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# Dynamic response of economic growth to environmental degradation in Nigeria

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## ABSTRACT

With the global climate change threat, achieving environmental sustainability has become a major concern among the world leaders, scholars, and researchers in the fields of environmental and economic growth-related studies. The aim of this paper is to examine the dynamic response of economic growth to environmental degradation in Nigeria from 1980 to 2022. Using the econometric technique of autoregressive distributed lags (ARDL) model, findings show that while environmental degradation often accompanies economic growth, its impact on long-term growth is weak and not statistically significant. Variables such as carbon emissions, financial development, and trade openness show mixed results regarding their influence on economic growth. Interest rates are identified as having a minor positive effect on GDP, particularly in the short run. The study concludes that a growing population positively affects GDP by expanding the labour force and enhancing economic productivity. The study emphasises the need for integrated economic policies that consider both financial and environmental management to ensure sustainable growth.

**Contribution/ Originality:** In the previous literature, a very scanty studies captured the dynamic response of economic growth to environmental degradation in the case of Nigeria. This paper backs the literature by specifically examining Nigeria. Its recency is also an additional contribution to the literature in the field of energy and growth. The paper also contributed in the area of policy recommendations to Nigerian government and policy makers.

## 1. INTRODUCTION

The 21st century has witnessed an increase in demand for environmental sustainability beyond the previous demand. This comes when environmental threats have increased excessively (Osuntuyi & Lean, 2023). The interaction between human and economic activities with respect to the given environment has been interesting even from different disciplines for sustainable development. The main idea is that through human intermediation, the environment supplies the essential foundation for development. The idea of how countries might continue their economic endeavours with little to no environmental harm is becoming more and more popular. Indeed, it is imperative to create an environment in which the next generation is not endangered. In recent times, researchers have been focusing on the growing issues of climate change and environmental degradation. However, a few studies comparing environmental growth and degradation have shown that economic activity and the environment are clearly related, as well as a reciprocal relationship between the two (Acheampong & Opoku, 2023). The

Environmental Kuznets Curve theory has been the underpinning for much of the economics literature's attention, which has primarily focused on how economic growth affects environmental degradation.

There is widespread scientific agreement that human-driven economic production and consumption activities provide a more significant challenge and have the potential to alter the global environment on a never-before-seen scale. Fossil fuel combustion, exhaust emissions, and thermal power plants are other sources of pollution. These all release dangerous pollutants such as carbon monoxide, sulphur dioxide, and others that lead to acid rain, global warming, and haemoglobin malfunction (Ukpong, 1994). By releasing ozone-depleting compounds and greenhouse gases (GHG) like carbon dioxide, methane, nitrous oxide, and water vapour, these events have changed the chemical makeup of the atmosphere, causing significant changes to key biogeochemical cycles and hastening the extinction of species. As the primary contributor to greenhouse gas emissions and a significant contributor to climate change and global warming (IPCC, 2018) carbon dioxide is predicted to continue to rise as the primary driver of environmental degradation. According to statistics, between 1750 and 2005, one factor contributed more to climate change than any other (Union of Concerned Scientists, 2017). Between 1990 and 2012, worldwide emissions increased from 22.3 billion metric tonnes to 31.6 billion metric tonnes in 2008 and 35.6 billion metric tonnes in 2012. This indicates that emissions have increased by 41% since 1990. China accounted for 29% of all emissions in 2012, followed by the United States at at16%, the European Union at 11%, India at 6%, and the Russian Federation at 5%, while Japan came in at 4%.

The earth's surface temperature has increased as a result of activities that began with the industrial revolution, increasing the greenhouse effect (U.S. Environmental Protection Agency, 2017). In addition to worsening the biological environment, growing industrialisation has accelerated global warming (Adom, 2017). Fossil fuel combustion—primarily from coal, oil, and natural gas—is the primary source of anthropogenic emissions, with other contributions from energy production, agriculture, and consumption. Middle-income nations in Asia, particularly China and India, contribute the largest percentage of emissions. There is general agreement in the literature that policies that promote economic expansion lead to poor environmental quality. It is commonly acknowledged that the use of fossil fuels for industrial and residential reasons contributes to environmental deterioration and depletion, which is correlated with economic growth. The Kuznets model states that as money rises, so does the demand for environmental quality. This demonstrates that while there is a negative correlation at higher income levels, there is a positive correlation at lower income levels between environmental deterioration and income. Over the past few decades, Nigeria, the most populous country in Africa and one of the major economies on the continent, has had notable economic expansion (World Bank, 2020). The oil industry, which provides a sizeable amount of the nation's GDP and government revenue, is the main driver of the economy (U.S. Energy Information Administration (EIA), 2020). Furthermore, industries like manufacturing, services, and agriculture contribute significantly to economic activity (African Development Bank, 2019).

Despite economic growth, Nigeria faces severe environmental degradation challenges across various dimensions (World Bank, 2020). These challenges include deforestation, soil erosion, pollution of water, air pollution, and improper waste management (UNEP, 2016). Rapid urbanisation, industrial activities, unsustainable agricultural practices, and oil exploration activities contribute significantly to environmental degradation (Adewuyi et al., 2020). The consequences of environmental degradation in Nigeria are multifaceted and far-reaching (World Health Organization, 2019). The pollution and degradation of natural resources may adversely deteriorate public health conditions, therefore leading to respiratory diseases and other related health issues. Additionally, environmental degradation threatens food security, exacerbates poverty, and undermines the resilience of communities, particularly those dependent on natural resources for their livelihoods (Food and Agriculture Organization, 2020).

