

CO₂ Emissions, Human Capital Development and Economic Growth in Nigeria

Rosemary Chidinma Onwe¹, Douglas Nwaonuma Nnachi², Mgbodichimma K. Okoro³

^{1, 3}Department of Economics Alex Ekwueme Federal University Ndufu Alike Ikwo

²Department of Economics Ebonyi State University, Abakaliki

Corresponding author's email: onwerosemaryn@gmail.com

ABSTRACT

Economic growth remains a key macroeconomic objective for developing economies such as Nigeria; however, the country continues to face persistent constraints arising from environmental pressures, structural weaknesses, inflationary pressures, and human capital challenges. This study investigates the impact of carbon dioxide (CO₂) emissions, human capital development, gross fixed capital formation, natural resource rent, and inflation on economic growth in Nigeria over the period 1981–2024. The objective is to examine how environmental degradation, human capital, investment dynamics, and resource dependence influence economic growth, with real GDP used as a proxy for economic performance. Human capital is measured using the human capital index, CO₂ emissions capture environmental degradation, gross fixed capital formation reflects investment levels, natural resource rent measures resource dependence, and consumer price index captures macroeconomic stability. The study employs the Dynamic Autoregressive Distributed Lag (DYARDL) model to estimate both short-run and long-run relationships, allowing for dynamic adjustment and mixed integration properties. The findings reveal a stable long-run relationship among the variables. CO₂ emissions have a positive but statistically insignificant effect on economic growth, indicating a weak direct influence of environmental degradation on output. Human capital development exerts a positive and statistically significant effect on economic growth in both the short run and long run, highlighting its central role in productivity and long-term economic performance. In contrast, gross fixed capital formation has a negative effect on economic growth, reflecting inefficient investment outcomes and macroeconomic instability. Natural resource rent shows a positive but context-dependent effect, indicating reliance on resource revenues with varying productive spillovers. In sum, the study concludes that Nigeria's economic growth is driven more by human capital and natural resources than by physical capital accumulation or environmental factors. It recommends strengthening human capital investment, improving investment efficiency, and ensuring more productive use of natural resource revenues for sustainable economic growth.

Keywords: Economic Growth, Human Capital, CO₂ Emissions, Gross Fixed Capital Formation, Natural Resource Rent, Nigeria

Suggested citation: Onwe, R. C., Nnach, D. N., & Okoro, M. K. (2026). CO₂ emissions, human capital development and economic growth in Nigeria. *Economic and Business Review*, 2(1), 224-243.

1. Introduction

The relationship between environmental quality, human capital development, and economic growth has attracted increasing scholarly attention, particularly in developing economies such as Nigeria. Economic growth is a central objective of every nation, often measured by increases in

real gross domestic product (GDP). However, rapid economic expansion is frequently accompanied by environmental degradation, especially through rising carbon dioxide (CO₂) emissions resulting from industrialization, urbanization, and energy consumption (Azam et al., 2016; Rehman et al., 2022).

CO₂ emission is a major contributor to climate change, which poses significant risks to both human welfare and economic productivity (Rehman et al., 2022). In Nigeria, the dependence on fossil fuels, particularly crude oil and natural gas, has intensified environmental challenges, including air pollution and global warming. These environmental issues have implications for human capital development, as deteriorating environmental quality can adversely affect health outcomes, reduce life expectancy, and hinder educational attainment (Wasti & Zaidi, 2020; Otim & Mutumba, 2025).

Nigeria has experienced plummeting economic growth over the years despite its abundant natural resources and large labour force. Successive governments have increased investments in human capital through spending on education and healthcare, while also expanding physical capital through infrastructure development such as roads, transportation networks, electricity supply, and public facilities. In addition, revenues from natural resource rents, particularly crude oil and gas earnings, have provided substantial government income and foreign exchange inflows to support development programmes. However, despite these investments and resource inflows, economic growth has remained unstable, suggesting weak transmission of these inputs into sustained long-term performance. This challenge is further intensified by rising environmental pressures, especially increasing carbon dioxide (CO₂) emissions associated with economic activities.

Evidently, available data from WDI (2025) show that CO₂ emissions in Nigeria have followed an upward trend, reflecting increased industrialization, urbanization, transportation activities, gas flaring, and dependence on fossil fuels. Example, emissions increased from 73.3114 Mt in 1981 to 75.1111 Mt in 1990, and further to 100.1949 Mt in 2000. Although there was a slight decline to 94.4036 Mt in 2010, emissions rose again to 118.9178 Mt in 2020 and reached 131.9101 Mt in 2024. This persistent increase highlights growing environmental pressure linked to Nigeria's production structure and energy consumption pattern. The rising CO₂ emissions pose additional risks to economic performance by undermining human capital development. Environmental degradation contributes to poor air quality, climate-related diseases, and heat stress, all of which reduce labour productivity, increase healthcare costs, and weaken workforce capacity. This suggests that potential gains from investments in education, healthcare, and infrastructure may be eroded by deteriorating environmental conditions.

Similarly, income per capita reflects an unstable growth trajectory. For instance, GDP per capita declined from \$1,834.288 in 1981 to \$1,577.196 in 1990 and further to \$1,421.68 in 2000. Although it improved to \$2,315.467 in 2010, it later declined to \$2,228.686 in 2020 before slightly rising to \$2,324.649 in 2024 (WDI, 2025). This volatility persists despite sustained government investment in education and healthcare, with education spending averaging 5–7% of total expenditure and health spending remaining below the 15% Abuja Declaration benchmark. These patterns suggest that improvements in human capital investment have not been effectively translated into stable and sustained economic growth.

2. Review of Related Literature

2.1 Endogenous Growth Theory

The Endogenous Growth Theory, developed by Paul Romer and Robert Lucas, argues that long-run economic growth is driven mainly by internal factors such as innovation, human capital accumulation, knowledge spillovers, and capital investment. Romer (1986) emphasized that education, research, and technological progress generate self-sustaining growth through increasing returns and knowledge diffusion, while Lucas (1988) highlighted continuous human capital accumulation as a major source of productivity improvement. Similarly, Philippe Aghion and Peter Howitt (1992) stressed the importance of innovation-driven competition and R&D in sustaining growth. The theory is relevant to this study because it links human capital development and gross fixed capital formation to economic growth, while technological innovation may also contribute to CO₂ reduction. However, critics argue that the theory often overlooks governance quality, institutional weaknesses, and environmental sustainability challenges.

