



Mediating Effect Between Population Growth and Literacy Rate on Carbon Dioxide Emission (CO₂) in Nigeria

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Abstract

This study examines the impact of population growth and literacy on Nigeria's carbon dioxide (CO₂) emissions between 1981 and 2023. Carbon dioxide emissions (CEM) served as the dependent variable, while the explanatory variables included working population growth (WPG), dependent population growth (DPG), literacy rate (LTR), and their interactions (WPGLTR and DPGLTR). The analysis employed descriptive statistics, unit root tests, bounds cointegration, and the autoregressive distributed lag (ARDL) model. The findings indicate that WPG exerts a significant negative effect on CO₂ emissions in the medium and long run, while DPG has a weak but negative effect. LTR shows a short-run positive but insignificant effect on CEM and a long-run negative yet insignificant effect. The interaction term DPGLTR exhibits mixed effects: negative and insignificant in the short run, negative and significant in the long run, and positive but inconsequential in the short term. Overall, CO₂ emissions declined in both the short and long run as a result of WPG, DPG, LTR, and the DPGLTR interaction. However, the interaction between WPG and LTR was found to increase CO₂ emissions

over time, both in the short and long run. The study concludes that literacy in Nigeria, while valuable, has limited direct influence on reducing carbon emissions. Accordingly, literacy initiatives should go beyond basic reading and writing to incorporate environmental literacy and green skills. Strengthening ecological awareness among the working-age population could help offset the environmental consequences of industrialisation and economic activities, thereby mitigating long-term carbon emissions.

Keywords: Dependent Population, Literacy Rate, Mediating Effect, and Carbon Dioxide Emission, Population Growth, Working Population Growth

1. Introduction

The urgency of addressing climate change and environmental degradation has intensified globally, particularly in developing economies where rapid socio-economic transitions exacerbate ecological pressures. Nigeria, Africa's most populous nation, presents a distinctive and complex case. The country's population has grown from approximately 75 million in 1981 to more than 223 million in 2024, with projections suggesting continued expansion in the coming decades (World Bank, 2024). This demographic surge has placed considerable strain on infrastructure, energy systems, transport networks, and industrial production – factors that have collectively driven up carbon dioxide (CO₂) emissions (IEA, 2023).

Parallel to this demographic trend, Nigeria's literacy rate has increased markedly, rising from around 47% in 1981 to over 68% in 2024 (UNESCO, 2024). In theory, education enhances environmental awareness, shapes attitudes, and promotes pro-sustainability behaviours. A more literate population is expected to be cognisant of environmental challenges and supportive of sustainable practices (Afzal et al., 2010). However, the Nigerian case complicates this assumption: despite rising literacy rates, CO₂ emissions have continued to increase. This apparent disconnect raises questions about the nature and effectiveness of literacy in shaping environmentally responsible knowledge, attitudes, and behaviours.

While the relationship between population growth and CO₂ emissions has been widely documented in both national and international research, the potential mediating role of literacy has not been sufficiently examined. Mediating variables illuminate the mechanisms through which independent variables influence dependent outcomes. In this context, literacy may either mitigate or exacerbate the environmental consequences of population growth. On the one hand, literacy can promote environmental awareness

and responsible consumption, thereby reducing ecological pressures. On the other hand, if education systems fail to equip individuals with environmental competencies and green skills, rising literacy may translate into increased consumption, urbanisation, and industrial activity, which worsen environmental degradation (Nathaniel et al., 2021).

Despite its policy relevance, few empirical studies have simultaneously examined the interconnections among population growth, literacy, and CO₂ emissions in Nigeria. Most existing studies tend to address these dimensions in isolation, overlooking possible interaction effects or mediating pathways. This gap limits the ability of policymakers to design comprehensive strategies that address both demographic and educational factors in tackling environmental challenges. In a socio-economically and geographically diverse country like Nigeria, such partial approaches may result in ineffective or even counterproductive policies.

This study addresses this gap by investigating how literacy interacts with population growth to influence CO₂ emissions in Nigeria. Specifically, it explores whether literacy mediates the environmental impacts of demographic shifts. The findings are expected to provide valuable insights for the formulation of integrated education and environmental policies. This is particularly relevant for Nigeria's commitment to the United Nations Sustainable Development Goals (SDGs), notably Goal 4 (Quality Education), Goal 11 (Sustainable Cities and Communities), and Goal 13 (Climate Action).

2. Literature Review

2.1 Conceptual Clarifications

2.1.1 Population Growth

Population growth refers to the increase in the number of people within a given geographical area over time. It is commonly expressed as a percentage and results from either natural increase (the difference between birth and death rates) or net migration (the difference between immigration and emigration) (Weeks, 2015). Positive population growth occurs when the population rises, while negative growth occurs when it declines due to low fertility, higher mortality, or outward migration.