Environmental degradation imposes substantial economic costs on Nigeria's economy (OECD, 2021). The degradation of natural resources undermines agricultural productivity, diminishes the sustainability of fisheries and forestry, and disrupts ecosystem services essential for economic activities (International Fund for Agricultural Development, 2019). Moreover, the adverse effects of environmental degradation on human health led to increased healthcare expenditure and productivity losses (World Bank, 2016). In recent times, Nigeria has established various policies, regulations, and institutions aimed at addressing environmental degradation and promoting sustainable development (Federal Ministry of Environment, 2020). These include environmental protection laws, conservation initiatives, and efforts to promote renewable energy and green technologies (NEWMAP, 2018). But it's still hard to put these measures into action and make sure they're followed because of weak institutions, problems with governance, and different development priorities (United Nations Development Programme, 2017).

Relatively speaking, Nigeria, an oil-rich nation, faces difficulties with poor environmental quality, mostly as a result of oil exploration and production, which directly affects the sea and the land used for farming and fishing. Key biological resources, such as mangroves, tropical rainforests, and significant fishing grounds, are home to oil installations and operations. The oil spills can cause significant harm to these locations. People get sick, farmers lose money because they can't cultivate the soil, and drinking water gets contaminated. The primary source of drinking water contamination in the Niger Delta area is thought to be the combustion from oil industries, endangering the livelihoods and health of nearby farmers. Nigeria's inadequate electrical supply is yet another factor contributing to environmental deterioration. Both the home and commercial sectors are looking for alternate energy sources as a result of the electricity shortage, mostly using petrol generators to power equipment that produces noise and air pollution. Based on this, the current study intends to examine how Nigeria's economic growth has responded dynamically to environmental deterioration between 1980 and 2022.

The rest of the paper is arranged as follows: The second section is the literature review, while the third section discusses the study's methodology. The fourth segment deals with the interpretation and analysis of data. The fifth section concludes by discussing the conclusion and policy recommendations.

## 2. LITERATURE REVIEW

The review covers both the theoretical and empirical literature. The theoretical review is on the extant theoretical foundations that establish the integral aspects of economic structure with changes in economic growth in relation to environmental degradation. Additionally, empirical investigations on the primary relationship of the study are included in the empirical review. As stated by Kousar and Shabbir (2021); Rao, Talan, Abbas, Dev, and Taghizadeh-Hesary (2023) and Koçak and Çelik (2022) the theoretical link between economic expansion and environmental deterioration is complex. The growth-environment concept highlights how countries' aspirations for economic expansion strain the environment and cause environmental deterioration.

The green Solow growth model by Brock and Taylor (2005) expanded the Solow growth model by incorporating pollution abatement and technology advancements into the traditional Solow framework, highlighting the significance of harmonising economic growth with environmental protection. The theory indicates that technological advancements play a significant role in reducing pollution. As technology improves, it enhances both production efficiency and pollution abatement, leading to sustainable growth. The model modifies the traditional capital accumulation equation to include pollution abatement costs and emissions, showing how these factors impact economic growth. In the same vein, the endogenous growth model emphasises that economic growth is largely determined by internal factors rather than external influences. The theory highlights the role of innovation, knowledge, and human capital in driving economic growth. Environmental degradation can negatively impact these factors by harming public health, reducing labour productivity, and curbing innovation in green technologies. Conversely, investment in sustainable practices and environmental protection can spur innovation, leading to long-term growth.

The green Solow theory allows for the analysis of how internal policies, such as environmental regulations, taxation, and investment in green technologies, can influence the relationship between economic growth and environmental degradation. The theory also focuses on how a nation's economic growth can be sustained through policies that address environmental concerns by ensuring that growth does not come at the expense of long-term environmental and economic health. This theory is well-suited to explore the mechanisms through which environmental protection can become a driver of continuous growth.

In an empirical study by Poumanyvong, Kaneko, and Dhakal (2012) they examined the effects of urbanisation on national residential energy consumption and emissions in 88 high-, middle-, and low-income countries between 1975 and 2005. By employing the Stochastic Impacts by Regression on Population, Affluence, and Technology (STIRPAT) technique, the results show that urbanisation increases energy use in high-income countries while it decreases household energy use in low-income ones. The findings show that, in middle-income countries, household energy consumption first decreases before rising due to urbanisation, reaching a threshold at about 70%. However, when the sample size was lowered to 80 nations, the findings indicate that in low-and middle-income nations, urbanisation increases residential emissions. In high-income countries, residential emissions increase initially and then decrease as urbanisation increases, reaching a turning point of 66%.

Also, by examined newly industrialised nations, Hossain (2012) empirically tested the dynamic causal link between emissions, energy consumption, economic growth, trade openness, and urbanisation. Long-term causation between trade openness, economic growth, emissions, energy consumption, urbanisation, and economic development is not shown. Emissions, energy consumption elasticity is stronger than its short-term elasticity. Energy consumption increases emissions and environmental impact in the nations under consideration. Economic expansion, commercial openness, and urbanisation have long affected the environment.

Zhang and Lin (2012) used the STIRPAT model at the national and regional levels in China and looked at how emissions, energy use, and urbanisation interacted between 1995 and 2010. The result demonstrates that, nationally, urbanisation raises energy consumption and emissions. However, at the regional level, its influence on energy consumption and emissions varies by area, with the central region seeing a greater impact on emissions than the eastern region. However, in the eastern area, the effect of urbanisation on energy consumption outweighs that of emissions.

