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Climate Change and Population Growth Rate: any Implications for Economic Growth in Nigeria?

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Abstract

The study was on Nigeria's CC, PGR, and economic growth (1986-2021). Secondary data collected from the Central Bank of Nigeria Statistical Bulletin, World Bank, WDI, and Nigerian Meteorological Agency (NIMET) were analyzed using unit root test, Auto-regressive distributed lag model (ARDL) for climate change since variables were of I(1) & I(0) as there was no co-integration. In contrast, the Error Correction Model (ECM) was used for population growth rate as variables were of I(1) and I(0), and there was co-integration. The GC test was adopted to determine the causal relationship among variables. The results showed that the coefficient values of lag one and two of LNRGDP had a significant relation with economic growth at both 10% and 1%, respectively, while lag three period of CAE was significant at a 5% level of probability. The study showed that birth growth rate and net migration positively and negatively impacted economic growth. It also showed unidirectional causality between crude death rate and economic growth and life expectancy at birth with economic growth. The study, therefore, recommends that the government invest in critical policies (real sectors of the economy) for economic growth and research the area of clean energy and eco-friendly approaches and population management with awareness campaigns that can ensure sustainable economic development.

Keywords: *Climate Change; Population Growth Rate; ARDL, ECM; Economic growth*

JEL Classification: Q54, Q56, 04.

1. Background of the Study

CC has continued to be a significant contemporary issue affecting societies worldwide, and it poses a serious threat to Nigeria, a developing nation with a population of over 200 million people.

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There is mounting evidence indicating that CC-related factors, including rising temperatures, altered rainfall patterns, sea-level rise, disruptions to freshwater resources, extreme weather events, widespread flooding, droughts in the northern regions, and heightened health risks, contribute to the country's vulnerability. These climate-induced issues are taking a toll on Nigeria's economy, exacerbating environmental concerns and negatively affecting the overall economic well-being of its citizens [Adejumo, 2021]. Climate change is a prolonged and persistent alteration in statistical climate patterns, typically lasting a decade or more. It encompasses variations in the frequency and intensity of sporadic weather events and the gradual, ongoing global average surface temperature increase, as documented by the Intergovernmental Panel on Climate Change (IPCC) in 2001. The German Advisory Council on Climate Change has emphasized that climate change poses a substantial and current threat to human society and the natural environment, affecting developed and developing nations. Its impacts extend to health, food production, housing, safety, and employment, with certain regions, such as small island nations and developing countries, facing heightened exposure to climate-related challenges.

One of the world's fastest-growing nations is Nigeria, with a projected estimated population of 233.34 million by the year 2025 and an annual growth rate of 2.9%, which equally stands as Sub-Saharan Africa's most populous country and the tenth most populous globally. However, the majority of its population falls within the youthful demographic, with 49% being individuals under the age of 21, resulting in a high dependency ratio estimated at 89%. According to a study conducted by Fadairo, Osayomi, Adelakun, Olaniyan, Olutegbe, and Nathaniel in 2020, Nigeria's large population heavily relies on climate-sensitive sectors such as agriculture and fisheries, as well as natural resources like water, biodiversity, and grasslands for their sustenance and livelihood. To achieve sustainable growth and environmental well-being, it is imperative to establish the link between economic growth and climate change.

Nigeria has historically utilized population censuses to formulate viable economic strategies, but the results have proven insufficient for economic planners and policymakers, especially in light of the alarming population expansion relative to limited available resources. This scenario makes achieving economic growth challenging, necessitating policy formulation to address this issue, as discussed in the work of Aidi, Emecheta, and Ngwudiobu in 2016.

Akintunde, Olomola, and Oladeji (2013) assert that improving the welfare of the society entails a right population policy and its growth rate in the development plans of many third-world countries. The relationship between PGR and economic output has been studied extensively, with some analysts suggesting that economic growth in high-income countries may slow due to projected declines in population growth. Others argue that population growth poses a problem as it leads to increased resource consumption, thereby diminishing long-term growth potential, a viewpoint supported by Linden (2017). PGR and economic growth are recognized as primary drivers of rising emissions that contribute to climate change, as articulated by the IPCC (2014). These factors act as "threat multipliers," amplifying many risks to natural and human systems. EG is defined as an increase in the production of economic goods and services over time, has a positive impact on poverty reduction, according to Potters (2021). Despite growing concerns about climate change, there is a lack of precise and reliable figures to measure the economic costs of its negative impacts on individuals or society in Nigeria, as indicated by Adejumo in 2021. Research on the relationship between climate change and economic growth is inadequate with respect to

Nigeria, with some studies suggesting a negative connection between these variables, as climate change's effects hinder EG. However, others posited no clear relationship, as demonstrated in Aidi et al.'s 2016 study on population growth and economic growth in Nigeria.

Some studies have shown a detrimental relationship between climate change and the Nigerian economy. Ogbuabor and Egwuchukwu (2017) found that carbon pollution negatively affects both short-term and long-term economic growth. Naeem (2012) assessed the impact of climate change on economic growth in selected Oriental countries and concluded that changes in temperature, precipitation, and population growth have adverse effects on economic growth, while civilization and human development stimulate it.