2.2 Ecological Theory

Ecological Economics Theory explains that the economy is embedded within the natural environment and is therefore constrained by ecological limits rather than capable of infinite expansion (Daly, 1996; Costanza et al., 2014). Within this framework, CO₂ emissions represent environmental stress arising from fossil-fuel-based production and consumption, contributing to climate change and ecological degradation. Such environmental damage can reduce long-term economic growth by increasing health costs, lowering labour productivity, and causing climate-related disruptions to agriculture, infrastructure, and output (Stern, 2007). It also imposes adaptation and mitigation costs that divert resources from productive investment. Unlike conventional growth theories, ecological economics argues that technological progress cannot fully offset environmental limits. Thus, sustained economic growth depends on balancing economic activity with environmental sustainability, making CO₂ emissions a key factor in understanding long-run economic performance in Nigeria (Daly & Farley, 2011).

2.3 Resource Curse Theory

The Resource Curse Theory suggests that countries with abundant natural resources may experience slower economic growth due to overdependence on resource rents, weak institutions, and volatility in resource prices (Auty, 1993; Sachs & Warner, 2001). It argues that instead of promoting development, natural resource wealth can distort economic incentives, reduce diversification, and encourage rent-seeking behaviour. This theory is relevant to the inclusion of natural resource rent in this study, as Nigeria's economy is highly dependent on oil revenues, which may have mixed effects on sustainable economic growth (Khan et al., 2023; Hidayat et al., 2024).

2.4 Empirical Literature Review

The study reviewed existing empirical studies on the relationship between key macroeconomic and environmental variables and economic growth. The literature is organized thematically into

four strands: CO₂ emissions and economic growth, human capital and economic growth, physical capital and economic growth, and natural resources and economic growth, for easy understanding.

Azam et al. (2016) examined the impact of CO₂ emissions, energy use, trade, and human capital on economic growth in China, the USA, India, and Japan from 1971–2013. Economic growth was the dependent variable, while CO₂ emissions, energy use, trade, and human capital were explanatory variables. Using panel FMOLS, the study found a long-run relationship among variables. CO₂ emissions and energy use negatively affected growth at the panel level, while trade and human capital had positive effects. Country results showed CO₂ emissions increased growth in China, Japan, and the USA but reduced it in India, highlighting policy heterogeneity.

Rehman et al. (2022) investigated the effects of population growth, food production, economic growth, livestock production, and energy use on CO₂ emissions in Pakistan, with a broad focus on the drivers of environmental degradation. CO₂ emissions served as the dependent variable, while population growth, food production, economic growth, livestock production, and energy utilization were the explanatory variables. The study applied the STIRPAT model alongside the Autoregressive Distributed Lag (ARDL) technique to assess both short- and long-run dynamics. The findings revealed that population growth, economic growth, livestock production, and energy use increase CO₂ emissions, whereas food production and urbanization reduce emissions over time.

Wasti and Zaidi (2020) assessed the relationship among CO₂ emissions, energy consumption, economic growth, and trade liberalization in Kuwait. Using annual data from 1971–2017 sourced from the World Bank, CO₂ emissions and economic growth were key outcome variables, while energy consumption and trade liberalization were explanatory variables. Stationarity was tested using ADF and PP tests, followed by the ARDL model to capture long- and short-run dynamics. The results confirmed a long-run relationship among variables. CO₂ emissions and energy consumption positively influence economic growth. Causality tests revealed bidirectional causality between CO₂ emissions and energy use, and unidirectional links from GDP and energy use.

Otim and Mutumba (2025) examine the relationship between carbon emissions, economic governance, and economic growth in East African Community countries from 1996–2019. Using FMOLS alongside CIPS unit root, cointegration, and Dumitrescu–Hurlin causality tests, the study finds that economic governance, carbon emissions, capital formation, and human capital positively influence growth, while labour force and renewable energy negatively affect it. Causality runs from growth to emissions. The results further show that economic growth significantly enhances total factor productivity (TFP). The study concludes that strong governance frameworks are essential for promoting sustainable growth, improving productivity, and achieving effective environmental and economic policy outcomes.

Effiong and Panicker (2026) examine the relationship between CO₂ emissions and agricultural growth in Nigeria from 2000–2022. Using panel regression and OLS, the study finds a long-run cointegrating relationship, indicating that agricultural growth increases emissions. However, OLS results show that increased agricultural production reduces CO₂ emissions. Trade openness and agricultural GDP contribution raise emissions, while urban population reduces them. The study concludes that sustainable policies, economic diversification, and promotion of environmentally

friendly practices are essential for balancing agricultural growth with environmental sustainability in Nigeria.

Garza-Rodríguez et al. (2020) examined the relationship between human capital and economic growth in Mexico (1971–2010) using OLS and structural change models. The results showed that human capital and physical capital explain about 50% of GDP per worker variation. A 1% increase in secondary school enrolment raises GDP per worker by 1.08%, while capital investment increases it by 0.39%. Human capital had a stronger effect than physical capital, and Granger causality revealed a bidirectional relationship between human capital and economic growth.

In a Nigeria-focused study, Okoh et al. (2022) examined the effect of human capital development on manufacturing sector performance in Nigeria using annual data from 1981–2021 and the Ordinary Least Squares (OLS) technique. The study found that improvements in education, skills acquisition, and vocational training significantly enhance manufacturing productivity and overall sectoral performance.

Khan et al. (2023) controlled for physical capital, renewable energy, urbanization, and CO₂ emissions while examining the role of FDI in the relationship between human capital and economic growth in Pakistan (1990–2019) using ARDL and ECM methods. The results show that physical capital is a major driver of economic growth, alongside FDI, renewable energy, and human capital in both the short and long run. However, urbanization and CO₂ emissions negatively affect growth. The study recommends strengthening physical capital formation and attracting FDI.

Pomi et al. (2021) analysed the interaction between human capital and physical (material) capital on economic growth in Bangladesh from 2000–2019 using a Vector Autoregression (VAR) model. The findings show that both human capital and physical capital contribute to economic growth, though their effects vary over different time horizons. Physical capital plays a stronger role in sustaining short-term growth, while human capital supports longer-term development. The study recommends balanced policy support for both forms of capital to sustain economic growth.

Ehigiamusoe et al. (2024) examined the moderating roles of human and physical capital in the foreign aid-growth nexus in Nigeria from 1980–2020 using the ARDL approach. The findings show that foreign aid positively affects growth, while human and physical capital significantly influence the effectiveness of aid. However, when human and physical capital exceed threshold levels of 55% and 65%, respectively, additional aid no longer promotes growth. The study recommends greater investment in human and physical capital for sustainable development.