In Japan, Hossain (2012) examined the causative relationships between emissions, energy use, economic expansion, international commerce, and urbanisation from 1960 to 2009. Economic development, trade openness, and urbanisation have no long-term influence on environmental quality, according to the data, but rising energy use increases environmental pollution. His research examined the relationship between energy intensity in 76 emerging countries and income, urbanisation, and industrialisation. Akpan and Akpan (2012) used a multivariate vector error correction model to investigate the relationship between Nigerian economic development, carbon emissions, and energy consumption between 1970 and 2008. The results indicate that increased electricity consumption and improved overall economic performance may eventually lead to greater pollutants. The Granger causality result states that there is a unidirectional causal link between economic growth and emissions.

Ogboru and Anga (2015) looked at how environmental deterioration affected Nigeria's economy's ability to grow sustainably. According to the report, environmental pollution is a major obstacle to sustainable economic growth and is responsible for a significant number of cases of diseases, including cancer, TB, viral infections, etc. Additionally, instances of erosion, floods, and a sharp decline in agricultural productivity due to environmental deterioration were noted. According to the report, in order to move this development process in the right direction, financial tools and incentives are needed.

Ibrahim (2020) analysed panel data from nine significant African economies—Nigeria, South Africa, Egypt, Algeria, Angola, Morocco, Sudan, Kenya, and Ethiopia—spanning the years 1990 to 2011 to investigate the impact of energy consumption, economic development, and population growth on carbon dioxide emissions. Real GDP, energy consumption, emissions, and population growth were evaluated through panel data estimation techniques, including the Pedroni (1999); Im, Pesaran, and Shin (1997);Kao and Chian (2000) and Dumitrescu and Hurlin

(2012). The empirical findings indicate that Africa's energy policy, especially that of the panel, ought to enhance energy consumption efficiency to mitigate adverse effects on development. Evidence indicates that energy consumption is the primary driver of environmental degradation, and panel economies are unlikely to attain the turning point of the environmental Kuznets curve.

Arouri, Youssef, M'henni, and Rault (2012) examined the relationship among real GDP, energy consumption, and carbon dioxide emissions in 12 MENA countries, utilising data from 1981 to 2005. This study examines emissions, energy consumption, and real GDP per capita. We utilised the panel error correction model (ECM) technique, conducted bootstrap panel unit root testing, and performed co-integration analysis. In the long term, energy use significantly reduces emissions, according to the research. Of more importance, they demonstrate that, for the entire region, real GDP and emissions have a quadratic proportion. Even while the EKC hypothesis is satisfied by the calculated long-run coefficients of income and its square in the majority of the nations under study, the Environmental Kuznets Curve (EKC) hypothesis is not well supported by the turning points, which are sometimes extremely low and other times very high. Even though the MENA area's economy grew between 1981 and 2005, emissions per capita in the region have decreased. According to the study's econometric correlations, future emissions per capita reductions may be accomplished concurrently with the Middle East and North Africa (MENA) region's GDP per capita growth.

The groundbreaking work of Grossman and Krueger (1993) who hypothesised the nature of the interaction between income and the environment, led to the popularisation and widespread acceptance of the EKC hypothesis. They concluded that there was a period of improvement after increased environmental deterioration during the early stages of growth. In research on the link between income and environment for nations with different income levels, Shafik and Bandyopadhyay (1992) discovered that the relationship differs across developed and developing countries, suggesting that the EKC hypothesis cannot be applied universally.

The link between economic growth and the environment was re-examined by Ghosh and Dutta (2023) for high, middle, and low-income nations. Panel data from a cross-section of nations was used to develop a structural model. The study broke down the environmental impact's size, makeup, and approach. According to the study, the rise in economic activity during the early phases of expansion is to blame for the deterioration in environmental quality. However, the new environmental problems are addressed by legislative reforms and technical developments. Their study's main conclusion was that the procedure is not the same in every nation.

Apergis and Payne (2010) investigated the relationship between emissions, energy use, and economic development using data from the Commonwealth of Independent States. Emissions and economic growth were shown to be positively correlated by the study; however, it was noted that this correlation eventually becomes statistically insignificant, especially when energy consumption is taken into account. Centred on their enquiry of the economic growth trend and the influence of pollution's environmental costs on economic development from 2000 to 2014, Araoye, Ajayi, Olatunji, and Aruwaji (2018) approached the decision that pollution costs had little bearing on Nigeria's economic growth. Cheng et al. (2016) used literature research and case study analysis to investigate the connection between technological innovation and green growth. They come to the conclusion that green growth is positively impacted by technological innovation. Investment in eco-friendly technology should be promoted, Chen et al. said.

Sinha and Sinha (2020) examine the complex connection between India's growth and emissions. The Autoregressive Distributed Lag (ARDL) model is used in the study to examine how emissions affect economic growth in the short term. The results point to a positively significant association, with a short-term rise in carbon dioxide emissions being linked to a 6.5% increase in productivity. Cointegration tests in the long-term analysis of the study show that emissions are a poor and statistically negligible predictor of economic performance, even if there is a link between environmental deterioration and economic growth. This suggests that GDP cannot be reliably forecasted based solely on emissions.