Globally, population growth has been shaped by improvements in healthcare, sanitation, economic development, and agriculture, which have lowered mortality rates and, in some cases, maintained higher birth rates (United Nations, 2022). Although developing nations continue to experience relatively high growth rates, many advanced economies are now witnessing slower or even negative population growth, largely due to sustained fertility decline. Understanding population dynamics is central to policy planning in areas such as urban development, resource management, education, and environmental sustainability (Cohen, 2003).

2.1.1a Working Population

The working population, also referred to as the economically active population, consists of individuals of working age (typically defined as 15 to 64 years) who are either employed or actively seeking employment (United Nations, 2022). By producing goods and services, generating income, and paying taxes, this group sustains national economies. In addition, the working-age population supports dependants at both ends of the age spectrum, underscoring its pivotal role in maintaining economic stability (Weeks, 2015).

2.1.1b Dependent Population

The dependent population comprises individuals who rely on the working-age group for support, primarily those under the age of 15 and those aged 65 and above. The dependency ratio, which measures the proportion of dependents relative to the working-age population, is a critical indicator of demographic and economic pressure. A high dependency ratio can strain public services, increase welfare costs, and limit overall economic productivity (Miller & Spoolman, 2019).

2.1.2 Literacy Rate

The literacy rate is the proportion of a population aged 15 years and above who can read and write a short, simple statement about their daily life (UNESCO, 2021). While some countries extend this measurement to younger cohorts, the indicator is widely recognised as a measure of human capital development. Higher literacy levels are strongly associated with improved public health, enhanced economic development, and increased civic and political participation (Weeks, 2015). Conversely, low literacy impedes social and economic advancement. Beyond its direct benefits, literacy plays a crucial role in poverty reduction and sustainable development (UNESCO, 2021).

2.1.3 Carbon Dioxide Emissions

Carbon dioxide (CO₂) emissions refer to the release of CO₂ gas into the atmosphere from human activities such as the burning of fossil fuels (coal, oil, and natural gas), industrial processes, and deforestation (IPCC, 2021). As the most significant long-lived greenhouse gas, CO₂ accounts for approximately three-quarters of total global greenhouse gas emissions and remains the principal driver of anthropogenic climate change (UNEP, 2022). Emissions are typically measured in metric tonnes per year and are used to assess the carbon footprint of countries, industries, and individuals.

2.2 Theoretical Literature

2.2.1 Demographic Transition Theory (DTT)

The Demographic Transition Theory (DTT) was first introduced by Warren Thompson in 1930, later expanded by Adolphe Landry in 1934, and formally refined by Frank W.

Notestein during the 1940s and 1950s. The theory posits that as societies undergo urbanisation, industrialisation, and rising levels of female education, both birth and mortality rates decline, leading to slower population growth. Population change is thus shaped by shifts in fertility and mortality, which in turn influence environmental, economic, and educational outcomes (Weeks, 2015).

The model generally outlines four (sometimes five) stages:

- **Stage 1:** High birth and death rates, leading to minimal growth.
- **Stage 2:** Falling mortality and high fertility, producing rapid growth.
- **Stage 3:** Declining fertility, resulting in slower growth.
- **Stage 4:** Low birth and death rates, stabilising population levels.
- **Stage 5 (optional):** Population decline in some advanced economies.

This theory is relevant to Nigeria as it links demographic dynamics, literacy, and CO₂ emissions. Higher literacy, particularly among women, tends to reduce fertility, slow population growth, and foster ecological awareness. In this way, Nigeria could indirectly reduce emissions by progressing toward later stages of demographic transition, characterised by slower growth and greater educational attainment.

2.2.2 IPAT Model of Environmental Impact

The IPAT equation, developed in the 1970s through the work of Paul Ehrlich, John Holdren, and Barry Commoner, provides a conceptual framework for analysing environmental change. It expresses environmental impact (I) as the product of population (P), affluence (A), and technology (T):

$$I = P \times A \times T$$

The model is particularly useful in this study because it connects CO₂ emissions to population growth, economic development (including literacy as a proxy for affluence and human capacity), and technological change. In Nigeria, population growth (P) exerts direct pressure on emissions, while literacy influences affluence (A) and technology (T). Literacy can moderate impacts by promoting sustainable consumption patterns, slowing fertility through education, and encouraging adoption of cleaner technologies that reduce emissions intensity. Thus, literacy emerges as a strategic pathway for mitigating the environmental costs of demographic expansion.

