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RESEARCH PAPER

Population growth and environmental degradation in Nigeria: A comparative analysis of Carbon dioxide emissions and ecological footprint

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ABSTRACT

This study examines the effect of population growth on environmental degradation in Nigeria from 1980 to 2019, using two environmental indicators. The Auto-regressive distributed lag (ARDL) technique is employed in estimating short and long run dynamics of the variables. Similarly, the Dynamic Ordinary Least Square (DOLS) method is used as robustness check for estimated results. Short run ARDL results are consistent for both EFP and CO_2 emissions with regards to population growth. However, population growth affects only EFP in the long run. DOLS results are in tandem with long run ARDL results for EFP and CO_2 emissions. Energy consumption and gross fixed capital formation have reducing effect on EFP in the short run. In the long run, energy consumption is seen to increase CO_2 emissions, while gross domestic product per capita has an increasing effect on ecological footprint. The study recommends that adequate population control measures should put in place by government and a proper sensitization should be done on the ills of environmental degradation.

Keywords: Degradation, Environment, Footprint, Population.

1. INTRODUCTION

There has been consistent increase in world population over the years with a current figure of about 7.8 billion people of which Asia and Sub-Saharan Africa (SSA) takes the largest share [1]. Of this increasing population, Nigeria takes a share of about 202 million people [2]. The multiplier effect of this increasing population will be an increase in resource consumption followed by a high emission rate that will pose an environmental threat [3].

Environmental degradation has been an issue of great concern to policymakers across the world. This owes largely to global warming threat and its resulting socioeconomic impacts. Given an increasing population, the supply-demand gap of these resources could be widened as the ecosystems that provide these resources and absorb its carbon emissions can no longer meet up.

The ecological footprint (EFP) therefore, measures the supply of natural resources as well as human demand on the environment. It measures the environmental resources required for production and consumption activities, such that the emissions generated from these activities are absorbed by the environment [4]. It also describes the factors that lead to problems associated with climate change such as deforestation and species extinction [5].

There is a plethora of studies on the energy consumption-environmental degradation nexus for Nigeria [6-10]. However, not too many studies have examined the effect of population growth on environmental degradation in Nigeria [11-13].

Existing studies for Nigeria with respect to environmental degradation have employed carbon-dioxide (CO_2) emissions as the major factor. Environmental degradation should however not be limited to CO_2 emissions alone but should extend to other elements that deteriorate the environment. This study attempts to examine the extent to which an increasing population affects the environment in Nigeria using two environmental indicators; CO_2 emissions and ecological footprint over the period 1981-2019.

The study contributes to empirical literature by doing a comparison between CO_2 emissions and ecological footprint as environmental indicators in the population-environment nexus, as against most studies that have employed either of these variables. Secondly, the study deviates from other studies for Nigeria that have employed the EKC hypothesis as the underlying theory in their environmental analysis by adopting the STIRPAT model. The paper is organized with the next section providing information on the reviewed literature and section three comprising the methodology adopted for the study. Discussion of results is done in section four, while the study is concluded in section five with policy implications.

2. METHODOLOGY

There are different theoretical approaches to the population-environment analysis. The Impact, Population, Affluence, Technology (IPAT) model is a multiplicative model propounded by Ehrlich and Holdren (1971) [14] while establishing the fact that environmental impact (I) is a function of population (P), affluence (A) measured by GDP per capita and technology (T).

$$I = P.A.T \quad (1)$$

This theory posits a negative relationship between population growth and the environment owing to an increase in the demand for environmental resources following population increase [14]. This theory was adopted by some studies before being criticised for its inadequacy for hypotheses testing due to its proportionate estimation of the variables causing environmental degradation [15]. The Stochastic Impacts by Regression on Population, Affluence, and Technology (STIRPAT) model was later formulated by Thomas Dietz and Eugene Rosa to address the limitations of the IPAT model. The STIRPAT model is a stochastic transformation of the IPAT model, retaining its ecological foundation but reformulating it by allowing the independent estimation of each variable affecting the environment. The STIRPAT model is also applicable for hypotheses testing and allows the inclusion of other demographic, economic, social and cultural factors that may affect the environment into the model [16]. The model is given as:

$$I_i = aP^b A^c T^d e \tag{2}$$

Where population (P), affluence (A) and technology (T) are the determinants of environmental degradation (I).

In logarithmic form, it is formulated as:

$$lnI_t = a + b(lnP_t) + c(lnA_t) + d(lnT_t) + e \tag{3}$$

Where t denotes the year; b, c, and d are the coefficients of P, A, and T, respectively; e is the error term, and a is the constant. Eq. (3) presents the linear relationship between population, affluence and technology [17].