In Sub-Saharan Africa, Ssekibaala, Ariffin, and Duasa (2022) evaluated economic growth, international commerce, and environmental deterioration. They examined the PHH, FEH, and environmental Kuznets hypotheses. The bias-corrected least square dummy variable (LSDVC) estimate is used to evaluate annual data from 41 sub-Saharan African nations from 1990 to 2017. Deforestation, $CO_2$, and $PM_{2.5}$ emissions indicate environmental degradation. The EKC hypothesis applies to PM2.5 and deforestation but not CO2. Deforestation is reduced by international trade, and the PHH and FEH apply to PM2.5 emissions.

Osuntuyi and Lean (2023) employed the econometrics techniques of fully modified ordinary least squares, dynamic ordinary least squares, and other techniques to examine education's direct and moderating effects on growth-energy-environment connections in 92 countries with varied income groups between 1985 and 2018. The study found that economic growth in the long-term solves environmental degradation in high- and upper-middle-income countries but otherwise in low- and lower-middle-income countries. The study also demonstrates that energy use is associated with environmental deterioration at all income levels. However, education's direct effects exacerbate environmental deterioration at all income levels, and that education's moderating effect reduces the adverse implications of energy use on the environment in high and upper-middle-income groups while increasing it in lower-middle and low-income groups.

From 1984 to 2017, Arnaut, Dada, Sharimakin, and Al-Faryan (2023) investigated the symmetric and asymmetric effects of the formal and informal sectors on the environmental quality of Nigeria. The ecological footprint was utilised in the study to assess the quality of the ecosystem. Estimation methods include vector error correction Granger causality, the nonlinear ARDL cointegration framework, and autoregressive distributed lag (ARDL). The study found that financial development has a part in environmental deterioration, as do the official and informal sectors. Ajudua (2023) examined how environmental deterioration affected Nigeria's economic expansion between 1986 and 2016. The amount of gas flared, the amount of oil split, and the amount of forest loss were employed in the study as stand-ins for environmental deterioration. According to the study, the independent variables of oil spill volume and forest loss have a detrimental influence on both the environment and economic growth. The study also shows a long-term correlation between environmental deterioration and economic growth. The study's conclusions indicate that Nigeria, as a developing economy, should review its environmental protection laws and policies to lessen the impact of deterioration. Acheampong and Opoku (2023) investigated the potential correlation between economic expansion and the increase in environmental deterioration. It also looks at the possible ways that environmental deterioration can impact economic expansion. The two-step dynamic system-generalised approach of moment methodology was used to regulate endogeneity in a worldwide panel of 140 nations from 1980 to 2021. The results usually showed that environmental deterioration had a slowing influence on economic growth.

Taiwo (2024) used data from 1986 to 2020 and the autoregressive distributed lag approach to investigate the relationship between environmental deterioration and poverty alleviation in Nigeria. The cointegration test revealed an established relationship between the variables. The regression's results indicate that reducing poverty and environmental degradation has both short- and long-term trade-offs. In this case, reducing poverty requires greater environmental degradation, while reducing poverty causes environmental degradation to rise. In order to improve environmental quality without making poverty worse, he suggested that investment be encouraged in environmentally benign and technologically advanced companies.

## 3. METHODOLOGY AND THE DATA

Annual time series data was used for the study from 1980 to 2022. Data were sourced from World Development Bank Indicators database, 2024.

### *3.1. Theoretical Framework*

The framework developed in this study is based on the Green Solow model formulated by Brock and Taylor (2005). The model is an extension of the traditional Solow growth model that emphasises the importance of environmental quality as a cause of sustainable economic growth. It recognises that natural resources and environmental health can affect productivity and growth. Similarly to the traditional Solow model, the Green Solow Model includes physical capital accumulation, but it also considers the role of natural capital (i.e., environmental resources) in the production process.

The model assumes that there are diminishing returns of capital; that is, as more capital is accumulated (both physical and natural), the incremental output gained from additional capital decreases over time. This reflects the limits of resource availability. As a result, economies will ultimately reach a point where financial expansion is no longer necessary to spur economic expansion. We refer to this state as a steady one. According to the concept, nations may break out of this stagnant condition and keep expanding if they adopt the right technical advancements, which make natural resources more interchangeable with tangible capital and boost output without harming the environment. Technological progress occurs independently of the economic system and can lead to improvements in environmental performance over time. According to the model, investments in human capital (education and skills) lead to enhanced productivity and promote the adoption of environmentally friendly technologies. Using the Cobb-Douglas production function framework as follows:

$Y = Tf(K, L)$, where $Y$ is the total output, $T$ is the technology progress, $K$ is the physical capital, and $L$ is the labour. Finding the total differentiation of the total output, the result is.

$$dY = f dT + T(f_K dK + f_L dL) \quad (1)$$

Incorporating Green growth model variable of environmental degradation, Equation 1 becomes.

$$dY = f dT + T(f_K dK + f_L dL) + f dENV \quad (2)$$

Similar to Mo (2001) a decomposed equation form of Equation 2 will give.

$$\frac{dY}{Y} = \frac{dT}{T} + Tf_K \frac{dK}{Y} + \frac{f_L L}{f} \frac{dL}{L} + \frac{dENV}{ENV} \quad (3)$$