Research into the impact of PGR on economic growth has been conducted in various countries, mostly in Europe and Asia. Still, there is a lack of comprehensive studies on the Nigerian case. This study aims to fill this gap by investigating the impact of PGR economic growth in Nigeria for the period. While some studies, like Eli, Mohammed, and Amade's (2015) work, suggested a positive relationship between population growth and economic growth, others argued that population growth can be problematic by increasing resource utilization and limiting long-term growth potential, in line with Linden's (2017) perspective.

Furthermore, many existing reviews in this field are not up to date in terms of data scope. For ample, Ogbuabor and Egwuchukwu's (2017) studied the impact of CC on the Nigerian economy using data from 1981 to 2014. Similarly, studies on the impact of population growth on economic growth in Nigeria, such as Eli et al. (2015) and Adejumo (2021), relied on data from the 1980s to early 2010s. Given these considerations, the research addresses the following questions: Is there any effect of climate change on economic growth? What is the impact of population growth rate on economic growth? Is there a causal relationship between climate change, population growth rate, and economic growth in Nigeria?

The primary focus of this study is to determine the influence of climate change and population growth rate on Nigeria's economic growth. The study's hypotheses aimed at determining whether there is a significant effect of CC and PGR on economic growth in Nigeria and whether a causal relationship exists among CC, PGR , and economic growth in Nigeria.

This research holds value for the government, policymakers, and researchers as it sheds light on the relationships between CC, PGR, and EG. The study's scope was chosen based on data availability and encompasses variables such as RGDP, PGR (including birth rate, crude death rate, net migration rate, and life expectancy at birth), and CC indicators (temperature, rainfall, and CO2).

2. Literature review

2.1. Theories of Climate Change (CC)

Numerous theories have been proposed to explain climate change, with the Anthropogenic Global Warming (AGW) theory standing as one of the foremost theories related to global warming. The AGW hypothesis asserts that human activities, specifically the release of greenhouse gases like carbon dioxide (CO2), methane, and nitrous oxide, are responsible for a perilous escalation in global temperatures. This process is driven by the enhanced greenhouse effect.

The enhanced greenhouse effect functions as follows: Solar energy from the sun traverses through space and reaches the Earth. The Earth's atmosphere is largely transparent to this incoming sunlight, allowing it to reach its surface, where some of it is absorbed while the rest is reflected back into the atmosphere as heat. Certain gases in the atmosphere, referred to as "greenhouse gases," absorb the outgoing reflected or internal thermal radiation, causing the Earth's atmosphere to become warmer than it would be without this effect [Ogbuabor and Egwuchukwu, 2017].

Over the past century, human activities such as burning wood, fossil fuels, and forests are believed to have increased the concentration of CO2 in the atmosphere by roughly 50%. Advocates of the AGW theory argued that human-induced CO2 emissions are the primary drivers behind various disasters, including floods, droughts, extreme weather events, crop failures, species extinctions, disease spread, coral reef bleaching, famines, and numerous other catastrophic occurrences. They posited that these calamities would become more frequent and severe as global temperatures continued to rise, emphasizing that substantial and rapid reductions in human emissions are essential to avert these catastrophic events [Ogbuabor, 2017].

Much like other environmental issues, climate change entails the concept of externalities, as greenhouse gas emissions harm other economic entities who are not compensated by the entity causing the emissions. The standard theory of externalities suggests a solution involving taxation of the emitter amounting to the marginal social cost of the externalities they generate. However, in cases marked by weak representation of those most affected, long-term horizons, global-scale uncertainties, and intricate interactions with other market failures, resolving the externality problem can be highly complex. Consequently, while the standard theory offers valuable initial insights, the economic policy problem is more complex. It involves inter-temporal international collective action, substantial uncertainty, and interconnected market failures [Ogbuabor, 2017].

2.2.Theories of Population

2.2.1. Malthus Theory

Thomas Robert Malthus (1766-1834) contributed a lot to the analysis of population statistics, and his work on population remains a significant milestone in the history of population theories. Malthus provided a detailed analysis of the relationship between population dynamics and social change. Malthus posited that due to the strong attraction between the sexes, the population could grow exponentially, doubling in size in about twenty-five years. He argued that this uncontrolled population growth would eventually outstrip the capacity of food production to keep pace and the eventual economic grow of nations in which Nigeria is not an exception. Malthus made a crucial distinction between population growth rates and food production. He believed that human reproduction had the potential to grow at an exponential rate (1, 2, 4, 8, and so on), while the production of sustenance from the land could only increase at a linear rate (1, 2, 3, 4, and so forth). Consequently, Malthus contended that the world's population was expanding at a faster rate than the available food supply could support. This stark assessment of the population-food dynamics contributed significantly to the discourse on the challenges posed by unchecked population growth.

2.2.2. Theory of Demographic Transition

The term "DT," initially coined by Thompson in 1929 and later popularized by Notestein in 1945, refers to a historical process of change that accounts for the trends in births, deaths, and population growth observed in today's industrialized societies, particularly European ones. This process of demographic transformation started in the late 18th century. It's essential to view demographic transition not as an absolute "law of population growth" but rather as a general description of a development process. In simpler terms, it serves as a theory aiming to outline the typical patterns by which human populations change in size and composition during industrialization. It is widely acknowledged as a valuable tool for explaining the demographic history of a country.

This theory postulates a specific trajectory of demographic change, starting with high fertility and high mortality rates and evolving towards low fertility and low mortality rates as society shifts from a predominantly rural, agrarian, and largely illiterate state to a more urban, industrialized, literate, and modern one.