This study therefore adopts the STIRPAT model as developed by Dietz and Rosa (1994) in estimating the effect of population growth on environmental degradation in Nigeria [16]. Thus, the model for ecological footprint is specified as follows;

$$ln\ EFPt = \beta_1 + \beta_2 lnPOP_t + \beta_3 lnGDP_t + \beta_4 lnE_t + \beta_5 lnGFCF_t + \mu_t \tag{4}$$

Where: lnEFPt is the natural logarithm of ecological footprint, lnPOPt is the natural logarithm of population growth rate, lnGDPt is the natural logarithm of gross domestic product per capita used as proxy for affluence, lnEt is the natural logarithm of energy consumption used as proxy for technology, lnGFCFt is the natural logarithm of gross fixed capital formation and μ_t is the error term.

Similarly, following Audi and Ali (2016) [18] as well as Sulaiman and AbdulRahim (2018) [12], the model for CO_2 emission is specified as;

$$ln\ EFPt = \beta_1 + \beta_2 lnPOP_t + \beta_3 lnGDP_t + \beta_4 lnE_t + \beta_5 lnGFCF_t + \mu_t \tag{5}$$

Data set for this study consists of annual time series for years ranging from 1981-2019. Data employed include population growth, per capita income, energy consumption used as a proxy for technology, gross fixed capital formation as a proxy for investment, carbon dioxide emissions sourced from World Development Indicator and ecological footprint sourced from Global Footprint Network.

Unit-root test is conducted to ascertain the time-series properties of the data. The Augmented-Dickey Fuller (ADF) and Phillip Perron (PP) tests are employed. The Bounds test analysis of the Autoregressive Distributed Lag (ARDL) technique is used to establish the presence (absence) of long run relationship between the variables. If co-integration is established, the long and short-run ARDL models will be estimated. For the ecological footprint model, equations (4) and (5) represent the long and short-run ARDL specifications respectively. Similarly, for the CO2 model, equations (6) and (7) represent the long and short-run ARDL specifications.

$lnEFP_t = \beta_0 + \sum_{i=1}^{n} \beta_1 lnPOP_{t-1} + \sum_{i=1}^{n} \beta_2 lnGDP_{t-1} + \sum_{i=1}^{n} \beta_3 lnE_{t-1} + \sum_{i=1}^{n} \beta_4 lnGFCF_{t-1} + \mu_{3t}$	(6)

$lnEFP_t = \beta_0 + \sum_{i=1}^{n} \beta_1 \Delta lnPOP_{t-1} + \sum_{i=1}^{n} \beta_2 \Delta lnGDP_{t-1} + \sum_{i=1}^{n} \beta_3 \Delta lnE_{t-1} + \sum_{i=1}^{n} \beta_4 \Delta lnGFCF_{t-1} + \emptyset ECM_{t-1} + \mu_{4t}$	(7)

$lnCO_{2t} = \beta_0 + \sum_{i=1}^{n} \beta_1 lnPOP_{t-1} + \sum_{i=1}^{n} \beta_2 lnGDP_{t-1} + \sum_{i=1}^{n} \beta_3 lnE_{t-1} + \sum_{i=1}^{n} \beta_4 lnGFCF_{t-1} + \mu_{3t}$	(8)

$lnCO_{2t} = \beta_0 + \sum_{i=1}^{n} \beta_1 \Delta lnPOP_{t-1} + \sum_{i=1}^{n} \beta_2 \Delta lnGDP_{t-1} + \sum_{i=1}^{n} \beta_3 \Delta lnE_{t-1} + \sum_{i=1}^{n} \beta_4 \Delta lnGFCF_{t-1} + \emptyset ECM_{t-1} + \mu_{4t}$	(9)

Where ecm is the error correction representation in equation (5) and $\emptyset$ is the speed of adjustment. As a robustness check for the long run ARDL results, the study adopts the Dynamic -Ordinary Least Square (DOLS) technique. This technique can also be used for variables with a mixed order of integration and as such is adopted to validate the ARDL estimates.

3. RESULTS AND DISCUSSION

3.1. Unit Root Test:

Unit-root test is adopted in examining the time-series properties of the data. The result is presented in table 1.