In Equation 3, the growth of physical capital and labour represents the growth components, whereas the technological progress indicates the variable of environmental degradation. Improvement in technology represents the driving force for economic growth in the Cobb-Douglas production function. As stated by Levine and Renelt (1992) the important four factors driving the extent of productivity growth rate are: investment, population growth rate, human capital, and initial real GDP per capita. Based on this, the environmental degradation factor and other control variables are included in Equation 4 in order to capture the impact of environmental changes. Hence, the growth rate equation is written as:

$$GDP_r = f(\mathrm{ENV}, \mathrm{INR}, \mathrm{OPEN}, \mathrm{POP}) \quad (4)$$

### *3.2. Model Specification*

The link between environmental degradation and economic growth in Nigeria was modelled using the green growth theoretical framework outlined above; the study adopted the endogenous growth model as well. As a modification, economic growth (GDP) is the dependent variable, and environmental degradation proxies by carbon emissions, interest rates, trade openness, and population are used as independent variables. Hence, the functional relationship for the model is presented in Equation 4. When our dependent variable and the independent variables are assumed to have a linear relationship, the statistical equation is:

$$GDP_t = \beta_0 + \beta_1 ENV + \beta_2 INR + \beta_3 OPEN + \beta_4 POP + \varepsilon_t \qquad (5)$$

The model is linearized by taking the semi-logarithm of Equation 5 in other to standardize the measurement. Then, it can be expressed as:

$$lnGDP_t = \beta_0 + \beta_1 lnENV + \beta_2 INR + \beta_3 lnOPEN + \beta_4 lnPOP + \varepsilon_t \qquad (6)$$

In order to estimate the long-run dynamic response of economic growth to environmental degradation, the study employed the autoregressive distributed lag (ARDL) model as follows.

$$lnGDP_t = \beta_0 + \beta_1 \sum_{i=1}^{\rho} lnGDP_{t-1} + \beta_2 \sum_{i=1}^{\rho} lnENV_{t-1} + \beta_3 \sum_{i=1}^{\rho} INR_{t-1} + \beta_4 \sum_{i=1}^{\rho} lnOPEN_{t-1} + \beta_5 \sum_{i=1}^{\rho} lnPOP_{t-1} + \varepsilon_t \qquad (7)$$

Equation 7 determines the long-run relationship among economic growth, environmental degradation, interest rate, trade openness, and total population in Nigeria. Once this has been achieved, the next calibration is to determine the short-run relationship, and the error correction mechanism. This is achieved by estimating Equation 8 which is written as.

$$\Delta lnGDP_t = \alpha_0 + \alpha_1 \sum_{i=1}^{\rho} \Delta lnGDP_{t-1} + \alpha_2 \sum_{i=1}^{\rho} \Delta lnENV_{t-1} + \alpha_3 \sum_{i=1}^{\rho} \Delta INR_{t-1} + \alpha_4 \sum_{i=1}^{\rho} \Delta lnOPEN_{t-1} + \alpha_5 \sum_{i=1}^{\rho} \Delta lnPOP_{t-1} + \emptyset ECT_t + \varepsilon_t \qquad (8)$$

Where:

$lnGDP$ = Logarithm of real GDP per capita (as a proxy for economic growth).

$lnENV$ = Logarithm of carbon dioxide (as a proxy for environmental degradation).

$INR$ = Interest rate.

$lnOPEN$ = Logarithm of trade openness.

$lnPOP$ = Logarithm of total population.

$\beta_0$ = Constant.

$\beta_1 - \beta_5$ = Parameter of the Equation 6.

$\alpha_1 - \alpha_5$ = Parameter of the Equation 7.

$ECT$ = Error correction mechanism

$\varepsilon_t$ = Error term.

## 4. DISCUSSION OF RESULTS

### *4.1. Descriptive Statistics of the Variables*

Data series descriptive statistics give information on sample statistics including mean, median, minimum, maximum, and distribution as determined by skewness, kurtosis, and Jarque-Bera statistics. Table 1 reports the descriptive statistics result for the study from 1980 to 2022.

**Table 1 shows the result of the descriptive** statistics

| OUTCOME | GDP | $CO_2$ | INR | OPEN | POP |
|---|---|---|---|---|---|
| Mean | 3.264 | -0.158 | 0.337 | 1.521 | 8.091 |
| Median | 3.228 | -0.138 | 4.310 | 1.537 | 8.089 |
| Maximum | 3.428 | -0.037 | 18.180 | 1.726 | 8.318 |
| Minimum | 3.148 | -0.350 | -65.857 | 0.960 | 7.863 |
| Std. dev. | 0.102 | 0.081 | 14.272 | 0.157 | 0.136 |
| Skewness | 0.334 | -0.377 | -2.685 | -1.396 | 0.015 |
| Kurtosis | 1.474 | 2.060 | 12.775 | 5.424 | 1.795 |
| Jarque-Bera | 4.737 | 2.482 | 212.525 | 23.373 | 2.479 |
| Probability | 0.093 | 0.288 | 0.000 | 0.000 | 0.289 |
| Sum | 133.848 | -6.516 | 13.821 | 62.367 | 331.768 |
| Sum sq. dev. | 0.416 | 0.266 | 8147.812 | 0.990 | 0.745 |
| Observations | 41 | 41 | 41 | 41 | 41 |

Table 1 shows that population (POP) has the highest mean value at 8.09; this is followed by Gross Domestic Product (GDP) with a mean value of 3.26. The next higher mean value is Trade Openness (OPEN), which has 1.52. The interest rate (INR) has a mean value of 0.33; the lowest mean value is that of carbon emissions, with a mean value of -0.15. In terms of standard deviation, carbon emission has the lowest standard deviation at 0.08, while interest rate (INR) has the highest at 14.1. Nonetheless, the very low standard deviation for the majority of the series indicates that the actual data's variations from their mean values are quite minor. However, the mean value of all the series is highly consistent, with mean and median values lying between their lowest and maximum values.