2.3. Theories on Economic Growth

2.3.1. Endogenous Growth Theory

The endogenous growth theory is the concept that economic growth is due to factors that are internal to the economy and not because of external ones. The theory is built on innovation, knowledge, and human capital improvements lead to increased productivity and economic outlook [Corporate Financial Institute (CFI, 2020]. In particular, the theory was established to refute the neoclassical exogenous growth models, as it made predictions about economic growth without factoring in technological change.

The endogenous growth theory challenges such an idea by placing importance on the role of technological advancements. Since long-term economic growth is derived from the growth rate of economic output per person, it would depend on productivity levels. In turn, productivity would depend on the progress of technological change, which relies on innovation and human capital; these factors are considered internal to an economy, not external.

2.4. Empirical review

Empirical research has also shown evidence of the substantial role of CC on the overall economy and the relationship between population growth and economic growth.

Ozor (2009) conducted a study on CC to enhance the concept's understanding. The research extensively detailed the repercussions of climate change on various aspects of national development, including diminished agricultural productivity, food insecurity, resource conflicts, unemployment, environmentally induced migration and health issues. These impacts were attributed to the devastating effects of climate change, such as flooding, drought, erosion sea level rise, heat stress, pests and diseases, and erratic rainfall patterns. The study supported a need for climate policy in Nigeria, establishing a National Council on Climate Change (NCCC), developing a national framework for climate change adaptation, and adopting emerging technologies.

Onuoha (2009) explored the threats posed by climate change on a global scale, with special focus on developing countries heavily dependent on agriculture, which relies on weather and climate conditions. The study used the sustainable development model,

exemplified by the Green Wall Sahara Nigeria Program, as a step to combat desertification and drought in Northern Nigeria. It concluded that addressing the challenges of climate change to economic growth and sustainable development in Nigeria necessitates creative thinking, holistic solutions, innovative approaches, and the active involvement of all stakeholders.

Wade and Jennings (2016) conducted an investigation into the global economic consequences of climate change and highlighted that as global temperatures rise, increased operating costs would negatively impact the global economy, with some studies suggesting a potential annual reduction of 1% in GDP growth. Moreso, Berlemann and Wenzel (2018) explored the short- and long-term growth effects of rainfall using a rigorous panel dataset spanning over 150 countries from 1951 to 2013. Their research provided robust empirical evidence for long-term negative growth consequences of rainfall deficits in poor and emerging countries.

Stock (2020) conducted research on the relations between CC, climate policy, and economic growth, considering factors such as TEMP, CO2 and GDP. The study underscored that rising TEMP causing various CC including droughts, heatwaves, heavy rainfall, and more severe storms, all of which have local variations. The primary driver of this warming is anthropogenic carbon dioxide (CO2) emissions resulting from fossil fuel combustion.

Baig, Chandio, Ozturk, Kumar, Khan, and Salam (2022) conducted an investigation into the dynamic relations between CC and rice production, considering other explanatory factors. Using time series data from India spanning from 1991 to 2018, they employed the nonlinear autoregressive distributed lag (NARDL) model and Granger causality analysis. The NARDL findings revealed that mean temperature had a detrimental long-term impact on rice yield while exerting a positive short-term effect. Moreover, positive shocks in rainfall and carbon emissions were found to have long-term and short-term negative and severe effects on rice yield. In contrast, negative rainfall shocks had significant long-term and short-term impacts on rice yield. The study highlighted a feedback effect between mean temperature, declining rainfall, rising carbon emissions, and rice yield, as indicated by the GC test.

Khan Tahir, Khurshid, Husnain, Ahmed, and Bougahanmi (2020) assessed the economic consequences of climate change-induced reductions in agricultural output in Pakistan, employed a combination of global climate, crop, and economic models. The study estimated that climate change-induced decreases in wheat and rice crop productivity could cost Pakistan $19.5 billion in real GDP by 2050. This would lead to rising commodity prices and a significant decline in domestic private consumption. The decline in agricultural output would not only affect those working in the agricultural sector but would also have a multiplier effect on the industrial and commercial sectors, posing a substantial challenge to the livelihoods of the entire population, particularly urban residents.

Klasen and Lawson (2007) examined the link between population, per capita growth, and poverty in Uganda, utilizing both cross-sectional data and panel data. Their estimates revealed that population growth had a positive impact on overall economic growth. However, the coefficient was consistently less than 1, suggesting that the additional people had a proportionately smaller influence on economic growth. The cross-sectional specification generally indicated a larger impact than the panel specifications, which was expected since the positive short-term effect of income growth on population growth is likely to reduce the negative coefficient in the panel specification.

Oramah (2006) investigated the effect of population growth on the economy of Nigeria. The study underscored the importance of population control in Nigeria, showing the potential dangers associated with the global trend of population growth. It emphasized the impact of population growth on non-renewable resource consumption and depletion, land degradation, waste disposal, weather modification, rapid urbanization, and desertification. The study identified several factors influencing population size in Nigeria, including religion, education, male-child preference, old-age social security, and high infant mortality rates.

Nwosu, Dike, and Okwara (2014) explored the relationship between population growth and economic growth in Nigeria from 1960 to 2008, using annual time series data. Their analysis combined OLS techniques with Granger causality testing. The core variables in their model included GDP and population growth. The researchers found that population growth impacted significantly on economic growth during the studied period under review.

