ANALYSIS OF POPULATION GROWTH, CARBON EMISSION, AND RENEWABLE ENERGY NEXUS IN NIGERIA

UCHECHUKWU EZE
Department of Economics, University of Nigeria, Nsukka, Enugu state
Email:: uchechukwu.eze.241866@unn.edu.ng, +2348144877675

***UGWUOKE CORNELIUS CHINEMEOGO**
Department of Economics, University of Nigeria, Nsukka, Enugu state
Email:chinemeogocornelius40@gmail.com, +234 8039217485.

ABSTRACT
This study investigated the impact of population growth and Carbon emission: a study on the contribution of renewable energy in Nigeria from 1990 to 2023 employing the Autoregressive Distributed Lag (ARDL) modeling. Some of the variables used in the analysis included population growth (POG), renewable energy consumption (REC), carbon emission (C02), real gross domestic product (RGDP), trade (TO), fossil fuel consumption (FFC), and gross fixed capital formation (GFCF). As discussed, the impact analysis of the independent variable on Carbon emission (C02) shows that population growth has long-run positive impacts on Carbon emissions (C02), and renewable energy hurts Carbon emissions. As for the other variables such as RGDP and FFC, they also were found to have a negative and significant relationship with the level of carbon emission in Nigeria in the short-run and long-run. On the other hand, variables like GFCF and To have no significant influence on Carbon emission (C02). Accordingly, the following policy recommendation is made: Nigerian government policies should assist in enhancing the uptake of renewable energy in Nigeria to reduce carbon emissions that are hazardous to the lives of the country's people and the effectiveness of the ozone layer. Further, production facilities needed to boost renewable energy consumption in the country like solar, electricity vehicles, etc. must be manufactured there.
Keywords: Carbon Emission, Population Growth, Renewable, Energy, Fossil Fuel.

JEL Codes Q01, O13, Q42, Q53, Q56, Q58.

1. INTRODUCTION

The global population has time and again been singled out as the major cause of the increase in the levels of carbon emissions ($CO2$). According to the World Bank (2023), Nigeria's population has grown from around 122 million in 2000 to over 220 million by 2023, which has likely influenced the rise in emissions.

This linkage emanates from the fact that the population increases in the geometric progression, which Malthus pointed out. Therefore, the increase in human activities has a loud influence on the level of emissions, while accentuating the call for the adoption of renewed energy use as the supreme measure to contain the effects of population-induced emission increase, particularly in developing countries such as Nigeria due to increasing population. This claim is backed by the International Energy Agency (IEA), which emphasizes that global CO2 emissions dropped by 6% in 2020 due to reduced fossil fuel consumption. It is vital to note that the share of renewable energy in Nigeria's energy production rose by about 2-3% (IEA 2023). This was also confirmed empirically by Mansoor et al. (2018) who demonstrated that a small increment of RE by 1% leads to a huge 13%—ninety-five percent reduction in CO2 emissions.

Dong et al. (2020) opine that renewed consumption of energy is a 'substitution away from' fossil fuel consumption and hence helps in easing out CO2 emissions reduction, an opinion echoed by Ali et al. (2020) and Hussain et al. (2021). On the other hand, similar observations are contrary to several works like Begum, Cook, and Mark Stegman, Sulaiman et al., and Rehman et al., (2023) who opine that population does not affect emissions significantly and the contribution of renewable energy still insignificant. While Rehman et al. (2022) argue that rural population growth negatively correlates with CO2 emissions, likely due to lower industrial activity, this claim can be contrasted with official data from the National Bureau of Statistics (NBS, 2022) which shows that urban areas like Lagos and Port Harcourt contribute disproportionately to Nigeria's carbon footprint. The NBS Energy Report (2023) highlights that the industrial and transportation sectors in urban centers consume the majority of fossil fuels, whereas rural areas rely more on biomass and less energy-intensive activities. Furthermore, FAO data shows that while rural energy use might be lower, deforestation practices linked to traditional biomass usage could still contribute to indirect emissions, challenging Rehman et al. (2022) conclusion.

Moreover, this research is of tremendous importance as it expands knowledge of the linkage existing between the growth of the human population and carbon emission level with a focus on the prospects of renewed sources of energy. By explaining these linkages, this study provides information essential for development and strategic policy decisions during global environmental changes. As for its methodological contribution, the present research employs a novel co-integration regression technique based on the ARDL technique of bounds testing. Hence, this methodology, which is known to be very robust, gives reliable and effective estimates that are useful in defining the right policies that should be implemented for steady economic growth. This study therefore looked into the effects of population growth, carbon emission, and renewable energy in Nigeria in a bid to add to the existing knowledge in this area. Henceforth, the subsequent sections the following are the contents of the paper: Section 2 reviews the literature, Section 3 presents the methodology, Section 4 discusses the findings, and Section 5 concludes with policy recommendations

2. LITERATURE REVIEW

2.2 Theoretical Literature

2. 2.1 STIRPAT Theory

The STIRPAT model is developed further from the IPAT model which in its traditional form describes environmental impact (I) as equal to population (P) multiplied by Affluence (A) and Technology (T). This theory is useful in recognizing the fact that population growth has a direct relation to the environmental effect and carbon emissions. There is also an indication that technological changes such as renewable energy innovation can either reduce or increase environmental pressures about affluence and consumption.