2.2.3 Human Capital Theory

The Human Capital Theory was first introduced by Adam Smith (1776) and later formalised by Chicago School economists such as Theodore Schultz (1961), Jacob Mincer (1958), and Gary Becker (1964). The theory conceptualises education, health, and skills as investments in human capital that enhance productivity, innovation, and economic returns, akin to investments in physical capital.

In the Nigerian context, literacy represents a critical form of human capital. Education can reduce the environmental impact of population growth by promoting sustainable practices, lowering fertility rates, and encouraging the adoption of green technologies. By enhancing productivity with less resource intensity, literacy can mediate the link between demographic expansion and carbon emissions.

2.2.4 Ecological Modernisation Theory (EMT)

Ecological Modernisation Theory (EMT), developed in the early 1980s by Joseph Huber and Udo Simonis and later expanded by Mol, Spaargaren, and Sonnenfeld, emphasises the role of technological innovation, institutional reform, and market forces in reconciling economic growth with environmental sustainability. The central premise is that “growth can become green” when modernisation is harnessed for ecological benefit.

For Nigeria, EMT suggests that literacy can play a transformative role by fostering the adoption of cleaner technologies, shaping positive environmental attitudes, and strengthening institutional capacity. Higher literacy enhances awareness and skill levels, which in turn can support sustainable consumption, industrial innovation, and stronger environmental governance. Thus, literacy is framed as a mediator that enables Nigeria to leverage modernisation to reduce CO₂ emissions, even in the face of population growth.

2.3 Empirical Literature

A growing body of empirical research has examined the relationship between population dynamics, education, energy use, and carbon dioxide (CO₂) emissions, though findings vary across contexts and methodological approaches.

Population Growth and CO₂ Emissions in Nigeria and Africa

Several studies have investigated the demographic–environment nexus in Nigeria. Lawal (2019), using ordinary least squares on data from 1975–2016, found that while population growth and technology were positively associated with CO₂ emissions, the overall impact of population growth on emissions was modest. Similarly, Yahaya et al. (2020), applying an ARDL framework, reported that in Nigeria, population density and energy resources exacerbate environmental degradation, though trade liberalisation improves environmental quality in the long run. More recently, Onwuemeka (2024) found no long-term relationship between population growth and CO₂ emissions in Nigeria between 1986 and 2022, although short-run results showed that population growth and fossil fuel consumption significantly increased emissions. Eze and Chinemeogo (2024) further confirmed that population growth exerts a long-run positive effect on CO₂ emissions despite gains from renewable energy consumption.

Broader African evidence aligns with these findings. Dimnwobi et al. (2021), analysing five densely populated African countries, showed that energy use, population density, and trade openness significantly contributed to environmental degradation, although urban population expansion was not a significant determinant.

Education, Literacy, and Environmental Outcomes

The role of education in mediating environmental outcomes has received growing attention. In Saudi Arabia, Alkatheeb et al. (2020) reported that secondary education reduced CO₂ emissions, while primary education had no significant effect, suggesting that the depth and quality of education matter. In Turkey, Eyuboglu and Uzar (2021) demonstrated that higher education negatively affected CO₂ emissions, underscoring the importance of advanced education in promoting environmental awareness and innovation. By contrast, Kelvey (2020) argued that economic growth linked to higher education may initially increase emissions, emphasising the need for targeted environmental education rather than education in general. Olaniyan et al. (2020), using household-level data, found that literacy ratio unexpectedly reduced CO₂ emissions alongside motorisation, household size, and income, though the results deviated from theoretical expectations. Collectively, these studies indicate that education can be a crucial moderating factor, but its effect depends on its type, quality, and environmental orientation.

Urbanisation, Tourism, and Population Dynamics

Urbanisation has emerged as another significant driver of CO₂ emissions. Zhang et al. (2021), examining Chinese data, found that interregional migration and the composition of urban residents significantly shaped the urbanisation–emissions relationship. Cheng and Hu (2022) further showed that both urbanisation and urban sprawl increased industrial, household, and transport-related emissions in China. In contrast, Lorente et al. (2021) reported that while urbanisation in BRICS countries reduced emissions, energy consumption and foreign direct investment amplified them.

Tourism-related studies also present nuanced findings. Chao and Jingjing (2019) identified an inverted U-shaped relationship between tourism growth and CO₂ emissions in China, highlighting the role of sustainable infrastructure. Liu et al. (2021), using panel data from 70 countries, showed that tourism had significant direct and indirect effects on emissions, with education and infrastructure investment mitigating negative impacts.