Ishfaq et al. (2024) examined the impact of natural, physical, and human capital formation on economic growth in Pakistan using annual data from 1971–2020 and the ARDL approach. The findings reveal that physical capital, human capital, natural capital, labour force participation, and financial development positively and significantly influence economic growth, while FDI shows an insignificant effect. The study concludes that capital formation is vital for economic growth and recommends greater investment in infrastructure, education, health, and natural resource management.

Uddin et al. (2025) examined the relationship between physical capital, human capital, globalization, and economic growth in BIMSTEC countries using panel data from 1990–2019 and

advanced econometric techniques. The findings show that physical and human capital positively influence economic growth, while globalization negatively moderates these relationships in the short run. However, the long-run effects remain positive. The study recommends aligning globalization policies with capital accumulation strategies to achieve sustainable economic development in BIMSTEC economies.

Tabash et al. (2022) studied how natural resources and economic complexity impact economic growth in a panel of 24 African countries from 1995 to 2017. The study employed the system GMM technique and found that natural resource rents influenced economic growth, while economic complexity had a positive effect. The interaction between these two factors also showed a positive impact on economic growth.

Khan et al. (2023) examined the effects of natural resources endowment and output growth in high-income G-7 countries between 1990 and 2020. The study also controlled for the impacts of CO2 emissions, human capital development, and clean growth. To estimate the parameters, the authors used the Method of Moments Quantile Regression (MMQ-Reg). The findings indicated that, at both aggregate and disaggregated levels, natural resource dependence impedes economic development in G-7 nations.

Hidayat et al. (2024) evaluated the role of natural resources, CO2 emissions, and renewable energy in promoting output growth in Association of South East Asian Nations (ASEAN) countries using data from 2000 to 2021. The study applied both static (Fixed Effect) and dynamic panel (GMM) estimation models. The results confirmed that natural resources promoted economic growth in the ASEAN region. The study further demonstrated that FDI and renewable energy are positive and significant influencers of economic growth in the ASEAN, while the effect of CO2 emissions was negative and insignificant.

Singh et al. (2024) found that natural resources had a decreasing effect on GDP in P5+1 countries (US, UK, France, China, Russia, and Germany). Using data from 1988 to 2019, the study employed quantile-on-quantile regression analysis to estimate the parameters.

Meziane and Brahim (2026) examined the impact of total and disaggregated natural resource rents on ecological footprint in Algeria from 1970/Q1–2022/Q4 using the NARDL model. The findings reveal asymmetric effects, with positive shocks in total natural resource rents increasing ecological footprint while negative shocks reduce it. Oil, gas, mineral, and forest rents significantly affect environmental sustainability, whereas coal rents are insignificant. The study recommends economic diversification, cleaner energy adoption, and sustainable forest management to reduce ecological degradation.

3. Methodology

This study anchors on ex-post facto research design using secondary data obtained from reputable sources. Economic growth, proxied by GDP capita, is employed as the dependent variable. The explanatory variables include CO₂ emissions (CO_{2e}), human capital (HC), physical capital (PC), natural resource rent (NRR) and consumer price index (CPI) serve as the explanatory variables.

The study applies the Dynamic Autoregressive Distributed Lag (Dynamic ARDL) approach to estimate both the short-run and long-run relationships among the variables. The Dynamic ARDL model is particularly suitable because it captures dynamic adjustments and simulates the effects of changes in explanatory variables on labour productivity over time. All estimations are conducted using Stata 16 and E-Views 12 to ensure accuracy and reliability of the findings.

3.1 Model Specification

Based on the operationalization of the endogenous model in equation (1), the testable form of the equation can be expressed as:

$$GDPc_t = \beta_0 + \beta_1 CO2e_t + \beta_2 HC_t + \beta_3 PK_t + \beta_4 RR_t + \beta_5 CPI_t + \mu_t \quad (2)$$

where:

- GDP = Gross domestic product per capita
- CO2e = Carbon dioxide emissions
- HC = Human capital
- PK = Physical capital
- RR = Natural resource rent
- CPI= Consumer Price Index
- β_0 = Constant term
- $\beta_1 - \beta_5$ Parameters to be estimated
- μ_t = Error term.
- All variables have converted to natural log form to reduce noise.

Gross Domestic Product (GDP) per capita is the dependent variable in this study, representing economic performance and average income per person. It serves as a proxy for economic growth, where higher values indicate improved productivity, stronger economic structure, and better living standards. Carbon dioxide (CO₂e) emission, measured in metric tons, is a key explanatory variable capturing industrial and economic activity. While moderate emissions may reflect productive expansion, excessive levels can reduce long-run output through environmental degradation and health-related productivity losses.

Human capital (HC), measured through education attainment or enrolment rates, reflects labour quality. Higher human capital enhances skills, innovation, efficiency, and technology adoption, thereby increasing GDP per capita. Physical capital (PK), proxied by gross fixed capital formation as a ratio of GDP, measures investment in infrastructure, machinery, and equipment. It strengthens productive capacity and improves output efficiency.

Natural resource rent (RR), expressed as a percentage of GDP, represents income from resources such as oil and gas. Although it can boost GDP in the short run, overdependence may create volatility and hinder diversification and sustainable growth. Consumer Price Index (CPI) captures inflation and general price levels. Rising CPI reduces purchasing power, distorts investment decisions, and negatively affects real economic growth.

Furthermore, the Dynamic ARDL approach minimizes post-estimation bias, captures dynamic interactions among variables, and better addresses endogeneity arising from lag structures. The technique is also suitable for small sample sizes and variables integrated of order I(0) and I(1), excluding I(2). Consequently, Dynamic ARDL provides more reliable estimates and improves policy interpretation and forecasting accuracy. Equations (3) and (4) represent ARDL and dynamic ARDL specifications:

$$\begin{aligned} \Delta GDP_c_t = & \alpha_0 + \sum_{i=1}^p \alpha_{1i} \Delta GDP_{c,t-i} + \sum_{i=0}^p \alpha_{2i} \Delta CO2e_{t-i} + \sum_{i=0}^p \alpha_{3i} \Delta HC_{t-i} + \sum_{i=0}^p \alpha_{4i} \Delta PK_{t-i} \\ & + \sum_{i=0}^p \alpha_{5i} \Delta RR_{t-i} + \sum_{i=0}^p \alpha_{6i} \Delta CPI_{5t-i} + \alpha_7 CO2e_{t-1} + \alpha_8 HC_{t-1} + \alpha_9 PK_{t-1} + \alpha_{10} HC_{t-1} \\ & + \alpha_{11} RR_{t-1} + \alpha_{12} CPI_{t-1} + \varepsilon_t \end{aligned} \quad (3)$$

$$\begin{aligned} \Delta GDP_c_t = & \alpha_0 + \phi_0 GDP_{c,t-1} + \delta_1 \Delta CO2e_t + \phi_1 CO2e_{t-1} + \delta_2 \Delta HC_t + \phi_2 HC_{t-1} + \\ & \delta_3 \Delta CPI_t + \phi_4 CPI_{t-1} + \gamma_1 ECT_{t-1} \end{aligned} \quad (4)$$

Where: $\delta_1 - \delta_n$ and $\phi_1 - \phi_n$ are the parameters to be estimated. ECT_{t-1} is the error correction term while Δ present the change element. All other variables remain as earlier defined.