2. 2.2 The Ecological Modernization Theory

Ecological modernization theory Which was formulated by Warren Thompson in 1929 notes that as societies evolve, they possess the capacity to handle environmental problems through technology and policies. About the usage of renewable energy, it recommends that a rise in population and economic development does not have to lead to the emission of carbon if technology is improved to result in the usage of renewable energy.

2. 2. 3 Demographic Transition Theory

The Demographic Transition Theory was done by Joseph Huber and Martin Jänicke in the 1980s and is suitable for explaining the relationship between population and the environment. They opined that due to the various demographic transitions, development and population growth rates of countries such as Nigeria have changed thereby influencing the issue of carbon emissions. However, in the early stages of growth, it is characterized by high population density and therefore high emission of carbon.

2.2 Related Empirical Literature

This present study focused on the influence of population on the emission and use of renewable energy on the performances of the African economy, Nigeria inclusive. Here, the study looked at previous empirical studies conducted in this area. For instance, Golpîra et al (2023) examined the development of the economic, fossil consumption, and density Population on emissions level with the data set of 1971 to 2014. Thus, in the present research, the ARDL model was adopted, with an emphasis placed on the Indian economy. The results confirmed the hypotheses of the (EKC) - environmental Kuznets curve, according to which the nexus between emissions and growth is U-shaped. Secondly, if the figures depicting the usage of fossil fuel sources and the density of the population are used in the long-term analysis then there is a positive relation with CO2 emissions.

Similarly, Rehman et al. (2023) conducted a study using the Nonlinear Autoregressive Distributed Lag (NARDL) approach to examine the relationship between economic development, renewable energy consumption, and CO2 emissions from 1985 to 2020. The findings provide empirical evidence as follows: while economic expansion has an inverse relationship with CO2 emissions, higher population growth increases emissions, and renewable energy consumption has no significant relationship with CO2 emissions.

Itoo et al. (2023) also had a similar approach and selected India for the analysis for the period 1980 to 2018. The determinants of emissions of dioxide included; population rate, natural resources, non-renewed use of energy, national income, remittance inflows, and industrial production. Used in the analysis of series were FMOLS, DOLS, and CCR. In light of these studies, it emerged that more people, national wealth, and energy consumption significantly enhanced pollution in India.

In this regard, Namahoro et al. (2021) examined the effect of renewed consumption of energy and growth in population on economic growth in countries in Africa—the research method used for the panel data to analyze the effect between 1980 and 2016. The result revealed that Renewed energy use adversely affects the level of emissions while economic growth and population exert positive effects. Regmi et al. (2021) turned to Nepal with the prospect of addressing the connectivity between the human population and emissions in the period 1971-2019. The method chosen to analyze conditions was the ARDL technique with cointegration for the recognition of variable behavior in the immediate and long-run processes. And, as shown by the study's outcomes, population growth together with the advancement in economic status is a negative influence on emissions.

In the same vein in Nigeria, Onyechi and Ejiofor (2021) examined the impact of carbon on the consumption of renewable energy. It comprised of the research year which was from 1990-2018. Consequently, the analysis disclosed a positive correlation between the existing level of C02 emissions and the utilization of renewable energy sources. The study also revealed that there is a negative correlation between urban population, oil rent, GDP per capita, and renewable energy consumption, and statistically significant at a 5% level, except for insignificant oil rent. As stated in the study, there is an urgent need to heighten consciousness and lobby the government and private persons to use efforts to develop and incorporate other clean sources of energy. That will be the right move in the drive to achieve affordable and clean energy and climate action.

Also, Hussain et al. (2021) investigated the influence of CO2 emissions on foreign direct investment, renewable energy consumption, and population growth in Pakistan from 1980-2020. The research revealed the following findings: population growth had a positive relationship with CO2 emissions, with p-values of 0.3577 and 0.5715In Malaysia, Ali et al. (2020) employed a panel data analysis to assess the relation with population, growth in GDP, generation of power, electricity, and carbon emissions level. The study employed Pearson correlation, and regression techniques to analyze the data from 1970 to 2014. The study exhibited a positive coefficient between population, generation of electricity, GDP, electricity, and GHG emissions. Since the human population of Malaysia is growing as well as an increase in GDP power generation and consumption have increased which in turn has increased carbon emissions.

Saidi et al. (2020) examined 15 major renewable energy-consuming nations between 1990 and 2014 using FMOLS and VECM. They discovered that renewed use of energy boosts growth while lowering emissions. The study also concluded no long-term causal link between CO2 emissions and renewable energy, although there is bidirectional causation between the variables in the short term. Miškinis et., (2021) utilized the five-factor model and the Divisia index (LMDI) method to understand the impact of renewable energies on climate change mitigation in the countries of Baltic during the timeframe spanning from 2010 to 2019. The results revealed that changes in greenhouse gas (GHG) emissions in these countries were affected by population changes, growth, reduced intensity of energy, increased deployment of energy renewable sources (RES), and a decrease in emission intensity. The system of GMM was employed by Hanif et al., (2019) to analyze data from twenty-five (25) economies, specifically those classified as upper-middle and lower-middle income, covering the period from 1990 - 2015. The result indicated that renewed energy played a positive role in mitigating the level of emissions, whereas non-renewable energy consumption was linked to an increase in emissions within the emerging Asian economies.