Table 1: Unit Root Test Result

Variable	ADF Test Statistic at level (I0)	PP Test Statistic at level (I0)	ADF Test Statistic at first difference (I1)	PP Test Statistic at first difference (I1)
EFP	-1.467	-1.413	-6.133*	-6.274*
Population Growth	-3.961724 **	-2.887	-	-4.078**
Gdp/Capita	-2.264107	-1.161	-4.381	-3.826
Energy Use	-2.788	-2.675	-5.704*	-6.743*
GFCF	-3.902**	-4.103**	-	-
CO_2	-2.115	-2.182	-5.981*	-5.981*
Critical Values				
1%	-4.226	-4.219	-4.244	-4.226
5%	-3.536	-3.533	-3.544	-3.533
10%	-3.2	-3.198	-3.205	-3.198

Note: *and ** indicate significance at 1% and 5% levels respectively.

Table 1 shown above reports unit root test for all our variables. Population growth and gross fixed capital formation are integrated of order zero 1(0), while ecological footprint, GDP per capita and energy use are integrated of order one I (1). This justifies our choice of ARDL methodology as variables exhibit a mix of integration order 1(0) and 1(1).

3.2. Bounds Test for Co-integration:

The null hypothesis is given as:

Null Hypothesis $H0$: φ1 =φ2 =φ3 =φ4 = 0

If the calculated F-statistics value exceeds the upper bound, then the null hypothesis of no co-integration is rejected [19]. Table 2 shows the result.

Table 2 reported above shows the Bound-Test for linear co-integration. Since the calculated F-Statistic (7.684) and (8.573) are greater than the upper bound at 1%, 5% and 10%, we therefore establish long-run relationship for the two models.

3.3. *ARDL Results*:

The short and long-run estimates for all variables are presented using the ARDL framework.

Table 2: Bound Test Result

	Dependent Variable: LNEFP			Dependent Variable: LNCO2
F-Statistic		7.684*		8.573*
Critical Values	1 %	5 %	10 %	
Lower Bound	3.29	2.56	2.22	
Upper Bound	4.37	3.49	3.09	

Note: ** indicates significance and rejection of the null hypothesis of no co-integration at 5% significance level.

Table 3: ARDL Result

Dependent Variable: LNEFP *Dependent Variable: LNCO2*

Selected model: 1,2,2,1,3 *Selected model: 2.4.4.0.4*

LONG RUN ESTIMATES				
Variable	Coefficient	Probability	Coefficient	Probability
LNPOP	1.792	0.015**	0.805	0.886
LNGDP	0.068	0.000*	-0.077	0.471
LNE	0.304	0.454	4.279	0.004*
LNGFCF	-0.2	0.000*	-0.265	0.505
C	0.483	0.832	-22.625	0.029**
SHORT RUN ESTIMATES				
DLNPOP	9.752	0.000*	71.074	0.000*
DLNPOP(-1)	-8.084	0.000*	-107.898	0.001*
DLNPOP(-2)	---------	-------	85.673	0.002*
DLNPOP(-3)	----------	-------	-28.253	0.013**
DLNGDP	-0.029	0.486	0.179	0.325
DLNGDP(-1)	0.11	0.013**	-0.169	0.421
DLNGDP(-2)	----------	---------	-0.722	0.002*
DLNGDP(-3)	----------	---------	-0.681	0.004*
DLNE	-0.455	0.044**	----------	---------
DLNGFCF	-0.052	0.030**	-0.103	0.439
DLNGFCF(-1)	0.112	0.000*	-0.023	0.808
DLNGFCF(-2)	0.041	0.052***	-0.212	0.090***
DLNGFCF(-3)	--------	---------	-0.168	0.128
ECM	-0.819	0.000*	-0.995	0.000*
R -Squared	0.753		0.846	
AdjustedR-Square	0.678		0.750	
DW Statistics	1.888		2.451	
Normality test	0.598		0.091	
Breusch-Pagan-Godfrey (Heteroskedasticity)	0.623		0.711	
Breusch-Godfrey (Serial Correlation)	0.079		0.296	

Note: *, ** and ***indicate probability value at 1%, 5% and 10% respectively.

For the ecological footprint specification, the long run estimate reveals that population growth significantly increases ecological footprint for Nigeria at 5 percent. This means that a percentage increase in population will increase EFP by 1.79 percent. This validates theory that an increase in population will increase environmental degradation by exerting pressure on natural resources. Similarly, in the long run, GDP per capita determines EFP significantly at 1 percent. A percentage increase in GDP per capita will therefore increase EFP by 0.06 percent. This also conforms with a-priori expectation as it is assumed that higher per capita income will increase consumption and therefore increase environmental degradation. Energy use does not significantly determine EFP in the long run but positively affects EFP. Gross fixed capital formation has a negative and significant relationship with EFP at 1 percent.