4. Results

Table 1: Descriptive Statistics

	Mean	Median	Max	Min	St Dev.	Skewness	Kurtosis	J-Bera	Pro.
GDPc	7.5067	7.4788	7.8578	7.2356	0.2294	0.1698	1.3713	5.0750	0.0791
CO ₂ e	4.5595	4.5571	4.8821	4.2157	0.2019	-0.0532	1.8243	2.5551	0.2787
HC	0.4319	0.4271	0.7582	0.1793	0.1948	0.0959	1.5558	3.8915	0.1429
GFC	3.4434	3.4864	4.4930	2.6506	0.5025	0.0612	2.2689	1.0074	0.6043
RR	2.4704	2.5106	3.5343	0.9515	0.5640	-0.4943	2.7697	1.8888	0.3889
CPI	3.2446	3.7474	6.5502	-0.7147	2.1774	-0.4760	1.9662	3.6206	0.1636
Obs	44	44	44	44	44	44	44	44	44

Source, Author's computation, 2026

Table 1 presents the descriptive statistics of the variables employed in the study, namely economic growth (GDPc), carbon dioxide emissions (CO₂e), human capital development (HC), gross fixed capital formation (GFC), natural resource rent (RR), and consumer price index (CPI) covering the period 1981–2024. The descriptive statistics provide information on the average behaviour, variability, and distributional characteristics of the variables used in the analysis. From results, the

mean values show that GDPC, CO₂e, HC, GFC, RR, and CPI averaged 7.5067, 4.5595, 0.4319, 3.4434, 2.4704, and 3.2446 respectively during the study period. The median values are close to their corresponding mean values, suggesting the absence of substantial divergence in the data distribution. The maximum and minimum values indicate the extent of variation across the series. CPI recorded the widest range with a maximum value of 6.5502 and a minimum value of -0.7147, reflecting high fluctuations in price levels. RR and GFC also exhibited noticeable variations over the period. The standard deviation values show that CPI had the highest volatility (2.1774), while HC (0.1948), CO₂e (0.2019), and GDPC (0.2294) exhibited relatively low dispersion from their mean values. The skewness statistics reveal that GDPC, HC, and GFC are positively skewed, whereas CO₂e, RR, and CPI are negatively skewed. Kurtosis values for all variables are below 3, indicating platykurtic distributions. The Jarque-Bera probability values are all greater than 0.05, confirming that the variables are normally distributed and suitable for econometric analysis.

4.1.3 Unit Test Results

Table 4: Ng-Perron Unit Root Test

Variable	Critical	MZA		MZt		MSB		MPT	
	Value(5%)	Level	Diff	Level	Diff	Level	Diff	Level	Diff
GDPC	8.100	-1.77	-9.59	-0.83	-2.15	0.47	0.22	12.32	2.72
CO ₂ e	8.100	-0.91	-20.73	-0.39	-3.20	0.42	0.15	13.40	1.24
HC	8.100	-14.24	4.47	-2.52	1.88	0.18	0.42	2.26	26.41
GFC	8.100	-0.56	-20.09	-0.45	-3.17	0.80	0.16	33.33	1.23
RR	8.100	-2.80	-19.48	-1.18	-3.11	0.42	0.16	8.74	1.27
CPI	8.100	-0.74	-24.99	-0.33	-3.49	0.45	0.14	14.59	1.14

Source: Author-computed, 2026

Table 4 presents the results of the Ng–Perron unit root test used to examine the stationarity properties of the variables. The test utilizes four statistics: MZA, MZt, MSB, and MPT. The decision rule requires that the absolute values of MZA and MZt should exceed the asymptotic critical value of 8.10, while MSB and MPT should be lower than their respective critical values at the 5 percent significance level before a variable can be considered stationary. The result shows that GDPC was non-stationary at level since the absolute MZA value of -1.77 was less than the critical value of 8.10. However, at first difference, the MZA statistic increased in absolute value to -9.59, exceeding the critical value, indicating stationarity at first difference. Similarly, CO₂e was non-stationary at level with an MZA value of -0.91, but became stationary after first differencing with an MZA statistic of -20.73.

However, HC was stationary at level because its MZA statistic of -14.24 exceeded the critical value of 8.10 in absolute terms. In contrast, GFC, RR, and CPI were non-stationary at level with MZA statistics of -0.56, -2.80, and -0.74 respectively, but became stationary after first differencing with MZA statistics of -20.09, -19.48, and -24.99 respectively. This is because the respective values are greater than 8.10 (the asymptotic value). Als, MZt, MSB, and MPT also satisfied the rules, the details can be found in appendix 4.

In all, the findings indicate that the variables are integrated of mixed order, comprising both I(0) and I(1) series, thereby justifying the use of the ARDL estimation technique.

4.1.5 Cointegration Results

Table 5: Pesaran, Shin, and Smith (2001) Bounds cointegration test

Statistic	10%		5%		1%		p-value	
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	1(0)	1(1)
F = 9.5	2.297	3.368	2.737	3.937	3.778	5.274	0.000	0.000
T = -5.0	-2.537	-3.846	-2.887	-4.261	-3.597	-5.096	0.000	0.012

Source: Author's computation, 2026

Table 5 presents the Pesaran, Shin, and Smith (2001) Bounds cointegration test results used to determine the existence of a long-run relationship among the variables. Cointegration is confirmed when the computed F-statistic exceeds the upper bound critical value I(1). If the statistic falls below the lower bound I(0), the null hypothesis of no cointegration cannot be rejected, while values lying between the lower and upper bounds indicate inconclusive evidence of cointegration among the variables.