In 2017 Jebli et al alongside panel cointegration methodologies and a Granger causality test studied the bi-directional causality between CO2 and real_ GDP for the top five countries in North Africa. A cross-sectional study was carried out which showed a reciprocal cause-effect link with these functional variables. In the immediate terms, there is a bi-Granger causality between CO2 and agriculture, agriculture to GDP causality is unidirectional, GDP to renewed use of energy causality is unidirectional, and renewed energy consumption to agriculture causality is unidirectional. Thus, long-run bidirectional causality was evidenced for the connectivity between agriculture and emission, and unidirectional causality in the long-run was detected from renewed energy to agriculture, as well as, from GDP to agriculture and emission. The Long-term estimates showed that the GDP and renewable energy consumption had a positive and significant effect on emissions, while agricultural value-added had a negative and significant effect on emissions level.

Gaps and Value addition

Literature by Amin et al. (2020), Habiba et al. (2021), Rezitis et al. (2015), and Saidi et al. (2017) are closely related to the research at hand. However, the key point of divergence lies in the focus of these prior studies, which primarily examine the pathway of influence among C02, population growth, and growth. In contrast, this present study expands its scope to incorporate the dynamic role of renewable energy. Furthermore, our research is distinctively country-specific, as it concentrates its analysis on the Nigerian economy. Moreover, the study enhances its methodology by employing co-integration regression, following the recommendation of Pesaran (2001). I affirm to the best of the researcher's knowledge, that no previous work related to this research has simultaneously investigated the interplay among population growth, carbo, and renewed energy use in Nigeria's context. This represents the primary innovation and unique contribution of the study.

3. STUDY METHODOLOGY

3.1The Model

This work is hinged on the STIRPAT framework, an expansion and improvement of the IPAT. This theory was adopted because it recognizes that population growth has a direct relation to the environmental effect and carbon emissions. The STIRPAT was formulated by Dietz and Rosa in 1997. The framework is also known as the IPAT model the "I = PAT" equation and it's based on the GHG emissions calculation, as well as projections as developed by Ehrlich Paul and John Holdren. The IPAT framework represents the impact on the environment (I) as the power of three elements: (P) - population, (A)- Affluence, and (T) – Technology. it is depicted below as it is expressed below as:

$$\mathbf{I = P*A*T} \qquad (1)$$

Where; P, T, and A are the same as defined above

3.2 Nature and Data Source

This work used a series of data from 1989 - 2023. The study period is to be chosen due to data availability and to give room for a good degree of freedom for the results. The data used in the study are summarized and described in Table 1.

Variables	Identity	Measurement	Source
CO2	Carbon emissions	This is assessed in respect of emissions per capita in MT.	WDI, 2023
POG	Population Growth	This is measured for the growth of the human population	WDI, 2023
RGDP	Real-Gross Domestic Product	It is captured in the domestic growth of the economy	WDI, 2023
FFC	Fossil Fuel Consumption	It captures the level of fossil consumption in the domestic economy	WDI, 2023
RE	Renewable Energy	It is a metric that captures energy consumption derived from natural sources.	WDI, 2023
TO	Trade	This is measured with trade % of GDP	WDI, 2023

GFCF	Gross fixed capital formation	This explains the level of capital formation % of GDP	WDI, 2023

Source: Authors' Computation

3.3 Method of Data Analysis and Model Specification

The study employed the ARDL bound test method to analyze data from 1989 to 2023. We modified the STIRPAT model to specify the relationship between population growth, carbon emission, and renewable energy consumption as given in the functional form below:

$$CO2 = (POG, RGDP, FFC, RE, TO, GFCF) \qquad (2)$$

Equation (2) depicts C02 as a function of POG, RGDP, FFC, RE, TO, and GFCF above. Equation (2) can be written in **Econometric Form** as given below

$$CO2_t = \Phi_0 + \lambda_1 POG + \lambda_2 RGDP + \lambda_3 FFC_t + \lambda_4 RE + \lambda_5 TO_t + \lambda_6 GFCF + v_t \qquad (3)$$

Where the identities in Eq. (2 &3) are the same as defined in Table 1

$\mu\boldsymbol{t}$ = Error term λ_1, λ_2, λ_3, λ_4 λ_5, λ_6 and λ_7 are the coefficients of the independent variables.