Energy Consumption, Technology, and Economic Growth

Energy use and technological innovation remain critical in explaining emissions trends. Shaari et al. (2021) found that in nine emerging economies, rural population growth did

not affect emissions, but economic growth and energy use significantly raised them. Rahman et al. (2021), analysing Pakistan, reported that while population expansion reduced CO₂ emissions in the short term, energy consumption, forestry, and temperature increases raised emissions. Anwar et al. (2021) and Rehman et al. (2023) highlighted the roles of urbanisation, renewable energy, and financial development in shaping emissions across Asian economies, with renewable energy often exerting only weak or insignificant effects. In the U.S., StoveTeam International (2022) demonstrated that technological improvements in stove manufacturing significantly reduced emissions, suggesting the effectiveness of innovation-based strategies.

The empirical literature demonstrates that while population growth frequently exacerbates emissions, its impact is often mediated by factors such as education, urbanisation, income, and energy consumption. Education, in particular, emerges as a potential moderating factor, though evidence is mixed: in some cases, literacy reduces emissions by fostering awareness and technology adoption, while in others it increases emissions by driving industrialisation and consumption. Despite the extensive research on population growth, education, and environmental quality globally, few studies have systematically examined the mediating role of literacy in Nigeria, a country experiencing both rapid population growth and rising literacy rates. This study therefore addresses this gap by empirically assessing how literacy interacts with demographic dynamics to influence CO₂ emissions in Nigeria.

3. Research Methodology

In this study, a quasi-experimental design was adopted, which is considered appropriate in the social sciences where random assignment of data is often not feasible. This design allows the researcher to examine cause-and-effect relationships between the dependent and independent variables without strict experimental control. By employing this approach, the study establishes empirical relationships while accommodating the complexities of real-world economic and environmental data.

The model specification of this study is in line with the work of Onwuemeka (2024) with a further modification. Onwuemeka (2024) investigated how Nigeria's population growth increases carbon dioxide emissions using the following model:

$$\text{CO}_2 = f(\text{AGRPOP}, \text{GDPPCGR}, \text{FOSC}, \text{FD}, \text{MVA})$$

(3.1)

Where;

CO₂ stands for carbon dioxide emissions, a proxy for environmental pollution.

AGRPOP stands for annual growth rate of the population.

GDPPCGR stands for GDP per capita growth rate.

FOSC stands for fossil fuel energy consumption.

FD stands for financial development.

MVA stands for manufacturing value added.

However, by investigating the relationship between Nigeria's population growth, literacy rate, and carbon dioxide emissions, the new study departs from previous research. Carbon dioxide emission (CEM) was used as the dependent variable, while dependent population growth, working population growth, literacy rate, and the interaction between dependent population growth and literacy rate (DPG*LTR) and working population growth and literacy rate (WPG*LTR) were used as explanatory variables.

$$CEM = f(DPG, WPG, LTR, DPG*LTR, WPG*LTR) \quad (3.2)$$

The mathematical form of the model is stated:

$$CEM = \alpha_0 + \alpha_1 DPG_t + \alpha_2 WPG_t + \alpha_3 LTR_t + \alpha_4 DPG*LTR_t + \alpha_5 WPG*LTR_t \quad (3.3)$$

The econometric form of the model is stated:

$$CEM_t = \alpha_0 + \alpha_1 DPG_t + \alpha_2 WPG_t + \alpha_3 LTR_t + \alpha_4 DPG*LTR_t + \alpha_5 WPG*LTR_t + \mu_1 t \quad (3.4)$$

Where;

CEM = Carbon dioxide emission

DPG = Dependent population growth

WPG = Working population growth

LTR = Literacy rate

DPG*LTR = Interaction between dependent population growth and literacy rate

WPG*LTR = Interaction between working population growth and literacy rate

CEM, DPG, WPG, LTR, DPG*LTR, and WPG*LTR as earlier defined

α_0 = the constant term

$\alpha_1 - \alpha_5$ = the coefficient of the explanatory variables

CEM, DPG, WPG, LTR, DPG*LTR, and WPG*LTR are as earlier defined.

α_0 = the constant term

$\alpha_1 - \alpha_4$ = the coefficient of the explanatory variables

μ_1 = Error term

a priori expectations are > 0 , > 0 , < 0 , $\alpha_4 < 0$ and $\alpha_5 < 0$.

This study examines the short- and long-term effects of the relationship between population growth and carbon dioxide emissions through literacy rate using Autoregressive Distributive Lag (ARDL). The research covers 43 years, from 1981 to 2023. To determine if each variable is stationary, the Augmented Dickey-Fuller (ADF) test for stationarity was used. The World Bank World Development Indicators provided the annual time series data used in this analysis for the years 1981–2023.

4. Results and Discussion

4.1 Descriptive statistics

The descriptive statistics summary for the variables used in this investigation is shown in Table 4.1. It displays the mean, median, maximum, minimum, and standard deviation, among other data.