Ukpolo (2022) empirically measured the economic connection between population growth and African economic growth. The study relied on annual time series data collected from two selected countries, Nigeria and Cote d'Ivoire. The estimation results revealed that the variables were co-integrated, indicating a long-term relationship between them in Nigeria but not in Cote d'Ivoire. Furthermore, the results indicated a negative long-run causal relationship between population growth and economic growth in Nigeria, implying that population growth negatively affected economic growth over the long term. In Cote d'Ivoire, the findings indicated that population growth caused economic growth only in the short term.

3. Methodology

3.1. Theoretical framework

3.1.1. Population and EG

The theoretical framework of this research aligns with the Endogenous (AK model) growth theory, which posits that economic growth primarily arises from internal, rather than external, factors. This theory emphasizes that investments in human capital, innovation, and knowledge play pivotal roles in driving economic growth.

Endogenous economic growth theories focus on models capable of generating continued growth without relying on outer changes in technology or population. These models typically incorporate the concept of constant or increasing returns in factors that can be accumulated (as discussed by Lucas, 1998, and Romer, 1994).

Thomas Robert Malthus, known for his population growth theory, is one of the prominent figures in this context. His theory generalizes the relationship between population dynamics and societal change. Malthus argued that the population would eventually surpass the point where food making could sustain it adequately. He pointed out that human reproductive capacity outpaced the rate at which subsistence could be increased from the land. Malthus famously stated that "Population when unchecked expands in a geometrical ratio, subsistence increases only in an arithmetical ratio." In simpler terms, he contended that the global population was growing more rapidly than the available food supply. He asserted that while food supply increased linearly (1, 2, 3, 4, and so on), the population expanded exponentially (1, 2, 4, 8, and so on). He posited that the gap between food supply and population would widen over time. Malthus further argued that even though food production would increase, it would ultimately prove insufficient to meet the expanding population's

needs. Additionally, he noted that factors like famine and natural disasters contributed to widespread suffering and elevated death rates, serving as nature's checks against overpopulation.

3.2. CC and EG

To assess the effects of CC on economic growth, two predominant approaches are commonly employed: the enumerative approach and the dynamic approach.

In the enumerative approach, the economic implications of climate change are examined on a sector-by-sector basis. This involves analyzing the impacts of climate change on various sectors such as agriculture, ecosystem, and tourism. The cumulative effects across these sectors are aggregated to estimate the overall change in social welfare resulting from climate change [Ahmed, 2020]. Conversely, the dynamic approach involves building in climate change indicators into growth models to understand its impact on EG. Widely utilized growth models for this purpose include those developed by Liu, Huang, and Yang in 2020 and Khan, Yu, Sharif, and Golpîra (2020). These models directly link the impact of CC on GDP and are instrumental in examining the influence of CC on economic growth. Some studies combine elements of both approaches to varying degrees. They explored the effect of CC on overall economic growth and its constituent components, including agriculture, manufacturing, and services. For instance, Guntukula and Goyari in 2020 introduced CC considerations into the production function. Their model is a foundational reference point for this study, offering a theoretical framework for integrating climate change into economic growth equations.

Consider the production function:

$$Yt = e^{\alpha Tt}, A_t, L_t, K_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

$$\Delta A_t / A_t = \beta T_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

Where; Y is GDP, L is labor force,
A is technology and can also be referred as labor productivity,
T is the impacts of climate and K is physical capital.

In the first equation, the direct impact of climate change on economic growth is represented, while the second equation captures the indirect effect of climate on other variables that indirectly influence GDP growth. It's important to note that climate change is directly linked to GDP in equation (1), whereas in equation (2), climate change affects labor productivity, which subsequently affects GDP growth. Both equations identify the direct and indirect effects of climate change, which have an impact on the GDP growth rate in the initial period. However, while the direct effect is reversed when the climate returns to its prior state, the indirect effect persists even in normal conditions. For example, a rise in temperature may harm agricultural production, but when the temperature returns to normal levels, agricultural production will accelerate once again. Conversely, failure in human capital development results in a permanent deterioration in human capital and economic growth, illustrating the persistence of the indirect effect.

3.3. Model specification

The model specification for this study will follow the theoretical concept of Endogenous (AK model) growth theory with modification. The model of the relationship

between Climate change and RGDP growth as a proxy for EG will follow the work of Kareem et al., (2022). Model 1 is on the determination of the effect of climate change on economic growth in Nigeria is implicitly defined as stated below.

RGDP = f (climate change [CC]) ……..……3

Equation 3 is further classified into climatic change variables, as stated in Equation 4.

RGDP = f (CAE, TEM, RAF) ……4

The linear function of the model is a modified form of the equation, and it is explicitly expressed below:

$RGDPt = \beta0 + \beta1\ TEMt + \beta2\ CAEt + \beta3\ RAFt + \varepsilon t$……5

In the natural logarithm function, it is expressed as:

$lnRGDPt = \beta0 + \beta1 lnTEMt + \beta2 lnCAEt + \beta3 lnRAFt + \varepsilon t$……....6

Where: RGDP = Real gross domestic product (N' Billion)
CAE = Carbon emission CO2 (kt)
TEM = Temperature (0C)
RAF= Average Total Annual Rainfall (mm)
Ln= Natural Logarithm ε= error term
β0 = constant term β1-β3 = Parameters to be estimated
t=Time periods between 1986-2021(35 years)

Model 2: Determination of the impact of population growth rate on economic growth. The model specification for this study will follow Eli et al., (2015) using a simple model expressing the relationship between GDP growth rate as a proxy for economic growth and important macroeconomic variables for having a bearing on economic growth. Life expectancy at birth rate is included as a control variable, contributing to the population growth rate and affecting economic growth.