Pesaran et al., (2001) model of ARDL is as follows for equation (3):

$$\Delta C02_t = \alpha_0 + \sum_{i=1}^{p} \alpha_1 \Delta C02_{t-i} + \sum_{i=0}^{p} \alpha_2 \Delta POG_{t-i} + \sum_{i=0}^{p} \alpha_3 \Delta RGDP_{t-i} + \sum_{i=0}^{p} \alpha_{14} \Delta FFC_{t-i} + \sum_{i=0}^{p} \alpha_5 \Delta RE_{t-i} + \sum_{i=0}^{p} \alpha_6 \Delta TO_{t-i} + \sum_{i=0}^{p} \alpha_7 + \lambda_1 C02_t + \lambda_2 POG_t + \lambda_3 RGDP_t + \lambda_4 FFC_t + \lambda_5 RE_t + \lambda_6 TO_t + \lambda_7 GFCF_t \qquad (4)$$

The range of values from λ1 to λ7 to the right shows the relationship of variables in the long run, whereas the range of values from α 1 to α 7 with the summation signs shows how the variables change over the short term. α 0 is the drift constant, while μt is the disturbance term when considering the other hand of the equation. H0: λ1 = λ2 = λ3 = λ4 = λ5 = λ6 = λ7 = 0 represents the null hypothesis in equation (4) This suggests that long-term relationships are therefore non-existent. H1: λ1≠ 0, λ2≠ 0, λ3 ≠ 0, λ4 ≠ λ5 ≠ λ5 ≠ λ6 ≠ λ7 ≠0 represents the alternative hypothesis. The error correction model and short-run dynamics are modeled below.

$$\Delta C02_t = \alpha_0 + \sum_{i=1}^{p} \phi_i \Delta C02_{t-i} + \sum_{i=0}^{p} \theta_i \Delta POG_{t-i} + \sum_{i=0}^{p} ꟿ_i \Delta RGDP_{t-i} + \sum_{i=0}^{p} \Psi_i \Delta FFC_{t-i} + \sum_{i=0}^{p} \Omega_i \Delta RE_{t-i} + \sum_{i=0}^{p} ϙ_i \Delta TO_{t-i} + \sum_{i=0}^{p} \odot_i \Delta GFCF_{t-i} + \delta_1 ECM_t + \varpi_t \qquad (5)$$

The ECM also assesses the rates at which equilibrium gradually returns after short-run shocks as indicated by the model, Dankumo et al, (2024), Oshota (2023), and Ihediwa (2023). Ojonugwa et al (2024) say that for any equilibrium to occur in the system, the coefficient of the error correction model should be negative and less than zero. The identities in Eq. (2, 3,4 &5) are the same as defined earlier.

4.1 Unit Root Test Result:

The unit root test is used to ascertain if the data series is consistent with a deterministic trend associated with the I (0) process or a stochastic trend associated with the I (1) process. To check for the stationarity of the variables, this study used the Augmented Dickey-Fuller (ADF) method.

Test Hypotheses:

H_0: Present of unit root (not stationary) vs H1: Absence of unit root (stationary)**.**

D_Rule: Reject H_0 if ADF |T-stat| or |T-cal| > ADF Critical value at |5%| significance level and finalize that unit root is not present. Hence, it is stationary. If otherwise, do not reject and conclude otherwise too.

Table 2. The Outcome of the Stationarity Test

Variables	ADF test statistic	Critical-V (5% level)	P-value	Order of integration	Decision
CO2	-5.189772	-3.557759	0.0010	I(1)	Stationary
FFC	-5.684594	-3.557759	0.0003	I(1)	Stationary
GFCF	-5.730939	-3.568379	0.0003	I(0)	Stationary
RGDP	-3.006774	-2.957110	0.0449	I(1)	Stationary
POG	-4.102271	-3.568379	0.0157	I(1)	Stationary
REC	-6.009440	-3.557759	0.0001	I(1)	Stationary
TO	-3.589461	-3.552973	0.0463	I(0)	Stationary

Source: Authors' conceptualization

The result above shows that each series attends stationary at first difference except GFCF and trade (TO) which show stationary at the level. The mixed differencing makes it suitable to employ the ARDL estimation approach.

4.2 Wald’s Test

The ARDL bound determines when more than two non-stationary variables at the base level have a long-term relationship. In this study, we use Wald's bound test on co-integration, subject to a fundamental constraint involving a combination of stationarity orders.

H_0 indicates no co-integration (no stable long-term link).

H_1 indicates co-integration (a steady long-term link).

If the F-statistic depicts greater than the upper critical limit at the level of significance (5%), reject H 0. If not, refrain from rejecting and coming to the conclusion that there are no enduring, stable relationships. Table 3 below displays the test results;

Table 3: ARDL Bound Test Result

Test Statistic	Value	Signif.	I(0)	I(1)	Result
F-statistic	9.313157	10%	2.12	3.23	
		5%	2.45	3.61	Co-Integrated
		2.50%	2.75	3.99	
		1%	3.15	4.43	

Source: Authors' conceptualization

Table 3 above shows that, at a 5% level of significance, the f-value derived from the test in Table 3 surpasses both the lower and upper critical boundaries. Consequently, we fail to accept the null hypothesis and conclude that co-integration exists with the series investigated in this research. This implies that there is a solid, long-term partnership. To account for adjustment time, the study will proceed with estimating the long and short-run models also with the error correction model (ECM).