Table 4.1: Descriptive Statistics

	CEM	DPG	WPG	LTR	DPG_LT R	WPG_LT R
Mean	0.721628	47.31791	52.68209	55.33674	2613.399	2920.257
Median	0.740000	47.32000	52.68000	55.16000	2614.370	2910.178
Maximum	0.960000	48.72000	55.48000	70.00000	3297.020	3772.613
Minimum	0.500000	44.52000	51.28000	43.90000	2137.110	2252.886
Std. Dev.	0.122162	0.972502	0.972502	6.806362	282.3831	402.5360
Skewness	-0.002223	- 0.754176	0.754176	0.218872	0.253720	0.255808
Kurtosis	1.713668	3.756498	3.756498	2.685748	3.002572	2.618226
Jarque-Bera	2.964617	9.191842	8.918049	0.520253	0.461357	0.730110
Probability	0.227113	0.010093	0.011574	0.770954	0.793995	0.694159
Sum	31.03000	2034.670	2265.330	2379.480	112376.2	125571.0
Sum Sq. Dev.	0.626786	39.72191	39.72191	1945.716	3349089.	6805479.
Observations	43	43	43	43	43	43

Source: *Author's Computation (2025)*

According to Table 4.1's descriptive data, the mean value of carbon dioxide emissions (CEM) is 0.721628, with a standard deviation of 0.122162. The long-left tail of carbon dioxide emission is indicated by its negative skewness score (-0.002223). Furthermore, the Carbon Dioxide Emission (CEM) kurtosis value of 1.713668 (less than 3) suggests that it is platykurtic. When the values go below the sample mean, this implies a flatter distribution.

The Dependent Population (DPG) has a mean of 47.31791, and its standard deviation is 0.972502. Additionally, the Dependent Population (DPG) has a long-left tail, as indicated by its negative skewness score of -0.754176. The kurtosis value of 3.756498 (more than 3) shows that the Dependent Population (DPG) is also leptokurtic, having a peak distribution where values are higher than the sample mean.

The standard deviation is 0.972502, and the mean for the Working Population (WPG) is 52.68209. The Working Population's (WPG) long-left tail is indicated by its positive

skewness score of 0.754176. As evidenced by its kurtosis score of 3.756498 (more than 3), the Working Population (WPG) is similarly leptokurtic, having a peak distribution when values exceed the sample mean.

The standard deviation is 6.806362, and the literacy rate (LTR) mean is 55.33674. A platykurtic distribution is suggested by the literacy rate's (LTR) kurtosis of 2.685748, which is less than 3, despite its positive skewness of 0.218872, which indicates a long-left tail. With values that primarily fall below the sample mean, this points to a somewhat flat distribution.

The mean and standard deviation of the Dependent Population and Literacy Rate (DPG*LTR) interaction are 2613.399 and 282.3831, respectively. The interaction between dependent population and literacy rate (DPG*LTR) shows a mesokurtic distribution with a kurtosis of 3.002572, or nearly 3, and a positive skewness of 0.253720, which indicates a long right tail. The values appear to have a normal distribution since they are clustered around the mean.

The mean and standard deviation of the Working Population and Literacy Rate Interaction (WPG*LTR) are 2920.257 and 402.5360, respectively. With a positive skewness of 0.255808, indicating a long right tail, and a kurtosis of 2.618226, less than 3, the interaction between working population and literacy rate (WPG*LTR) exhibits a platykurtic distribution. With values that primarily fall below the sample mean, this points to a somewhat flat distribution. The variables' Jarque-Bera statistics are a key component of this table. The DPG and WPG values are higher than 5.99, suggesting that these variables are not normally distributed. The fact that the CEM, LTR, DPG*LTR, and WPG*LTR values are less than 5.99, however, indicates that they do, in fact, follow a normal distribution.

Given these findings, it is crucial to test for the stationarity and long-term correlations of the variables, as utilising the variables at their level may lead to false conclusions. The study uses the Augmented Dickey Fuller (ADF) technique to do a unit root test to make sure the variables are stable.

4.2 Unit Root Test

Table 4.2 displays the stationarity test results for each variable used with the Augmented Dickey Fuller (ADF) test.