However, from the results, the computed F-statistic of 9.5 exceeds the upper bound critical values of 3.368, 3.937, and 5.274 at the 10 percent, 5 percent, and 1 percent significance levels, respectively. This leads to the rejection of the null hypothesis of no long-run relationship among the variables across all levels of significance. Similarly, the computed t-statistic of -5.0 exceeds the upper bound critical values in absolute terms, further confirming the existence of cointegration. The probability values also validate this result, as the p-values for both the F-statistic (0.000) and t-statistic (0.002) are less than 0.05. The findings therefore confirm a stable long-run equilibrium relationship among carbon dioxide emissions, human capital development, natural resource rent, gross fixed capital formation, inflation, and economic growth in Nigeria.

4.2 Parameter Estimation Results

Table 6 presents the Dynamic ARDL simulation estimates for both the short-run and long-run relationships among the variables. The results show that Carbon dioxide emissions (CO₂e) exert a positive effect on economic growth in both the short run and long run with coefficients of 0.0311 and 0.0496 respectively. However, the effects are statistically insignificant in both periods, as the p-values of 0.680 and 0.598 exceed the 5 percent significance level. This implies that carbon emissions do not significantly influence economic growth in Nigeria.

Table 6: Dynamic ARDL Simulations Estimates

Variable	Coefficient	Std.error	T statistic	Prob.
Panel A: Short-run Coefficients				
ECM(-1)	-0.3748	0.0847	-4.43	0.000
Δ CO ₂ e	0.0311	0.0747	0.42	0.680
ΔHC	-0.3294	0.5864	-0.56	0.579
ΔGFC	-0.0820	0.0442	-1.86	0.073
ΔRR	0.0336	0.0189	1.78	0.086
ΔCPI	-0.0957	0.0461	-2.08	0.047

Panel B: Long-run coefficients				
Variable	Coefficient	Std.error	T statistic	Prob.
C	2.5523	0.7560	3.38	0.002
CO2e	0.0496	0.0929	0.53	0.598
HC	0.97467	0.2434	4.00	0.000
GFC	-0.0958	0.0272	-3.52	0.001
RR	0.0731	0.0197	3.70	0.001
CPI	-0.0665	0.0218	-3.05	0.005
R-squared	0.671			
Adj-Rsquared	0.534			
F-stat (12, 29)	4.92			
P-value of F-stat	0.000			
No. of Obs	42			
Simulations	5000			

Source: Author, calculation, 2026

On the contrary, human capital development (HC) negatively affects economic growth in the short run with a coefficient of -0.3294, although the effect is statistically insignificant given a p-value of 0.579. But in the long run, HC exerts a positive and statistically significant effect on economic growth with a coefficient of 0.9747 and a p-value of 0.000. This suggests that improvements in human capital enhance economic growth over time.

Surprisingly, gross fixed capital formation (GFC) has a negative coefficient in both the short run and long run with values of -0.0820 and -0.0958, respectively. The short-run effect is weakly significant at the 10 percent level with a p-value of 0.073, while the long-run effect is statistically significant at the 5 percent level with a p-value of 0.001. This indicates that increases in capital formation reduce economic growth during the study period.

Natural resource rent (RR) positively influences economic growth in both the short run and long run with coefficients of 0.0336 and 0.0731 respectively. The short-run effect is marginally significant at the 10 percent level with a p-value of 0.086, while the long-run effect is statistically significant at the 1 percent level with a p-value of 0.001. This implies that natural resource rent contributes positively to economic growth, particularly in the long run.

Consumer price index (CPI) exerts a negative effect on economic growth in both periods. In the short run, CPI has a coefficient of -0.0957 with a p-value of 0.047, indicating statistical significance at the 5 percent level. Similarly, the long-run coefficient of -0.0665 is statistically significant with a p-value of 0.005. This suggests that inflation adversely affects economic growth in Nigeria. The error correction term, ECM(-1), has a coefficient of -0.3748 and is statistically significant at the 1 percent level with a p-value of 0.000. The negative and significant coefficient confirms the existence of long-run equilibrium and indicates that about 37.5 percent of short-run disequilibrium is corrected annually towards equilibrium.

The R-squared value of 0.671 indicates that about 67.1 percent of the variations in economic growth are explained by the explanatory variables included in the model. The F-statistic value of

4.92 with a probability value of 0.000 indicates that the model is jointly significant and suitable for statistical inference.