4. RESULT, FINDINGS AND DISCUSSION

4.3 Empirical Result

Long run Coefficients

Table 3: Dependent Variable: Carbon Emission (C02)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
POG	0.311413	0.092880	3.352864	0.0057
REC	-0.030559	0.004213	-7.253921	0.0000
FFC	-0.026913	0.004488	-5.996993	0.0001
LGFCF	-0.023773	0.028347	-0.838648	0.4181
LRGDP	-1.030758	0.089779	-11.481103	0.0000
TO	0.000734	0.001396	0.525408	0.6089
C	7.455727	0.499711	14.920089	0.0000
R-squared=0.996843		F-statistic=199.4027		Durbin-Watson stat=2.744227
Adjusted R-squared=0.991844		Prob(F-statistic) =0.000000		

Sources: Authors' Computation

Table 4: Short Run and ECM Result
Dependent Variable: Carbon Emission (C02)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(CO2(-1))	0.367352	0.158078	2.323865	0.0385
D(FFC)	-0.002076	0.005437	-0.381897	0.7092
D(FFC(-1))	0.007515	0.005327	1.410761	0.1837
D(LGFCF)	0.094086	0.057493	1.636483	0.1277
D(LGFCF(-1))	0.150377	0.069129	2.175310	0.0503
D(LRGDP)	-1.876387	0.336592	-5.574670	0.0001
D(POG)	0.158000	0.186226	0.848434	0.4128
D(POG(-1))	-0.323829	0.174361	-1.857232	0.0880
D(REC)	-0.016659	0.005952	-2.798961	0.0161
D(REC(-1))	0.011851	0.005978	1.982317	0.0708
D(TO)	0.000619	0.000858	0.721874	0.4842
D(TO(-1))	0.000887	0.000661	1.343343	0.2040
ecm(-1)*	-1.036320	0.195329	-5.305505	0.0002
Diagnostic Tests				

Test		**Prob. Value**
Jarque-Bera (JB) Statistic	0.449532	0.798703
Heteroscedasticity Test (Breusch-Pagan-Godfrey)	0.5541	0.4426
Autocorrelation Test	0.2131	0.1420
Specification Bias Test (Ramsay test)	0.7251	0.7251

Source: Authors' conceptualization

The influence of various variables on Carbon emission has therefore been established from the estimation of the short-run ARDL model as follows. More importantly, the lagged C02 is positive, with the coefficient estimates at 0. 367352 and quite a reliable probability figure of 0. 0385. However, gross fixed capital formation increases significantly contribute to Carbon emission, with coefficients of 0.094086 (probability value: 0.1277) and 0.150377 (probability value: 0.0503) for the current and lagged periods, respectively. Similarly, improvements in the real gross domestic product (coefficient: 1.876387, probability value: 0.0001), population growth (coefficient: 0.158000, probability value: 0.4128), Renewable energy consumption (coefficient: -0.016659, probability value: 0.0161) significantly enhance Carbon emission while trade (coefficient: 0.000619, probability value: 0.4842) does not significantly enhance C02.

Notably, the lagged effect of population and Renewed energy use, and a coefficient value of -0.323829, with a P-value of 0.0880, and a coefficient of 0.011851 probability value of 0.0708 respectively demonstrate a negative short-term impact. The coefficient associated with "ECM (-1)" is -1.036320, with a probability value of 0.0002, indicating that it is statistically significant. This negative coefficient suggests that divergence from the equilibrium in the long term is adjusted for in the immediate term. Additionally, the model's high explanatory power, with an R^2 of 0.996843 and an adjusted R^2 of 0.991844, suggests that approximately 99.6% of the variability in C02 is accounted for by the included variables, even after adjusting for the number of independent variables.

The ARDL long-run estimation results shed light on the sustained relationships among the variables concerning the influence of growth in population on emission level: the role of renewable energy. Population growth (POG) showed a substantial and positive long-term effect on emission (C02), with a coefficient of 0.311413 and a P- value of 0.0057. Similarly, consumption of Renewable energy demonstrated a substantial but adverse long-term effect on carbon emission, with a coefficient of -0.030559 and a probability value of 0.0000. Also, consumption of Fossil fuel (FFC) showed a substantial negative impact on carbon emission(C02) with a coefficient of -0.026913 and a P- value of 0.0001. Gross fixed capital formation (LGFCF) depicts a negative and insignificant influence on Carbon emission in the long term, with a coefficient of -0.023773 and a probability of 0.4181. Conversely, the real gross domestic product (LRGDP) does exhibit a significant but negative long-term effect on carbon emission in this model, with a coefficient of -1.030758 and a P-value of 0.0000. Trade (as % of GDP) positively and insignificant influences Carbon emission in the long term, with a coefficient of 0.000734 and a probability value of 0.6089.

Authors of the outlined studies provide more/less similar findings that elaborate the consistency of the outcome of the present research with the findings of other empirical works. Abu-Goodman et al. (2023) and Edziah et al. (2022) also establish that renewed energy use decreases CO2 levels in Nigeria, which supports the view that an increase in energy from renewed energy sources leads to less emissions in the environment. This finding is inconsistent with the finding of Onyechi & Ejiofor (2021), which found a positive nexus between C02 and renewable energy consumption. On the other hand, the positive relationship between population and long-term Carbon emission conforms with the study conducted by Begum, et al. (2020); and Hussain et al. (2021) where the authors concluded that population affects the level of carbon emission. In contrast, Onyechi & Ejiofor (2021), observed that there is a negative impact of urban population on C02. This evidence on the fossil fuels and carbon emissions signifies the finding done by Itoo et al (2023), they have also emphasized the great impact that has been contributed by it on the emission level.