GDPG = f (PGR)

GDPG = f (Birth growth rate, Death growth rate, Net-migration growth rate, and life expectancy at birth)

$GDPG_t = \alpha+\alpha_1 BIR_t + \alpha_2 CDR_t + \alpha_3 NTI_t + \alpha_4 LEX_t + \varepsilon_t$ …….……7

The linear function of the model is a modified form of the equation and it is explicitly expressed below

$lnGDPG_t = \alpha+\alpha_1 lnBIR_t + \alpha_2 lnCDR_t + \alpha_3 lnNTI_t + \alpha_4 lnLEX_t + \varepsilon$ ……...8

Where: GDPG = GDPGR t=1986-2021(35 years)
BIR = Birth growth rate (%). α_1-α_4 – parameters to be estimated
CDR = Crude Death growth Rate (%) α= constant term
NTI = Net migration growth Rate (%) ε = error term
LEX = Life Expectancy at Birth growth rate (%). Ln= Natural Logarithm

3.4. Estimation techniques

This study used descriptive and inferential techniques to test the impact of CC and PGR on economic growth.

The unit root test helps determine whether the data is stationary and whether there is a short-run or long-run relation between the variables. For climate change, after carrying out the unit root test, the variables were found to be stationary at level and 1st difference after using the ARDL bounds test to ascertain that there was no co-integration. The ARDL model was then used to determine the effect of climate change on economic growth. However, for PGR, although the variables were of mixed order I (1) &I (0), there was co-integration. ECM was then employed to analyze the data. Granger causality was also employed in this study to establish the causal relationship among variables.

3.5. Types and Sources of Data

To assess the influence of climate change and population growth on EG within the specified time frame, annual data was gathered and utilized for analysis. The data used in this study were obtained from secondary sources, including the CBN Statistical Bulletin for Real Gross Domestic Product (RGDP), the World Development Indicators (WDI) for PGR, Birth rate, Crude death rate, NMR, and Life expectancy at birth, and the Nigerian Meteorological Agency (NIMET) for Climate change indicators such as temperature, rainfall, and CO2 levels.

The dataset comprises annual data points spanning a period of 35 years, ranging from 1986 to 2021, specifically focusing on Nigeria.

4. Results

Table 1.

Unit Root Result on CC and EG

Series	Order (ADF)	Exogenous	ADF test(t-statistics) Prob. Values
LogRGDP	Level	Intercept	-0.598584 (0.8580)
LogRGDP	1ST Difference	Intercept	-3.785884 (0.0069)
TEM	Level	Intercept	-3.043389 (0.0406)
RAF	Level	Intercept	-6.980538 (0.0000)
CAE	Level	Intercept	-1.546266 (0.4988)
CAE	1ST Difference	Intercept	-5.883362 (0.0000)

(Source: Authors 2023)

Table 1 showed the unit root test output, and it revealed that LogRGDP, and CAE are stationary at the first difference, that is, I (1), and TEM, and RAF was stationary at I (0).

The mixture of the 1st difference and level variables leads to the ARDL bound test for co-integration to determine if there is a long-run relationship among the variables in the model.

4.1. ARDL bounds test

The table below represents the auto-regressive distributed lag model results to examine the effect of each independent variable on economic growth. Optimum lag was automatically selected for the estimated ARDL system using the Akaike information criterion.

Table 2.

ARDL bounds test for CC and EG

Test Statistic	**Value**	**K**
F-statistic	1.185145	3
Critical Value Bounds		
Significance	I0 Bound	I1 Bound
10%	2.72	3.77
5%	3.23	4.35
2.5%	3.69	4.89
1%	4.29	5.61

(Source: Authors 2023)

Table 2 shows the bound co-integration test for model 1. From the table, the bound co-integration test shows no co-integration. The f-statistics value of 1.185145 is lower than the lower bounds of all the critical values at 1%, 2.5%,5%, and 10%, respectively. Since there is a combination of both I (1) and I (0) variables in model 1, and there is no co-integration among the variables, the model is then subjected to Autoregressive redistributive lag model analysis (ARDL).

Table 3.

Lag length selection criteria result for Model 1

Lag	LogL	LR	FPE	AIC	SC	HQ
0	2.828326	NA	0.062934	0.071011	0.252405	0.132044
1	68.09053	110.7480*	0.001282	-3.823668	-3.596925	-3.747376
2	70.03842	3.187465	0.001213	-3.881116	-3.609024	-3.789566
3	72.00957	3.106059	0.001146*	-3.939974*	-3.622533*	-3.833165*

(Source: Authors 2023)

Table 4.