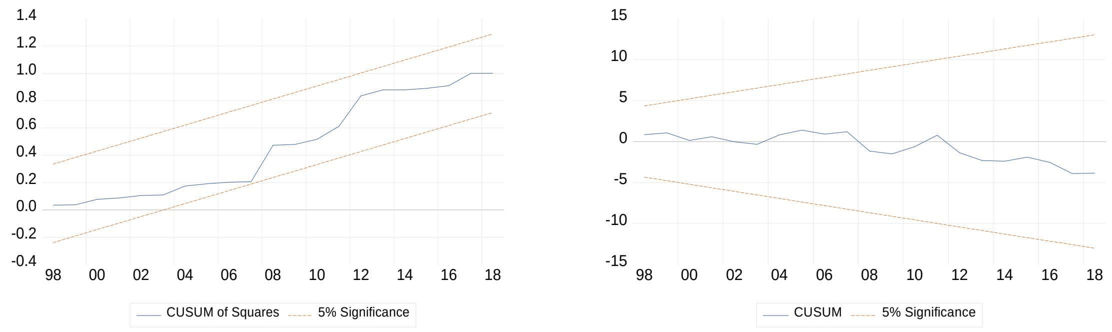

Image 1: CUSUM of Squares and CUSUM Test for EFP model

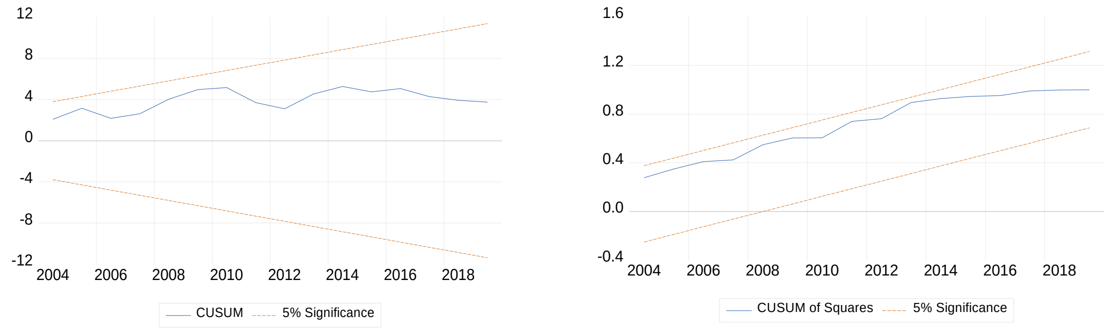

Image 2: CUSUM of Squares and CUSUM Test for CO_2 model

This means that a percentage increase in gross fixed capital formation lowers EFP by 0.20 percent.

Short run analysis also for the EFP model show that an increasing population positively determines EFP at 1 percent. One percent increase in population growth rate will increase EFP by 9.75 percent. This conforms with long run results. On the contrary, one lagged value of population growth has a negative and significant relationship with EFP at 1 percent. A percentage increase in population growth in this period will reduce EFP by 8.08 percent. One lagged value of income per capita has a positive and significant relationship with EFP at 5 percent. A percentage increase in GDP per capita in this period will increase EFP by 0.11 percent.

Energy use is seen to have a negatively significant relationship with EFP at 5 percent level of significance. An increase in energy use by one percent will therefore reduce EFP by 0.45 percent. Similarly, gross fixed capital formation (GFCF) has a negative and significant relationship with EFP at 5 percent. A percentage increase in GFCF in this period will reduce EFP by 0.05 percent. Lastly, one and two period lagged values of GFCF have positive and significant relationship with EFP at one percent. A percentage increase in GFCF in these periods will increase EFP by 0.11 and 0.04 per cents respectively. This conforms with a-priori expectation as GFCF is used as a measure of investment which drives environmental degradation.

Table 4: DOLS Results

	Dependent Variable: LNEFP		**Dependent Variable: $LNCO_2$**	
Variable	Coefficient	Probability	Coefficient	Probability
LNE	-0.526	0.362	5.558	0.187
LNGDP	0.082	0.001*	-0.069	0.651
LNGFCF	-0.193	0.006*	-0.531	0.247
LNPOP	3.003	0.006*	5.88	0.397
C	4.502	0.198	-29.621	0.237

Note: *, ** and *** indicate probability value at 1%, 5% and 10% respectively.