Moreover, the skewness of the variable shows that carbon emissions, interest rate (INR) and trade openness (OPEN) are negatively skewed. This means that these variables are characterised with a long tail and lower value than the sample mean value. Gross Domestic Product (GDP) and Population (POP), however, show normal skewness, as their distributions are symmetrical around their mean values. Since this series' kurtosis is more than three, it indicates that two variables—interest rates and trade openness—are leptokurtic in comparison to the norm. But the other four factors are playleykurtic. Finally, for all series, the likelihood that the Jarque-Bera statistics surpass the observed value (in absolute value) is often minimal.

### *4.2. Correlation Matrix of the Variables*

The study acquired the dependent and independent variables' correlation matrix in order to investigate the potential level of linkage between the variables. The study's variables' sample correlation matrix is shown in Table 2. The correlation table provides a first indication of the direction of the link between the variables that were chosen. Table 2's results usually indicate that the correlation coefficient is strong in terms of magnitude, with some showing positive correlations and others showing negative correlations.

**Table 2**. Pairwise correlation matrix result.

| Variables | GDP | $CO_2$ | INR | OPEN | POP |
|---|---|---|---|---|---|
| GDP | 1.000 | | | | |
| $CO_2$ | -0.656 | 1.000 | | | |
| INR | 0.273 | -0.339 | 1.000 | | |
| OPEN | 0.041 | 0.101 | -0.121 | 1.000 | |
| POP | 0.791 | -0.693 | 0.465 | 0.013 | 1.000 |

### *4.3. Unit Root Test Result*

To test for a long-run relationship in time series, the macroeconomic variables used in the study are assumed to be integrated of the same order at level I(0), or first difference, I(1), which means they are either stationary in level, or first difference, or mixture of both I(0) or I(1), and not I(2). Therefore, this section employed the Philip Perron (PP) and Augmented Dickey Fuller (ADF) unit root tests to examine the stationarity of the data used in this study. Both tests compare the null hypothesis of a unit root or series non-stationarity to the alternative.

Table 3 shows the results of the unit root tests. The fact that a non-stationary time series cannot be generalised to other time periods outside of the present underscores the significance of time series stationarity in regression. At the 5% significance level, the variables are stationary at both level and first difference. Therefore, the null hypothesis, according to which there are no unit roots in the first differences, is rejected since all test statistics for the first difference variables are significant.

**Table 3.** Unit root test result.

| Series | ADF | | PP | | |
|---|---|---|---|---|---|
| | Level | 1st difference | Level | 1st difference | |
| GDP | -2.314 | -3.028*** | -3.902*** | -4.248*** | I(1) |
| $CO_2$ | -4.041** | -9.533*** | -4.022** | -21.404*** | I(0) |
| DCP | -2.258 | -5.834*** | -2.408 | -5.952*** | I(1) |
| INR | -5.615*** | -13.419*** | -5.639*** | -13.506*** | I(0) |
| OPEN | -3.343* | -8.740*** | -3.3430* | -9.7184*** | I(0) |
| POP | -4.746*** | -1.216*** | -1.5661 | -3.2988*** | I(0) |

**Note:** ***, **, * denotes level of significance for 1%, 5%, and 10% respectively.

### *4.4. ARDL Cointegration Bound Test*

Once the integration of the variables of the same order, I(1), has been established. The study then goes on to determine if the variables are co-integrated, meaning they will eventually have a link. The study looked at the long-term link between economic expansion and environmental deterioration using a co-integration bound test. When variables are of different orders of integration, that is, first difference and level, the suitable econometric technique to be used is the autoregressive distributed lag model.

The findings in Table 4 demonstrate that, at any significance level, the F-statistics (10.176) are higher than the critical values of the upper and lower bounds. As a result, the study indicates that the variables in this study have a long-term link, rejecting the null hypothesis that the variables are not co-integrated. This suggests that estimations of the long-run and short-run coefficients can be made for analysis and interpretation.

**Table 4.** Co-integration bounds test.

| F-bounds test | | Null hypothesis: No levels relationship | | |
|---|---|---|---|---|
| **Test statistic** | **Value** | **Signif.** | **I(0)** | **I(1)** |
| F-statistic | 10.175 | 10% | 2.080 | 3.000 |
| K | 5 | 5% | 2.390 | 3.380 |

### *4.5. ARDL Short-Run and Long-Run Results*

From the short-run results in Table 5, at 5% significant level, carbon emissions positively affect economic growth. This suggests that an increase of one unit in carbon emissions corresponds to a 0.0647 unit rise in economic growth, all other things being equal. This result shows that while emissions are harmful, they are also a by-product of increased economic activities, thereby leading to economic development. This result is in line with the study of Shahbaz and Khan (2018) which revealed that carbon emissions positively affect economic growth. Also, at a 1%, the lag one value of trade openness showed a significant and positive relationship with economic growth. This implies that one unit of increase in trade openness increases economic growth by 0.040 units. Equally, at a 1% statistically significant level, population promotes economic growth. This implies that one unit of population promotes economic growth by 30.40 units. The R-squared value of 0.78 implies that the variation in the economic growth is explained by independent variables, while about the remaining 12% is accounted for other unconsidered factors in the estimated model. The ability of the variables in predicting economic growth was further reinstated by the adjusted R-squared value of 76 %, which is close to the R-squared value, suggesting that the predictors in the model accounted for a significant portion of economic growth. The standard error is 0.010, which is very low and implies a low risk of error in the estimated coefficients. Also, the Durbin-Watson statistic is greater than 2, which implies that the estimated model is free from an autocorrelation problem and reaffirms that, the effect of environmental degradation on economic growth, as indicated by adjusted R-squared, was not biased. The error correction mechanism value of 1 % level indicates that about 20 % disequilibrium in the short run is corrected in the long-run. This further reinstates that the series in the study has a long-run association. In the long-run, the result also confirms the positive impact of carbon emissions on economic growth, although the result is insignificant. This shows that improved government policies favouring a cleaner economy have the capacity to improve public health, thereby increasing economic growth in the long-run. Also, interest rates remained a positive but significant predictor of GDP in the long-run, thereby producing about a 0.03% increase in the level of GDP for every one-unit increase in interest rate. Moreover, in the long-run, trade openness reversed from being a positive and significant predictor of GDP in the short run to a significant negative predictor of GDP in its current value. To this end, GDP decreased by 20% for every 1% increase in trade openness, population was consistent in its positive and significant association with relationship with economic growth both in the short run and in the long-run. Hence, a 1% increase in population in its current value is associated with about an 82% significant increase in GDP.