ARDL Result for CC and EG

Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
C	0.011615	0.010037	1.157174	0.2615
D(LOGRGDP(-1))	0.386400	0.197726	1.954222	0.0656
D(LOGRGDP(-2))	0.540484	0.179805	3.005939	0.0073
D(LOGRGDP(-3))	-0.289506	0.189240	-1.529835	0.1425
D(TEM(-1))	-0.021259	0.025108	-0.846687	0.4077
D(TEM(-2))	-0.043861	0.022359	-1.961671	0.0646
D(TEM(-3))	-0.024797	0.022484	-1.102853	0.2839
D(RAF(-1))	0.000916	0.000904	1.012988	0.3238

D(RAF(-2))	0.000198	0.001140	0.173914	0.8638
D(RAF(-3))	-0.000219	0.000859	-0.255222	0.8013
D(CAE(-1))	-0.110905	0.110686	-1.001982	0.3289
D(CAE(-2))	-0.065312	0.106639	-0.612462	0.5475
D(CAE(-3))	-0.335809	0.126108	-2.662869	0.0154
R-S	0.624443	Mean dependent var		0.041473
Adjusted R-squared	0.387249	S.D. dependent var		0.038480
S.E. of regression	0.030122	Akaike info criterion		-3.875933
Sum squared resid	0.017239	Schwarz criterion		-3.280478
Log likelihood	75.01493	Hannan-Quinn criter.		-3.678556
F-statistic	2.632625	Durbin-Watson stat		2.022833
Prob(F-statistic)	0.028866			

(Source: Authors 2023)

Table 4 shows the ARDL results for Model 1, indicating that the co-efficient lag of one period value of LOGRGDP is 0.386400 with the probability value of 0.0656, shows a positive relationship between the variable and economic growth and it is statistically significant at 10% and it implies that a percentage increase in the period lag of RGDP will bring about a 38% increment on the current value of RGDP. The co-efficient lag of two period lag values of LOGRGDP is 0.540484 with a probability value of 0.0073, shows a positive relationship between the variable and economic growth and it is statistically insignificant and it implies that a percentage increase in two period lags of RGDP will bring about a 54% increment on the current value of Real Gross Domestic Product.

The co-efficient value of two-period lags of TEM is -0.043861 with a probability value of 0.0646, showing a negative relationship between annual temperature and economic growth. It's statistically significant at 10%, and it implies that a unit increase in temperature in the short run will bring about a 4.3% decrease in real gross domestic product.

The co-efficient lag of the three-period value of RAF is -0.335809 with a probability value of 0.0154, showing a negative relationship between the variable and economic growth (at a 5 percent level of probability - statistically significant). It implies that a percentage decrease in three-period lags of CAE will bring about a 33.5% decrease in the current value of Real Gross Domestic Product.

The R-squared value of 0.624443 shows that 62.4% of the total variation in the RGDP is explained by the explanatory variables (Annual Temperature, annual Rainfall, and Carbon emission). The F-Statistics value of 2.632625 with a probability of 0.028866 shows the model's fitness, which is statistically significant at 5% (Durbin-Watson value falls between the range of 0 and 4). A value of 2.0 means no autocorrelation detected in the model. Values from 0 to 2.0 indicate positive autocorrelation and values from 2.0 to 4 indicate negative autocorrelation. In the above table, the value of Durbin Watson is 2.02, which indicates that is a negative autocorrelation in the model.

Table 5.

Test for CC and EG

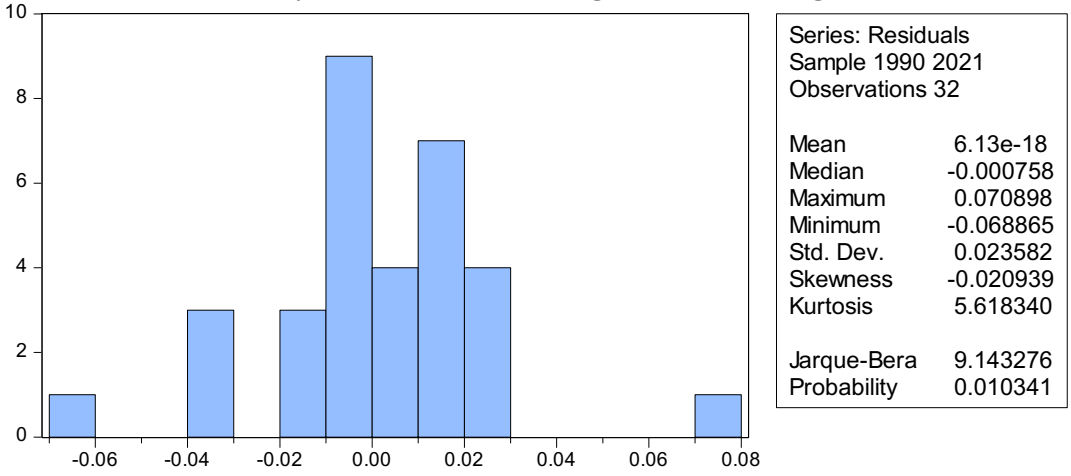
Test	F-statistics	Probability	Conclusion
Heteroscedasticity	1.149805	0.3805	There is no heteroscedasticity in the model
Serial correlation	2.034832	0.1327	Series is not serially correlated

(Source: Authors 2023)

The table 5 above reports the test for the model 1. The F-Statistic value is 1.149805, and the probability value is 0.3805. Giving that null hypothesis states that there is no heteroscedasticity. This study concludes that there is no heteroscedasticity as the null hypothesis is accepted. The table also shows serial correlation, the F-statistics value of 2.034832, and a probability value of 0.1327, which implies that the series is not serially correlated.

Figure 1.

Normality Test for Climate change and Economic growth



(Source: Authors 2023)

H0: Residuals are normally distributed.

H1: Residuals are not normally distributed.