4.3 Analysis of the Counterfactual Simulations

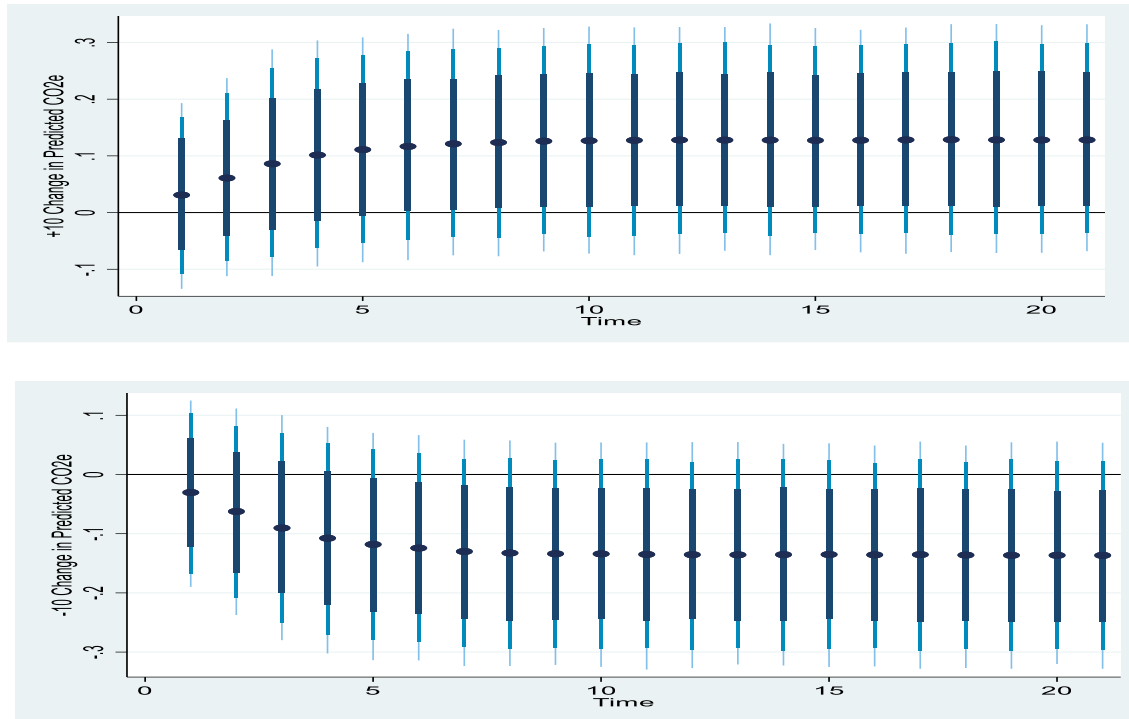


Figure 1: Response of GDP to ± 10 changes to CO₂ emission

Figure 1: Response of GDP to $\pm 10\%$ Changes in Changes in CO₂ Emissions

Figure 1 shows the response of GDP to positive and negative shocks in CO₂ emissions. The simulation indicates that a 10% increase in CO₂ emissions causes a slight rise in GDP, while a negative shock leads to a mild decline in economic growth. However, the response remains close to the equilibrium path, suggesting a weak effect. This aligns with the Dynamic ARDL estimates where CO₂ emissions positively but insignificantly influenced GDP. The result implies that emission-generating economic activities contribute marginally to growth in Nigeria, but the impact is not strong enough to produce substantial long-run economic expansion.

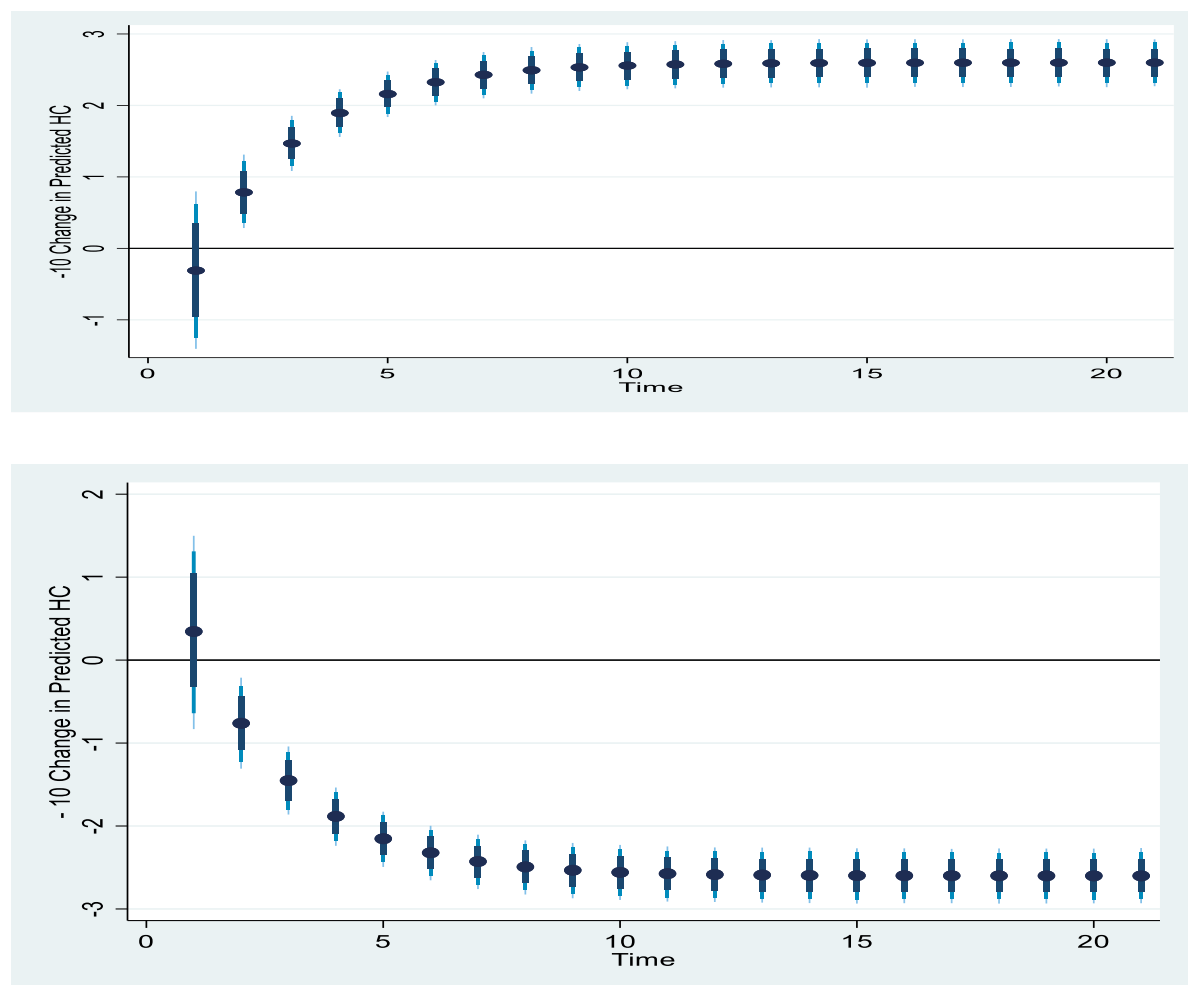


Figure 2: Response of GDP to ± 10 changes to human capital

Figure 2: Response of GDP to $\pm 10\%$ Changes in Changes in Human Capital

Figure 2 illustrates the response of GDP to shocks in human capital development. The graph reveals that a positive shock to human capital leads to a gradual and sustained increase in GDP, while a negative shock reduces economic growth over time. The widening gap between the positive and negative response paths suggests that improvements in education and health generate long-run growth benefits. This result supports the Dynamic ARDL findings where human capital had a positive and significant long-run effect on GDP. The simulation therefore confirms that investment in education, health, and workforce productivity is essential for sustainable economic growth in Nigeria.