Table 4.2: Unit Root Test Results

Augmented Dickey Fuller (ADF) Test				
Variables	Level	1 st Difference	Status	Remarks
CEM	-3.260718	-6.985450	I(1)	Stationary
DPG	-6.344507	-	I(0)	Stationary
WPG	-6.344507	-	I(0)	Stationary
LTR	-3.680635	-	I(0)	Stationary
DPG*LTR	-3.986983	-	I(0)	Stationary
WPG*LTR	-3.353475	-5.156507	I(1)	Stationary
Critical Values	Level	1 st Difference		
1%	-4.192337	-4.205004		
5%	-3.520787	-3.526609		
10%	-3.191277	-3.194611		

Source: *Author's Computation (2025)*

According to the model's unit root test result in Table 4.2, DPG, WPG, LTR, and DPG*LTR were all stationary at level, whereas CEM and WPG*LTR were stationary at first difference. The study comes to the conclusion that the dependent variable is integrated of order one, or I(1), while the independent variables employed in the model were integrated of both order zero and one, or I(1) and I(0). We cannot use the Engle-Granger and Johansen co-integration tests because the ADF result shows that the series have distinct integration orders. The Bounds co-integration test should be used in this investigation instead. According to Jawaid and Waheed (2016), Salisu (2016), Perasan, Shin, and Smith (2001), and Giles (1975), the bound co-integration test should be applied when the series employed in a study have distinct co-integration orders.

4.3 Bound Co-integration Test Result

Since the series are integration of order one and zero, or I(1) and I(0), we next carry out the bound co-integration. The results of the bound Co-integration test are shown in Table 4.3 below.

Table 4.3: Bound Co-integration Test Result for the Model

Test Statistic	Value	k
F-statistic	6.345240	3
Critical Value Bounds		
Significance	I0 Bound	I1 Bound
10%	2.75	3.79
5%	3.12	4.25
2.5%	3.49	4.67
1%	3.93	5.23

Source: Author's Computation (2025)

According to the bound co-integration test findings in Table 4.3, the computed f-statistic value of 6.345240 is higher than the theoretical critical value for the upper bound I(1) at the 5 percent level. Hence, there exists a long-term co-integration or association between DPG, WPG, LTR, DPG*LTR, and WPG*LTR and CEM in Nigeria over the reviewed period. We now estimate the short-term dynamics and long-term models using the ARDL technique because the variables have a long-term relationship.

4.4 Evaluation of the Short and Long-Term ARDL Estimation Outcomes of the Model

The model's short and long-term dynamics estimation results are shown in Table 4.4.

Table 4.4: Short Run and Long Run Result for the Model

Short Run Coefficients				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(CEM(-1))	0.243811	0.181292	1.344850	0.1888
D(DPG)	-0.001256	0.001315	-0.955396	0.3470
D(WPG)	-0.153482	0.060026	-2.556941	0.0159
D(LTR)	0.015835	0.024361	0.650003	0.5206
DLOG(DPG*LTR)	-2.626940	1.377852	-1.906548	0.0662
DLOG(WPG*LTR)	1.811877	1.500579	1.207452	0.2367
D(@TREND())	-0.010178	0.003077	-3.308137	0.0024
ECM (-1)	-0.876134	0.216648	-4.044044	0.0003

Adj-R² = 0.600501; F-Stat. = 13.32383 (F-Prob. Value = 0.000041); Durbin-Watson stat. = 2.041184				
Long Run Coefficients				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
DPG	-0.001434	0.001575	-0.910518	0.3698
WPG	-0.175181	0.064875	-2.700284	0.0113
LTR	-0.040330	0.022412	-1.799497	0.0820
LOG(DPG*LTR)	-2.998333	1.350606	-2.219991	0.0341
LOG(WPG*LTR)	5.332179	1.426443	3.738094	0.0008
C	-6.299980	8.410242	-0.749084	0.4596
@TREND	-0.011617	0.001360	-8.541487	0.0000

Source: *Author's Computation (2025)*

According to Table 4.4, the computed Adjusted-R square is 0.600501, which indicates that almost 60% of the variation in Carbon Dioxide Emission (CEM) can be explained by the model's regressors. The error term explains the remaining 40%, which comes from exogenous sources. Additionally, the F-calculated of 13.32383 and the f-stat prob value of 0.0000, both of which are below the 0.05 level, demonstrate that the overall regression result of the dynamic model is significant at the 5 percent level. The ECM is very important and signed. Because the data utilised are annual, it demonstrates that the Carbon Dioxide Emission (CEM) model's 88 percent disequilibrium from the prior year has been modified for the current year. Additionally, the Durbin-Watson (D.W.) statistics value of 2.041184 indicates that serial autocorrelation is not present in the model.

The short-term coefficient of Dependent Population growth (DPG), which stands at -0.001256 in Table 4.4, is also negative. This suggests that for every 1% rise in Dependent Population Growth (DPG), Carbon Dioxide Emissions (CEM) decline by 0.001256 percent. At the five percent level, the Dependent Population Growth (DPG) coefficient is not statistically significant. Dependent population growth's (DPG) insignificant impact suggests that it has no discernible impact on carbon dioxide emissions (CEM).