Also, the negative but significant correlation between the real gross domestic product and long-term carbon emission confirmed the revelation made by Namahoro et al (2021) and Mansoor, et al. (2018) which asserts that the volume of goods and products that are produced locally leads to carbon emission when the producers depend on the non-renewable energy source. Because of that, the post-estimation diagnostics of the BG tester indicate that in the null hypothesis, there is a lack of serial autocorrelation that can be accepted because the obtained p-value is not significant. The results of the BPG test which are the 'p' values are also non-significant which suggests that the residuals are homoscedastic. Based on the RESET test statistic, which has bigger probability values all of which are significant, the model passes the specification bias test and hence the individual hypotheses need to be rejected. In the end, the CUSUM test and CUSUM Square did not cross the important line and this informed that the residual from the ADRL model remains stable across time.

Parameter Stability Test (CUSUM Test) - Result

Figure 1: <u>Parameter Stability Test Plots</u>

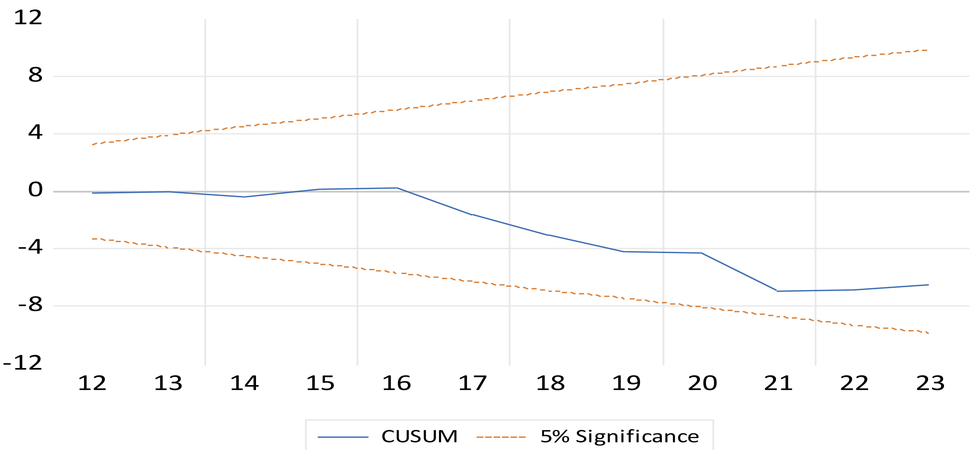
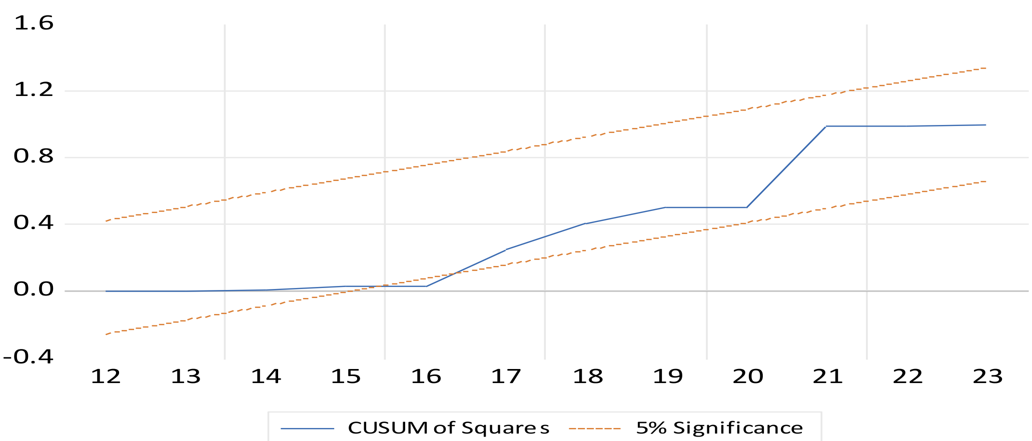


Figure 2: CUSUM (Squares)



5. CONCLUSION AND POLICY RECOMMENDATION

On this note, the empirical findings derived from the ARDL estimations bring out plausible forecasts for the dynamics of the nexus between the growing population and the renewable energy use on the level of emission (C02) in Nigeria. In the short run, therefore, population growth may not show a direct effect but the growth of population still holds the key to stability and the creation of an enabling surrounding on one hand and the other hand, in the long term, this present research indicates that population growth has a huge implication on the level of carbon and therefore the need to get it right through appropriate management of the teeming growth. Similarly, the short-run result established that consumption of renewed energy has a major influence on carbon emissions; this underscores the necessity of stability and the creation of a favorable environment, in contrast, a look in the long run revealed that renewable energy has a major contribution to the levels of carbon emission; this highlights the need to shift to clean energy consumption with little or no emissions.