For the carbon dioxide emission specification, long run estimates show that only energy consumption contributes significantly to CO_2 emissions. A percentage increase in energy consumption increases CO_2 emissions by 4.27 percent. This conforms with a-priori expectation as energy consumption in Nigeria is dominated by the fossil fuels (crude oil, natural gas and coal) which contribute a great deal to CO_2 emissions. In the short run, population growth in the current and two lagged period have positive and significant effects on CO_2 emissions at 1 percent. A percentage increase in population growth in the current and two lagged period will increase CO_2 emissions by 71 and 85 percent respectively.

Conversely, one and three lagged values of population growth have negative effects on CO_2 emissions. GDP per capita in the two and three lagged periods have significant and negative effects on CO_2 emissions at 1 percent. A percentage increase in GDP per capita in these periods reduces CO_2 emissions by 0.72 and 0.68 percent respectively. Gross fixed capital formation (GFCF) has negative and significant effect on CO_2 emissions in the two lagged period. A percentage increase in GFCF in this period will reduce CO_2 emissions by 0.21 percent.

It is important to note that with respect to population growth, short run results of ecological footprint are consistent with that obtained for CO_2 emissions. The error correction terms for the two models are negative and significant at one percent. This means that the speed of adjustment from short-run to long –run equilibrium given any shock in the models is about 81 percent for EFP and 99 percent for CO_2. To ensure the reliability of the results, some post-estimation diagnostic tests are done. Normality, heteroskedasticity and serial correlation test results show that the null hypotheses for all these tests could be rejected for the two models. Similarly, CUSUM and CUSUMSQ tests confirms the stability of the models.

Figures 1 and 2 shows that the models are stable as the residuals are within the critical bounds of 5% significance.

3.4. Robustness Check:

To validate the ARDL result, the Dynamic Ordinary Least Square (DOLS) analysis is presented below.

The DOLS result presented above conforms with the ARDL long run estimates for the EFP model. Energy consumption does not significantly determine EFP, while GDP per capita, GFCF and population growth determine EFP at 1% significance level. GDP per capita has a positive relationship with EFP as a percentage increase in GDP/Capita will increase EFP by 0.08 percent at 1% level of significance. In the same vein, population growth has a positive relationship with EFP. A percentage increase in population growth will increase EFP by 3 percent. However, gross fixed capital formation has a negative relationship with EFP. A percentage increase in GFCF will reduce EFP by 0.19 percent at 1% significance level. The DOLS result for the CO_2 model also corroborates the ARDL long run results.

4. CONCLUSION AND POLICY RECOMMENDATIONS

This study examines the effect of population growth on environmental degradation in Nigeria between 1981 and 2019, while comparing two environmental indicators vis-à-vis ecological footprint and carbon dioxide emissions. The STIRPAT model is analysed within the Autoregressive Distributed Lag (ARDL) framework and long run results are validated with the Dynamic Ordinary Least Square (DOLS) analysis. The estimated long run coefficient reveals that an increase in population increases EFP significantly while population growth does not significantly affect CO_2 emissions. GDP per capita and gross fixed capital formation are also seen to affect EFP significantly with GDP per capita having a positive effect and GFCF having a negative effect in the long run. However, these two variables do not have any significant effect on CO_2 emissions in the long run, while energy consumption is seen to affect CO_2 emissions positively.

Short run estimates for population growth reveal similar results for both EFP and CO_2 emissions. Population growth has a positive effect on EFP and CO2 emissions in the current period. However, population growth has a negative effect on the two environmental indicators in the one lagged period. Other variables such as energy consumption and GFCF have negative effects on EFP but do not significantly affect CO_2 emissions in the current period. The error correction terms are negative and significant for both CO_2 and EFP specifications, revealing that there is an evidence of long run relationship between the variable. DOLS results confirm long run ARDL results for the two specifications.

Based on the findings from this study, the main policy recommendation is that adequate population control measures should be put in place by government to reduce the increasing demand on the environment. This includes amongst other measures, an increasing awareness and proper sensitization of the population on the need for family planning and the environmental effects of overpopulation. Long run policies should also focus on renewable energy options such as solar, wind, hydro, amongst others that will reduce CO_2 emissions. As per capita income increases, it is expected that consumption will also increase thereby placing a huge demand on the environment. As such, responsible and environmentally friendly consumption practices should be encouraged in terms of building, energy, agriculture etc.

5. ACKNOWLEDGEMENT

NA

6. CONFLICT OF INTEREST

NA

7. SOURCE/S OF FUNDING

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