**Table 5.** ARDL short-run and long-run results.

| Variable | Coefficient | Std. error | t-statistic | Prob. |
|---|---|---|---|---|
| Short-run coefficients | | | | |
| D($CO_2$) | 0.065** | 0.027 | 2.412 | 0.023 |
| D(INR) | 0.000 | 0.000 | 1.674 | 0.106 |
| D(OPEN) | 0.007 | 0.012 | 0.615 | 0.544 |
| D(OPEN(-1)) | 0.040*** | 0.014 | 2.930 | 0.007 |
| D(POP) | 30.409*** | 3.217 | 9.453 | 0.000 |
| CointEq(-1)* | -0.202*** | 0.022 | -9.331 | 0.000 |
| Long-run coefficients | | | | |
| Variable | Coefficient | Std. error | t-statistic | Prob. |
| $CO_2$ | 0.033 | 0.267 | 0.125 | 0.902 |
| INR | 0.004*** | 0.002 | 2.052 | 0.050 |
| OPEN | -0.204 | 0.105 | -1.944 | 0.062 |
| POP | 0.820* | 0.168 | 4.892 | 0.000 |
| C | -4.730 | 1.517 | -3.118 | 0.004 |
| R-squared | | 0.788 | | |
| Adjusted R-squared | | 0.756 | | |
| S.E. of regression | | 0.010 | | |
| Durbin-Watson stat | | 2.037 | | |

**Note:** ***, **, and * denotes level of significance for 1%, 5%, and10% respectively.

### *4.6. Diagnostic Test Result*

This section presents the results from post estimation test conducted to ensure the reliability and robustness of the ARDL estimation technique. This test includes the stability test, normality test, heteroskedasticity tests and multicollinearity test as indicated below.

#### *4.6.1. Stability Test*

This is done by observing the CUMSUM test at 5%level of significance. The Figure 1 reveals that the trend of the model lies within the 5% range. This means that the model is a good fit for prediction.

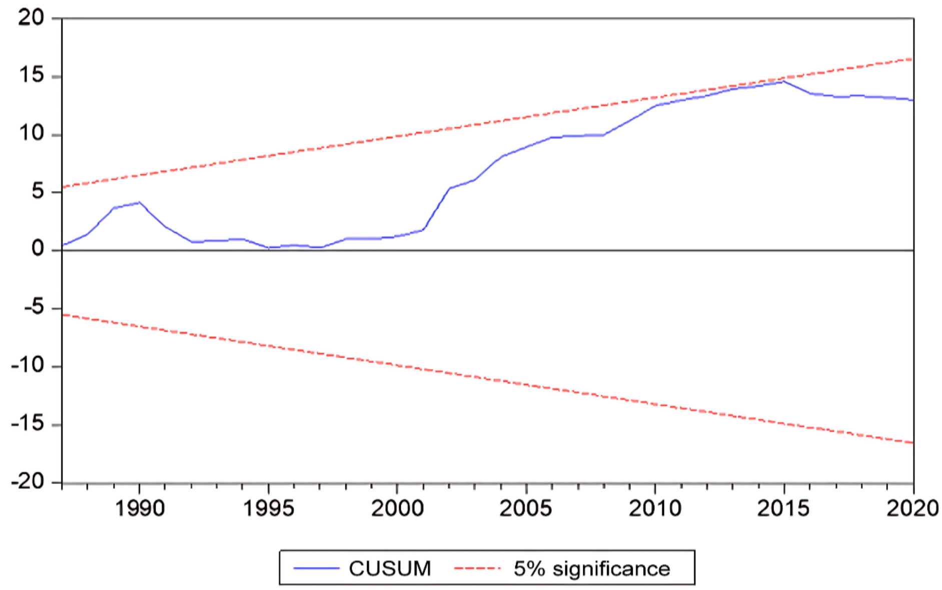


**Figure 1.** CUMSUM test.

#### *4.6.2. Normality Test*

The study uses the Jarque-Bera statistics to validate the normality of the residual. Figure 2 indicates a statices of 0.62, which lies within the normal range of model prediction.