Furthermore, the findings show that the Working Population Growth (WPG) coefficients for the short term are negative, at -0.153482. Accordingly, Carbon Dioxide Emissions (CEM) decrease by 0.153482 percent for every 1% increase in Working

Population Growth (WPG). At the five percent level, the Working Population Growth (WPG) coefficient is statistically significant. The fact that working population growth (WPG) has a large impact on carbon dioxide emissions (CEM) suggests that WPG has a big impact on CEM in Nigeria.

At 0.015835, the short-term Literacy Rate (LTR) coefficient is positive. Accordingly, carbon dioxide emissions (CEM) rise by 0.015835 percent for every 1% increase in the literacy rate (LTR). At the five percent level, the Literacy Rate (LTR) coefficient is not statistically significant. Literacy Rate (LTR) and Carbon Dioxide Emission (CEM) have a poor association, suggesting that LTR has no discernible impact on CEM in Nigeria.

The short-term interaction coefficients between the literacy rate and dependent population growth (DPG*LTR) are negative, or -2.626940. Accordingly, there is a 2.626940 percent drop in Carbon Dioxide Emission (CEM) for every 1% rise in the relationship between Dependent Population Growth and Literacy Rate (DPG*LTR). At the five percent level, the population growth coefficient (PPG) is not statistically significant. The small impact of the Dependent Population Growth and Literacy Rate (DPG*LTR) interaction on Carbon Dioxide Emission (CEM) in Nigeria indicates that CEM is not significantly impacted by this interaction.

The short-term working population growth and literacy rate (WPG*LTR) relationship is positive at 1.811877 once more. This indicates that while the working population growth and literacy rate (WPG*LTR) increased over the study period, Nigeria's carbon dioxide emissions (CEM) rose by roughly 1.811877 percent. At the five percent level, the working population growth and literacy rate (WPG*LTR) interaction coefficient is not statistically significant. The working population growth and literacy rate (WPG*LTR) interaction has a low impact on carbon dioxide emissions (CEM) in Nigeria, suggesting that it has no significant effect on CEM.

The long-term coefficient of Dependent Population growth (DPG) is negative, or -0.001434, as indicated in Table 4.4. This suggests that for every 1% rise in Dependent Population Growth (DPG), Carbon Dioxide Emissions (CEM) decline by 0.001434 percent. At the five percent level, the Dependent Population Growth (DPG) coefficient is not statistically significant. Dependent population growth's (DPG) insignificant impact suggests that it has no discernible impact on carbon dioxide emissions (CEM).

The findings also show that the Working Population Growth (WPG) coefficients are negative in the long term, at -0.175181. Accordingly, Carbon Dioxide Emissions (CEM) decrease by 0.175181 percent for every 1% increase in Working Population Growth (WPG). At the five percent level, the Working Population Growth (WPG) coefficient is statistically significant. The fact that working population growth (WPG) has a large

impact on carbon dioxide emissions (CEM) suggests that WPG has a big impact on CEM in Nigeria.

Furthermore, long-term data show that the Literacy Rate (LTR) coefficients are negative, or -0.040330. Accordingly, carbon dioxide emissions (CEM) rise by 0.040330 percent for every 1% increase in the literacy rate (LTR). At the five percent level, the Literacy Rate (LTR) coefficient is not statistically significant. Literacy Rate (LTR) and Carbon Dioxide Emission (CEM) have a poor association, suggesting that LTR has no discernible impact on CEM in Nigeria.

Furthermore, the findings show that the long-term interaction coefficients between the literacy rate and dependent population growth (DPG*LTR) are negative, or -2.998333. This suggests that Carbon Dioxide Emissions (CEM) would fall by 2.998333 percent for every 1% increase in the relationship between Dependent Population Growth and Literacy Rate (DPG*LTR). At the five percent level, the population growth coefficient (PPG) is statistically significant. The interplay between dependent population growth and literacy rate (DPG*LTR) and carbon dioxide emissions (CEM) has a considerable impact on CEM in Nigeria, as seen by the substantial influence of this interaction on CEM.

The long-term result once more demonstrates a positive relationship between the working population growth and the literacy rate (WPG*LTR) at 5.332179. This indicates that as the working population growth and literacy rate (WPG*LTR) increased during the study period, Nigeria's carbon dioxide emissions (CEM) rose by roughly 5.332179 percent. At the five percent level, the working population growth and literacy rate (WPG*LTR) interaction coefficient is statistically significant. In Nigeria, the working population growth and literacy rate (WPG*LTR) interaction has a significant effect on carbon dioxide emissions (CEM), as evidenced by the high effect on CEM.