From Figure 1, the Jarque-Bera value of 9.143276 has a probability of 0.010341 (1%), implying that the probability value of 0.010341(1%) is less than 5% and statistically significant at 1%. Hence, we reject the null hypothesis and conclude that the series are normally distributed.

Table 6.

Granger causality for CC and EG

Null Hypothesis	Obs	F-Statistic	Prob.	Remarks
TEM does not Granger Cause LOGRGDP	33	0.71189	0.5537	There is no Causality
LOGRGDP does not Granger Cause TEM		2.21131	0.1107	
RAF does not Granger Cause LOGRGDP	33	0.89072	0.4590	There is no Causality
LOGRGDP does not Granger Cause RAF		0.11910	0.9481	
CAE does not Granger Cause LOGRGDP	33	1.19466	0.3312	There is no Causality
LOGRGDP does not Granger Cause CAE		1.83463	0.1657	

(Source: Authors 2023)

Table 6 above shows the Granger causality relationship among the variables involved in model 1. TEM does not granger cause LOGRGDP with F-Statistics value (0.71189) and probability value of 0.5537 while LOGRGDP does not cause TEM with F-Statistics value of 2.21131 and probability value of 0.1107. This implies that there is no causality between TEM and LOGRGDPRAF does not guarantee cause LOGRGDP with an F-Statistics value of 0.89072 and probability value of 0.4590, while LOGRGDP does not

cause TEM with an F-Statistics value of 0.11910 and probability value of 0.9481. This implies that there is no causality between RAF and LOGRGDPCAE does not granger cause LOGRGDP with an F-Statistics value of 1.19466 and probability value of 0.3312. At the same time, LOGRGDP does not cause TEM with an F-Statistics value of 1.82463 and probability value of 0.1657. This implies that there is no causality between CAE and LOGRGDP.

Table 7.

Unit root test for Model 2

Series	Order (ADF)	Exogenous	ADF test (t-statistics) Prob. Values
GDPG	Level	Intercept	-3.984809 (0.0040)
BIR	Level	Intercept	-0.488006 (0.8818)
BIR	1st difference	Intercept	-5.607948 0.0000
CDR	Level	Intercept	-1.328142 (0.6055)
CDR	1st difference	Intercept	-5.747247 (0.0000)
NTI	Level	Intercept	-3.026044 (0.0422)
LEX	1st difference	Intercept	-5.721179 (0.0000)

(Source: Authors 2023)

Table 7 reports the respective level of stationarity of the variables after the unit root test. All variables are statistically significant at either 1% or 5%. Based on our analysis, we have found evidence to support the alternative hypothesis that the series does not have a unit root problem. Therefore, we can conclude that the null hypothesis is rejected. However, for model 1, while BIR, CDR, and LEX are stationary at the first difference, I (1), GDPG, and NTI are stationary at level, that is, I (0).

Table 8.

ARDL Bounds test for PGR and EG

Test Statistic	Value	K
F-statistic	5.007936	4
Critical Value Bounds		
Significance	I0 Bound	I1 Bound
10%	2.45	3.52
5%	2.86	4.01
2.5%	3.25	4.49
1%	3.74	5.06

(Source: Authors 2023)

Table 8 shows the bound co-integration test for model 2. From the table, the bound co-integration test shows that there is co-integration. FS value of 5.007936 is higher than the upper bounds of all the critical value bounds at 5%. This indicates that there is a long-run relationship among the variables. Since there is a combination of both I (1) and I (0) variables in model 1, and there is co-integration among the variables, the model is then subjected to Error Correction Model (ECM).

Table 9.

Lag Length selection criteria for PGR and EG

Lag	LogL	LR	FPE	AIC	SC	HQ
0	67.55012	NA*	0.001481	-3.679419	-3.454954*	-3.602870*
1	68.32261	1.272330	0.001503	-3.666036	-3.396678	-3.574177
2	69.87095	2.459126	0.001459*	-3.698291*	-3.384040	-3.591123

(Source: Authors 2023)

Table 9 shows the lag length selections based on the least selected lag length by different criteria. The appropriate lag length is Lag 2, which is the least based on the Akaike Information Criterion (AIC).

Table 10.

ECM result for Model Two

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-9.81E-05	0.005056	-0.019410	0.9847
D(GDPG(-1))	-0.194479	0.274717	-0.707926	0.4876
D(GDPG(-2))	0.317871	0.165396	1.921883	0.0697
D(BIR(-1))	3.960963	4.164104	0.951216	0.3534
D(BIR(-2))	13.20055	4.185013	3.154243	0.0052
D(CDR(-1))	-6.724597	5.282541	-1.272985	0.2184
D(CDR(-2))	3.875499	5.397471	0.718021	0.4815
D(NTI(-1))	0.066663	0.057233	1.164774	0.2585
D(NTI(-2))	-0.161515	0.054872	-2.943502	0.0083
D(LEX(-1))	-11.30337	11.11894	-1.016587	0.3221
D(LEX(-2))	11.28659	11.31931	0.997110	0.3312
ECT(-1)	-0.478637	0.385533	-1.241493	0.2295
RSQ	0.778427	Mean dependent var		0.000541
Adjusted R-squared	0.638485	S.D. dependent var		0.044090
S.E. of regression	0.026510	Akaike info criterion		-4.131398
Sum squared resid	0.013353	Schwarz criterion		-3.535943
Log likelihood	79.10237	Hannan-Quinn criter.		-3.934022
F-statistic	5.562530	Durbin-Watson stat		1.872199
Prob(F-statistic)	0.000490			

(Source: Authors 2023)

Table 10 above shows the ECM results for model 2. The coefficient value of a period lag of EGR, which is -0.194479 with a probability value of 0.4876, has a negative relationship with the current EGR. It implies that a percentage increase in a period lag of EGR will have 0.19 decrease on the current EGR and it is not statistically significant. The coefficient value of two-period lags of EGR, which is 0.317871, having a probability value of 0.0697, has a positive relationship with the current EGR. It implies that a percentage increase in two-period lags of EGR will have a 0.31% increase on the current EGR, which is statistically significant at 10 percent.