Also, in line with the previous analysis of the short-run data, while variables such as fossil fuel consumption, gross fixed formation of capital, trade, and gross domestic product in real terms facilitate Carbon emission one way or the other; the long-run analysis reveals the role played by fossil fuel consumption and the level of real gross domestic product in determining the level of Carbon emission. These results call for multi-faceted policy efforts in Nigeria on carbon emissions due to the numerous challenges implicated by these findings and or potential for clean energy utilization in the country.

The study's recommendations are as follows: The government should promote the efficient use of renewed energy (including but not limited to solar, wind, and hydro-electricity) through grants, tax Credits, and favorable legislation. This is because they can help shrink the dependence on fossil energies as a source of power; metrics in the efficiency management of energy mean the adoption of measures in the conservation of energy in buildings, transports, industries, and appliances.

It includes standards and codes for new construction, efficiency standards, provision of incentives for undertaking energy efficient investments, and campaigns; Providing finances for research and development of low-carbon technologies like public transport, electric cars/charging points, and renewable energy networks; The implementation of policies and measures to reduce emissions from industries, automobiles, and other producers. These may include emission standards, fuel economy standards, or requirements for the purchase and deployment of cleaner technologies and investment in research & development, and effective storage capacities, renewable power, energy storage, and other low-carbon technologies.

REFERENCES

Abu-Goodman, M., Güngör, H., & Usman, O. (2023). Are the impacts of renewable energy and globalization on carbon neutrality targets asymmetric in South Africa? A reconsideration using a nonlinear ARDL approach. *Environmental Science and Pollution Research*, *30*(9)

Acheampong, A. O., Adams, S., & Boateng, E. (2019). Do globalization and renewable energy contribute to carbon emissions mitigation in Sub-Saharan Africa? *Science of the Total Environment*, 677, 436-446.

Adams, S., & Nsiah, C. (2019). Reducing carbon dioxide emissions; Does renewable energy matter? *Science of the Total Environment*, 693, 133288.

Ali, S. S. S., Razman, M. R., & Awang, A. (2020). The nexus of population, GDP growth, electricity generation, electricity consumption, and carbon emissions output in Malaysia. *International Journal of Energy Economics and Policy*, 10(3), 84-89.

Amin, A., Altinoz, B., & Dogan, E. (2020). Analyzing the determinants of carbon emissions from transportation in European countries: the role of renewable energy and urbanization. *Clean Technologies and Environmental Policy*, *22*, 1725-1734.

Begum, R. A., Sohag, K., Abdullah, S. M. S., & Jaafar, M. (2015). CO2 emissions, energy consumption, economic and population growth in Malaysia. *Renewable and Sustainable Energy Reviews*, 41, 594-601.

Dankumo, A. M., Shido-Ikwu, S. B., Ibrahim, J., & Auta, Y. (2024). Impact Of Health and Education Expenditures on Poverty Reduction in Nigeria. *Journal of Economics and Allied Research (JEAR)*, 45.

Doğan, B., Altinoz, B., Altinay, G., & Güneş, S. (2021). The mitigating effects of economic complexity and renewable energy on carbon emissions in developed countries. *Sustainable Development*, 29(1), 1-12.

Dong, K., Dong, X., & Jiang, Q. (2020). How does renewable energy consumption lower global CO2 emissions? Evidence from countries with different income levels. *The World Economy*, 43(6), 1665-1698.

Dong, K., Hochman, G., Zhang, S., Sun, R., & Li, H. (2018). CO2 emissions, economic and population growth, and renewable energy: Empirical evidence across regions. *Energy Economics*, 75, 180-192.

Edziah, Bless Kofi, Huaping Sun, Philip Kofi Adom, Feng Wang, and Andrew Osei Agyemang. "The role of exogenous technological factors and renewable energy in carbon dioxide emission reduction in Sub-Saharan Africa." *Renewable Energy* 196 (2022): 1418-1428.

Ehigiamusoe, K. U., & Dogan, E. (2022). The role of interaction effect between renewable energy consumption and real income in carbon emissions: Evidence from low-income countries. *Renewable and Sustainable Energy Reviews*, 154, 111883.

Golpîra, H., Sadeghi, H. and Magazzino, C., 2023. The Impact of Economic Growth, Population, and Energy Consumption on Environmental Degradation: Evidence from OECD Countries. *Environmental Science and Pollution Research,*

Habiba, U., Xinbang, C., & Ahmad, R. I. (2021). The influence of stock market and financial institution development on carbon emissions with the importance of renewable energy consumption and foreign direct investment in G20 countries. *Environmental Science and Pollution Research*, 28, 67677-67688.

Hanif, I., Aziz, B., & Chaudhry, I. S. (2019). Carbon emissions across the spectrum of renewable and nonrenewable energy use in developing economies of Asia. *Renewable Energy*, 143, 586-595.

Hussain, I., & Rehman, A. (2021). Exploring the dynamic interaction of CO2 emission on population growth, foreign investment, and renewable energy by employing the ARDL bounds testing approach. *Environmental Science and Pollution Research*, 28, 39387-39397.

Ihediwa, C. C., & Adamu, A. (2023). Effect of Imports on Economic Growth in Nigeria: A Sectoral Analysis. *Available at SSRN 4342850*.