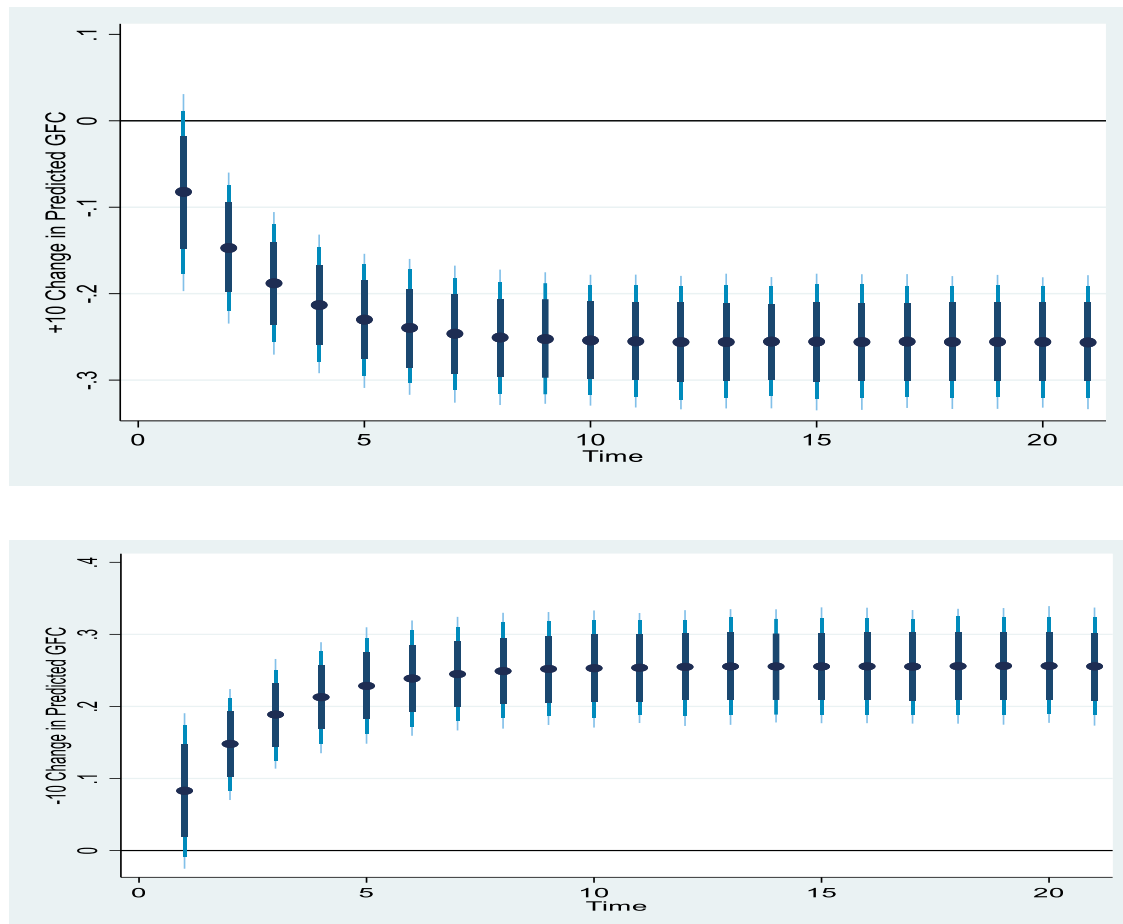


Figure 3: Response of GDP to ± 10 changes to Gross fixed capital formation

Figure 3: Response of GDP to $\pm 10\%$ Changes in Gross Fixed Capital Formation

Figure 3 presents the response of GDP to shocks in gross fixed capital formation (GFC). The simulation shows that a positive shock to GFC results in a decline in GDP, whereas a negative shock slightly improves economic growth. This outcome is consistent with the Dynamic ARDL estimates, which reported a negative relationship between GFC and GDP in both the short run and long run. The result suggests inefficiencies in capital allocation and the possibility that investment expenditures are directed toward unproductive projects. Hence, increased capital formation may not stimulate growth unless investments are efficiently utilized and properly managed.