The coefficient value of two period lags of Birth growth rate, which is 13.20055 with a probability value of 0.0052, has a positive relation with the current EGR. It implies that a percentage increase in two-period lags of birth growth rate will have a 13.20% increase on the current EGR, and it is statistically significant at 1 percent. The coefficient value of two period lags of net migration growth rate which is -0.161515 with probability value of

0.0083 has a negative relation with current EGR. It implies that a percentage decrease in two period lags of EGR will have 0.16% decrease on the current EGR and it is statistically significant at 1 percent level of probability. The coefficient value of a period lag of ECT, which is -0.478637 with a probability value of 0.2295, shows that 47.8% of disequilibrium between the short-run and long-run dynamics is corrected each year with the variables of interest (BIR, CDR, NTI, and LEX).

Table 11.

Wald test

Test Statistic	Value	Df	Probability
F-statistic	3.370562	(10, 19)	0.0110
Chi-square	33.70562	10	0.0002

(Source: Authors 2023)

Table 11. above reports the null hypothesis that is insignificant and has no joint significance on the dependent variable. The result indicates variables having joint significance on EGR.

Table 12.

GC for Model Two

Null Hypothesis	Obs.	F-Statistic	Prob.	Remarks
BIR does not Granger Cause GDPG	34	2.07921	0.1433	
GDPG does not Granger Cause BIR		2.17020	0.1323	There is no Causality
CDR does not Granger Cause GDPG	34	0.20522	0.8156	
GDPG does not Granger Cause CDR		4.96165	0.0140	Uni-directional Causality
NTI does not Granger Cause GDPG	34	1.78201	0.1862	
GDPG does not Granger Cause NTI		0.74250	0.4848	There is no Causality
LEX does not Granger Cause GDPG	34	0.10501	0.9007	
GDPG does not Granger Cause LEX		5.54445	0.0091	Uni-directional Causality

(Source: Authors 2023)

Table 12 above shows the Granger causality relationship among the variables involved in model 2. CDR does not granger cause GDPG with an F-Statistics value of 0.205222 and probability value of 0.8156, while GDPG granger causes CDR with an F-Statistics value of 4.96165 and probability value of 0.0140, which is significant at 5%. This implies that there is Uni-directional causality between CDR and GDPGLEX. It does not Granger cause GDPG with an F-Statistics value of 0.10501 and probability value of 0.9007, while GDPG Granger causes LEX with an F-Statistics value of 5.54445 and probability value of 0.0091, which is significant at 5%. This implies that there is Uni-directional causality between LEX and GDPG.

4.2. Discussion of findings

The study unveiled that both CE and TEMP exhibit a negative and significant relation with EG aligning with the initial (Apriori) expectations. These results are consistent with the research conducted by Jonathan and Emmanuel (2017) and Kareem et al. (2022), who also concluded that carbon emissions significantly adversely impact short-term EG. However, these results contradict the findings of Adejumo (2021), who identified a significant positive relationship between carbon emissions and economic growth.

The study further identified a positive and significant relationship between Birth growth rate and EGR, corroborating the work of Eli, Mohammed, and Amade (2015). Conversely, a negative relationship was observed between net migration and EG. Regarding Granger causality, the results indicate no causality between climate change and economic growth, which contrasts with the findings of Kareem et al. (2022) and contradicts the results of Adejumo (2021), who found a unidirectional causality between annual average rainfall and economic growth in Nigeria.

Additionally, the results reveal a unidirectional relation between Crude death rate and life expectancy at birth, deviating from the findings of Aidi, Emecheta, and Ngwudiobu (2016).

5. Conclusion and policy recommendations

Based on these findings and conclusions, the study offers the following recommendations for governments at various levels: to mitigate the negative impact of carbon emissions on economic growth, it is advisable for the government to invest in research and development focused on clean energy and eco-friendly methods, thus promoting sustainable ED.

Governments play a vital role in fostering sustainable economic growth by implementing policies that facilitate growth in the real sectors of the economy. It is essential to prioritize the formulation and implementation of such policies as they serve as the backbone of a healthy economy. These policies should be designed to address the needs of businesses and industries, incentivize investment and innovation, and create employment opportunities. Furthermore, it is essential to ensure that these policies align with broader socio-economic objectives, such as reducing poverty and inequality and promoting environmental sustainability. By prioritizing the development of policies that promote sustainable economic growth, governments can create a favorable business climate that encourages investment, spurs innovation, and ultimately leads to a thriving economy.

Given the significance of the birth growth rate, the government should emphasize population management and launch awareness campaigns to ensure sustainable economic development.

Recognizing the importance of net migration, the government should create a conducive business environment that can retain skilled migrants, thereby stimulating economic growth.

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