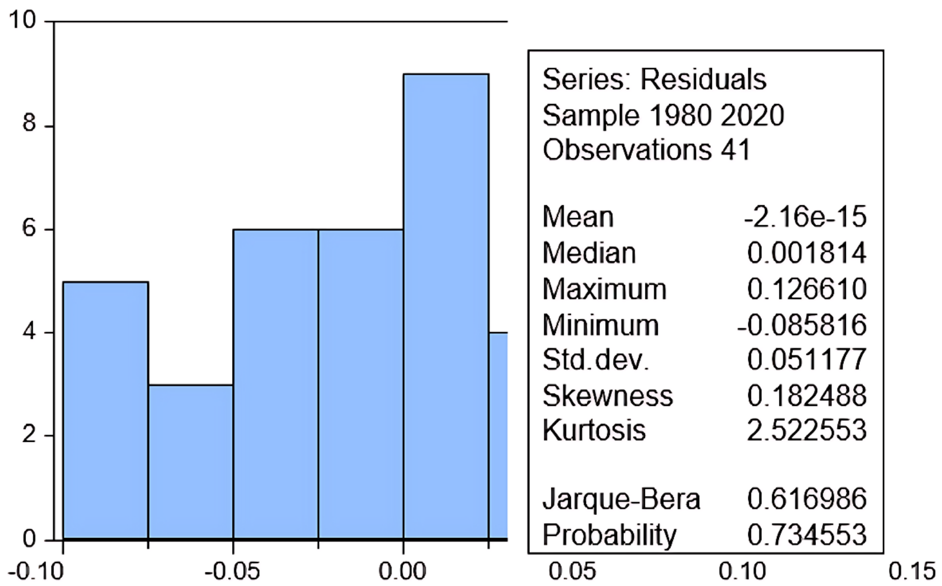


**Figure 2.** Normality test result.

### *4.6.3. Heteroscedasticity Test Result*

Heteroskedasticity was determined using the Breusch-Pagan test. The null hypothesis of the test makes the assumption that variance is constant across observations, or homoskedastic. Heteroskedasticity, which indicates that the variance of the errors varies among observations, is the alternative theory.

According to Table 6, the probability is 0.0765 and the F-statistic is 3.196. This implies that, at the 5% level of significance, the model does not exhibit any signs of heteroskedasticity. because the corresponding probability is higher than 0.05. The explained sum of squares is 7.129 with a probability of 0.002, and the Obs* R-squared is 12.851 with a probability of 0.08. These next two statistics, which are linked to the chisquare distribution, offer more proof that the model does not exhibit considerable heteroskedasticity.

**Table 6.** Breusch-pagan-Godfrey heteroskedasticity test result.

| | | | |
|---|---|---|---|
| F-statistic | 3.195 | Prob. F (5,35) | 0.076 |
| Obs*R-squared | 12.850 | Prob. Chi-square (5) | 0.084 |
| Scaled explained SS | 7.129 | Prob. Chi-square (5) | 0.002 |

### *4.6.4. Multicollinearity*

As a general rule, multicollinearity is acceptable when the Variance Inflation Factor (VIF) is less than 10 because this indicates mild collinearity. This model's maximum VIF value is 3.011. Since none of the independent variables have a VIF of up to 10, the result in Table 7 shows that multicollinearity is absent.

**Table 7.** Variance Inflation Factor test result.

| Variable | Uncentered | Centered | |
|---|---|---|---|
| | Variance | VIF | VIF |
| C | 0.698 | 9563.303 | NA |
| $CO_2$ | 0.022 | 9.903 | 2.026 |
| INR | 0.000 | 1.331 | 1.331 |
| OPEN | 0.003 | 102.156 | 1.055 |
| POP | 0.012 | 10842.730 | 3.011 |

## 5. CONCLUSION AND POLICY RECOMMENDATIONS

The purpose of this research is to assess the dynamic response of economic growth to environmental degradation over the period 1980-2022, providing insights into how these factors interact and affect each other. The relationship between economic growth and environmental degradation is complex. On one hand, economic growth can lead to improved living standards, increased employment opportunities, and better infrastructure. On the other hand, unchecked growth can result in environmental harm that undermines long-term sustainability and quality of life. For instance, while industrialisation may boost economic output, it can also deplete natural resources and pollute air and water sources, creating a trade-off between short-term economic benefits and long-term environmental health. This study is unique and significant as it supports efforts to achieve economic growth while addressing environmental challenges, contributing to a more sustainable future. On the finding of the study, carbon emissions have been found to have weak and statistically insignificant effects on economic growth.

This suggests that carbon dioxide alone does not robustly predict economic performance, indicating a need for broader and more integrated economic policies that address various aspects of financial and environmental management. Also, while trade openness initially supports economic growth in the short run, the long-term impact becomes negative, reflecting potential trade imbalances and vulnerabilities. Additionally, interest rates have a minor positive effect on GDP in the short run, suggesting that while they may contribute slightly to economic growth, controlling interest rates remains crucial for overall stability and long-term economic health. Also, a positive and significant relationship between population growth and GDP indicates that a growing population can substantially boost economic output. To fully capitalise on this demographic advantage, targeted investments in education, skill development, and training are essential for the large workforce emanating from the high population in Nigeria, thus enhancing productivity and sustaining economic growth. Given that carbon dioxide emissions are a positive but statistically insignificant predictor of economic growth, the government should focus on a broader set of economic and environmental indicators to develop growth strategies. Revealing that carbon emissions alone may not reliably predict economic growth, integrating sustainable practices and cleaner technologies can contribute to long-term economic and environmental benefits. The government should include incentivising green technologies and investments that promote both economic growth and environmental sustainability.

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**Transparency:** The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
**Data Availability Statement:** Upon a reasonable request, the supporting data of this study can be provided by the corresponding author.
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