International Energy Agency (IEA). (2023)

Ito, K. (2017). CO2 emissions, renewable and non-renewable energy consumption, and economic growth: Evidence from panel data for developing countries. *International Economics*, 151, 1-6.

Itoo, H. H., & Ali, N. (2023). Analyzing the causal nexus between CO2 emissions and its determinants in India: Evidence from ARDL and EKC approach. Management of Environmental Quality: *An International Journal,* 34(1), 192-213.

Jebli, M. B., & Youssef, S. B. (2017). The role of renewable energy and agriculture in reducing CO2 emissions: Evidence for North African countries. *Ecological Indicators*, 74, 295-301.

Lee, S.-H., & Jung, Y. (2018). Causal dynamics between renewable energy consumption and economic growth in South Korea: Empirical analysis and policy implications. *Energy & Environment*, 29(7), 1298-1315.

Lu, W.-C. (2017). Renewable energy, carbon emissions, and economic growth in 24 Asian countries: Evidence from panel cointegration analysis. *Environmental Science and Pollution Research*, 24, 26006-26015.

Mansoor, A., & Sultana, B. (2018). Impact of population, GDP and energy consumption on carbon emissions: Evidence from Pakistan using an analytic tool IPAT. *Asian Journal of Economics and Empirical Research*, 5(2), 183-190.

Miškinis, V., Rudzikas, M., Galinis, A., & Zavadskas, E. K. (2021). The role of renewable energy sources in dynamics of energy-related GHG emissions in the Baltic States. *Sustainability*, 13(18), 10215.

Namahoro, J. P., Wu, Q., Zhou, N., & Xue, S. (2021). The impact of renewable energy, economic and population growth on CO2 emissions in the East African region: *Evidence from common correlated effect means group and asymmetric analysis. Energies*, 14(2), 312.

National Bureau of Statistics (NBS). (2022). *Nigeria's energy consumption report*. National Bureau of Statistics.

Ojonugwa, A. M. (2024). External Debt Burden and Economic Growth in Nigeria Okekwu Ate Musa. *Journal Of Economics and Allied Research (JEAR)*, 218.

Onyechi, T. G., & Ejiofor, C. C. (2021). Decarbonizing Nigeria's Energy Mix: The Role of Renewable Energy Consumption. *Journal of Economics and Allied Research*, *6*(2), 2–22. Retrieved From Https://Jearecons.Com/Index.Php/Jearecons/Article/View/129

Oshota, S. O. (2023). Fiscal policy and sectoral output growth in Nigeria: new empirical evidence. *Journal of Economics and Allied Research (JEAR)*, *8*(3), 18-34.

Regmi, K., & Rehman, A. (2021). Do carbon emissions impact Nepal's population growth, energy utilization, and economic progress? Evidence from long-and short-run analyses. *Environmental Science and Pollution Research*, 28(39), 55465-55475.

Rehman, A., Ma, H., Ozturk, I., Murshed, M., & Dagar, V. (2022). Sustainable development and pollution: The effects of CO2 emission on population growth, food production, economic development, and energy consumption in Pakistan. *Environmental Science and Pollution Research*, 1-12.

Rehman, A., Ma, H., Ozturk, I., Murshed, M., Dagar, V., & Khan, Z. (2023). Globalization and renewable energy use: How are they contributing to an upsurge in CO2 emissions? *A global perspective. Environmental Science and Pollution Research*, 30(4), 9699-9712.

Rezitis, A. N., & Ahammad, S. M. (2015). The relationship between energy consumption and economic growth in South and Southeast Asian countries: A panel VAR approach and causality analysis. *International Journal of Energy Economics and Policy*, 5(3), 704-715.

Saidi, K., & Omri, A. (2020). The impact of renewable energy on carbon emissions and economic growth in 15 major renewable energy-consuming countries. *Environmental Research*, 186, 109567.

Saidi, K., Rahman, M. M., & Amamri, M. (2017). The causal nexus between economic growth and energy consumption: New evidence from a global panel of 53 countries. *Sustainable Cities and Society*, 33, 45-56.

Sulaiman, C., & Abdul-Rahim, A. S. (2017). The relationship between CO2 emission, energy consumption and economic growth in Malaysia: A three-way linkage approach. *Environmental Science and Pollution Research*, 24, 25204-25220.

Uzair Ali, M., Zahid, N. M., Iqbal, N., & Younis, M. (2022). CO2 emission, economic development, fossil fuel consumption, and population density in India, Pakistan, and Bangladesh: A panel investigation. *International Journal of Finance & Economics*, 27(1), 18-31.

Vélez-Henao, J.-A., Font Vivanco, D., & Hernández Riveros, J.-A. (2019). Technological change and the rebound effect in the STIRPAT model: *A critical view. Energy Policy,* 129, 1372-1381.

Vo, D. H. (2021). Renewable energy and population growth for sustainable development in the Southeast Asian countries. *Energy, Sustainability and Society*, 11(1), 1-15.

World Bank. (2023). *CO2 emissions and population growth in Nigeria*. World Development Indicators Database.