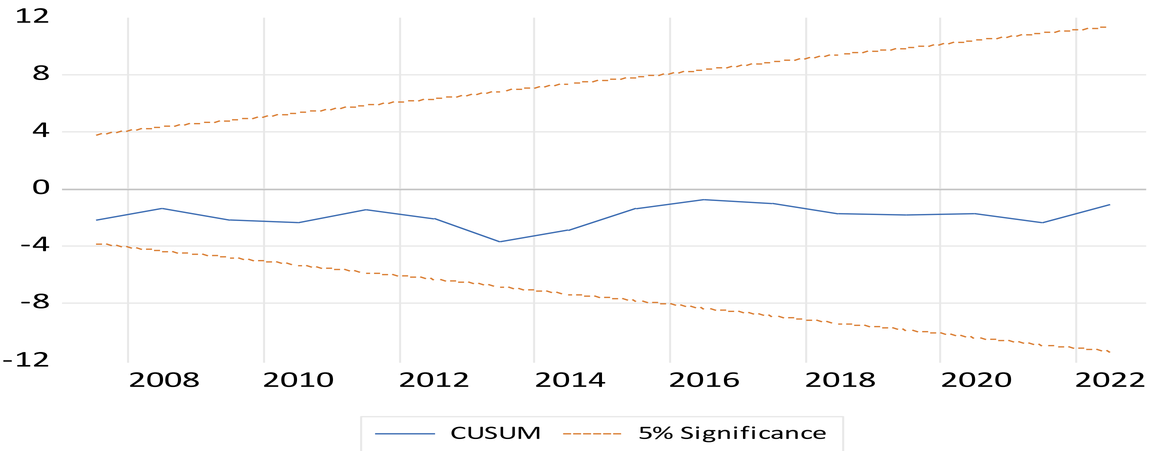

Fig. 1. Cusum test

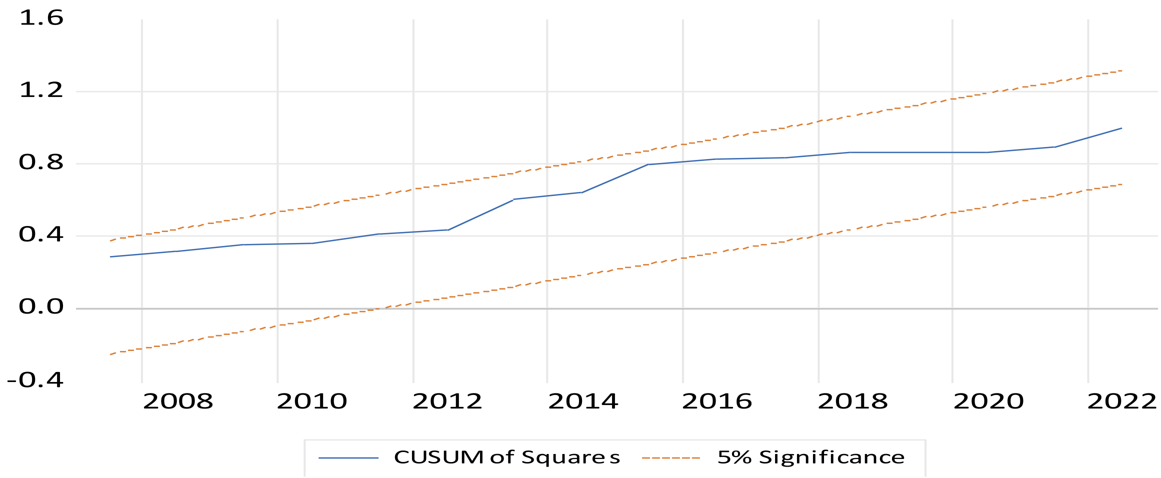

Fig. 2. Cusum square test

V. Conclusion

This study re-examines the Environmental Kuznets Curve (EKC) hypothesis in Nigeria by employing annual data ranges from 1980 to 2021. Autoregressive distributed lag (ARDL) model was used in testing the model. The bound test result shows that the variables co-move in the long-run. However, the result did not support the existence of EKC inverted U-shaped Hypothesis in Nigeria during the study period. The baseline long-run model shows that increase in Gross Domestic Income (GDI) will significantly leads to a reduction in CO_2 emissions. Likewise, increase in trade integration and GDP growth will significantly bring about a decrease in CO_2 emissions. Meanwhile, increase in urbanization growth and population growth will significantly induced increase in CO_2 emissions. In the short-run, increase in CO_2 emissions and GDI in the previous year will significantly lead to increase in CO_2 emissions in the current period. In contrary, increase in trade integration, GDP growth and population growth in the current period will significantly decrease CO_2 emissions in Nigeria in the current period. Also, increase in urbanization growth in the previous year will significantly decrease CO_2 emissions in the current period. The error correction term was negative and statistically significant and its speed of adjustment from short-run disequilibrium into a long-run equilibrium was shorter covering only 5 months. The model was healthy as reported by the results of the diagnostic checks, though, the initial result shows the presence of serial correlation but was corrected using HAC standard error and covariance method. The model was found to be correctly specified as shown by the result of Ramsey Reset test. The results from the cusum and cusum square also show stability of the model over a long-run period. Therefore, this study found that population growth accounts for huge volume of carbon emissions in Nigeria due to increasing demand for fossil fuel in manufacturing, industrial and transport sectors in order to meet the growing demand of the population. In light of this, government should liaise with the private sectors to ensure smooth transition to a cleaner technology especially in solar powered and wind powered technology which Nigeria has the potential to harness with a view to curbing the environmental pollutants leading to the attainment of the sustainable development goal.

Declaration of Competing Interest

The authors declared no conflicts of interest with respect to the research, authorship, and/or publication of the article.

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