4.5 Diagnostic Testing Results for the Model

Table 4.5 below displays the findings from the diagnostic or post-estimation testing. The results of the tests for heteroscedasticity (using the Breusch-Pagan-Godfrey Test) and serial correlation (using the Breusch-Godfrey Serial Correlation LM Test) are displayed in Table 4.5. The study comes to the conclusion that the model passes the full post-estimation test, as shown in Table 4.5.

Table 4.5: Diagnostic Test Results for the Model

Test	Result	Prob.
Normality Test (Jarque-Bera Test)	1.132353	0.567692
Linearity Test (Ramsey RESET Test)	0.331152	0.5694
Breusch-Godfrey Serial Correlation LM Test	0.032160	0.8589
Heteroskedasticity Test	0.479393	0.8901

Source: *Author's Computation (2025)*

5. Conclusion

This study examined the impact of Nigeria's population growth and literacy rate on carbon dioxide emissions (CEM) between 1981 and 2023. The dependent variable was carbon dioxide emissions, while the explanatory variables were working population growth (WPG), dependent population growth (DPG), literacy rate (LTR), and the interactions between *WPGLTR* and *DPGLTR*. Data were analysed using descriptive statistics, the Autoregressive Distributed Lag (ARDL) model, the Unit Root Test, and the Bound Cointegration Test.

The findings indicate that working population growth (WPG) exerts a significant negative influence on CEM in both the short and long run, suggesting that a larger working population can reduce emissions, possibly through productivity-driven efficiency. Dependent population growth (DPG) has a negligible but negative effect on emissions, while literacy rate (LTR) exerts a small positive short-term impact but a small negative long-term effect. Interaction effects show that *DPGLTR reduces emissions both in the short and long term, with the long-term effect being significant. Conversely, WPGLTR increases emissions over both time horizons, indicating that literacy among the working population is linked to greater industrial and energy-intensive activity, which drives up emissions.*

Overall, the study demonstrates that Nigeria's demographic dynamics and literacy levels jointly shape its environmental trajectory, with complex and sometimes contradictory effects across different population segments.

6. Recommendations

Based on these findings, the following policy recommendations are proposed:

- i. Refocus literacy programmes to include environmental literacy and green skills alongside reading and writing, since literacy alone has limited effect on reducing emissions. By linking literacy to sustainable practices, working-age individuals can become more environmentally conscious.

- ii. Promote eco-friendly vocational training and workplace policies. Both public and private sectors should embed environmental awareness into professional training while supporting the adoption of green technologies and sustainable business practices.
- iii. Strengthen investment in education and infrastructure for dependent groups. Although DPG has a negligible direct effect, its interaction with literacy significantly reduces emissions. Thus, investment in schools, healthcare, and renewable energy for children and the elderly can generate long-term environmental benefits.
- iv. Address the emission risks of WPG*LTR. Since literacy among the working population is associated with higher emissions, policies should counterbalance industrial expansion with clean manufacturing incentives, subsidies for renewable energy, and sustainable urban planning.
- v. Support interdisciplinary research and innovation. Government and academic institutions should collaborate on low-carbon development strategies, particularly those linking human capital development, climate change mitigation, and inclusive growth.
- vi. Integrate demographic, educational, and environmental policies. National strategies should explicitly align education reforms with climate policy and population management. For instance, the Ministry of Environment and Ministry of Education could jointly design curricula that embed sustainability principles into all levels of schooling.

7. Limitations and Suggestions for Further Research

Despite its contributions, this study has some limitations. First, it relied on secondary data for 1981–2023, and findings are constrained by the quality and consistency of these sources. Second, the ARDL model, while effective for mixed integration orders, may not fully capture nonlinear dynamics or structural breaks in Nigeria's demographic and economic history. Third, the study focused primarily on population and literacy, leaving out other key determinants of emissions such as energy structure, governance quality, and technological change.

Future research should:

- i. Incorporate additional explanatory variables (e.g., renewable energy adoption, industrial composition, and institutional quality).
- ii. Apply advanced econometric models (such as nonlinear ARDL, structural VAR, or panel quantile regression) to explore asymmetric and heterogeneous effects.
- iii. Conduct comparative analyses across African economies with similar demographic structures to contextualise Nigeria's trajectory.
- iv. Undertake micro-level studies at the household or firm level to examine how literacy influences energy-use behaviours and emissions.

- v. Pursue interdisciplinary approaches, integrating economics with sociology, education, and environmental sciences to better capture behavioural and cultural factors in the literacy.

By addressing these gaps, future research can provide deeper insights into how Nigeria and other developing countries can harmonise demographic transitions, human capital development, and environmental sustainability.

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