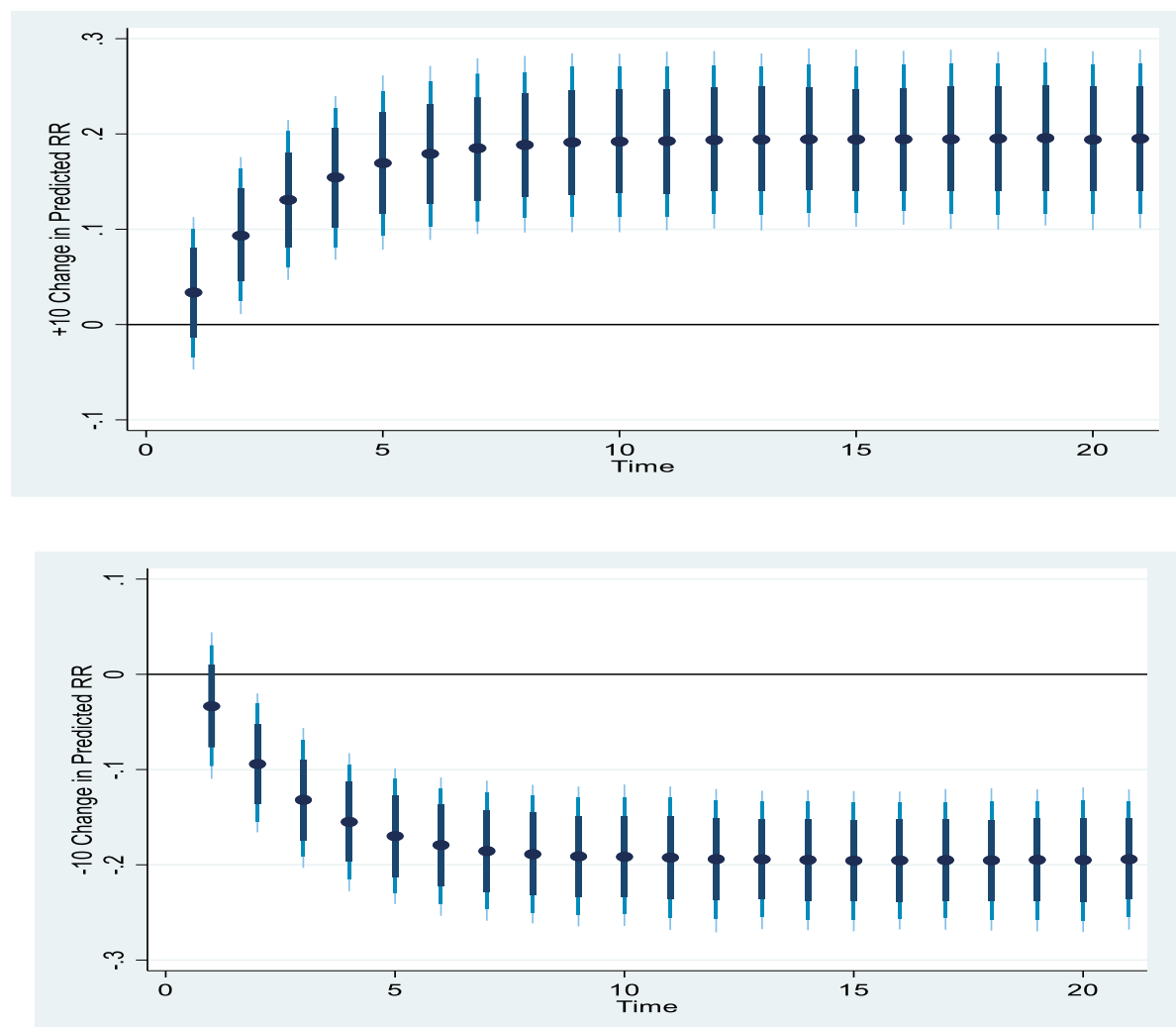


Figure 4: Response of GDP to ± 10 changes in natural resource rent

Figure 4: Response of GDP to $\pm 10\%$ Changes in Natural Resource Rent

Figure 4 shows the response of GDP to shocks in natural resource rent (RR). The graph indicates that a positive shock to resource rent generates a sustained increase in GDP, while a negative shock causes economic growth to decline. The positive response path gradually moves away from the equilibrium level, indicating that natural resource earnings contribute positively to Nigeria's economy. This finding supports the Dynamic ARDL estimates, where RR exerted a positive and significant long-run effect on GDP. The result highlights the importance of oil and natural resource revenues as key drivers of economic growth and development in Nigeria.

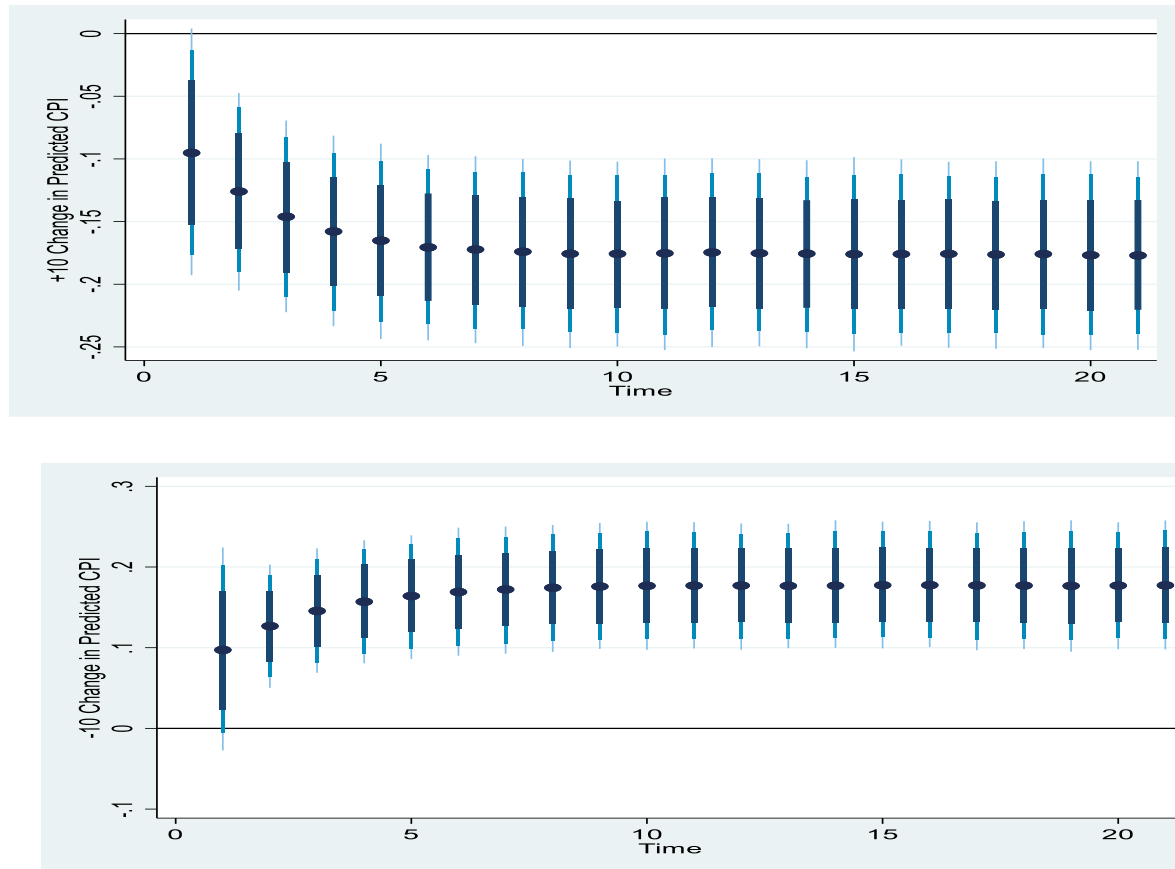


Figure 5: Response of GDP to ± 10 changes in consumer price index

Figure 5: Response of GDP to $\pm 10\%$ Changes in Consumer Price Index

Figure 5 presents the response of GDP to inflationary shocks measured by the consumer price index (CPI). The simulation reveals that a positive shock to CPI reduces GDP, while a decline in inflation improves economic growth. The persistent negative response confirms that inflation exerts a contractionary effect on the Nigerian economy. This finding is consistent with the Dynamic ARDL estimates, where CPI negatively and significantly affected GDP in both the short run and long run. Rising inflation increases production costs, weakens purchasing power, discourages investment, and creates macroeconomic instability, thereby constraining sustainable economic growth.

Implication of the Counterfactual Simulations

In all, the counterfactual simulations validate the Dynamic ARDL estimation results by showing the dynamic adjustment of GDP to shocks in the explanatory variables. The simulations reveal that human capital development and natural resource rent positively stimulate economic growth, while inflation and gross fixed capital formation reduce growth. CO₂ emissions exhibit only a insignificant positive influence on GDP. The findings imply that sustainable economic growth in Nigeria depends more on improving human capital quality, ensuring macroeconomic stability, and effectively managing natural resource revenues than on environmentally harmful production activities or inefficient capital.

4.4 Diagnostic Tests

Table 7 Residual Diagnostics tests

Test	lags(p)	df	chi2	Prob	Decision
ARCH LM (Hetero)	1	1	0.138	0.7104	Stable
B-Godfrey LM (Auto)	1	1	0.640	0.4205	Stable
RAMSEY RESET			2.31	0.0956	Stable
Jarque-Bera Norm.			0.3569	0.8366	Normal

Source: Author's estimation

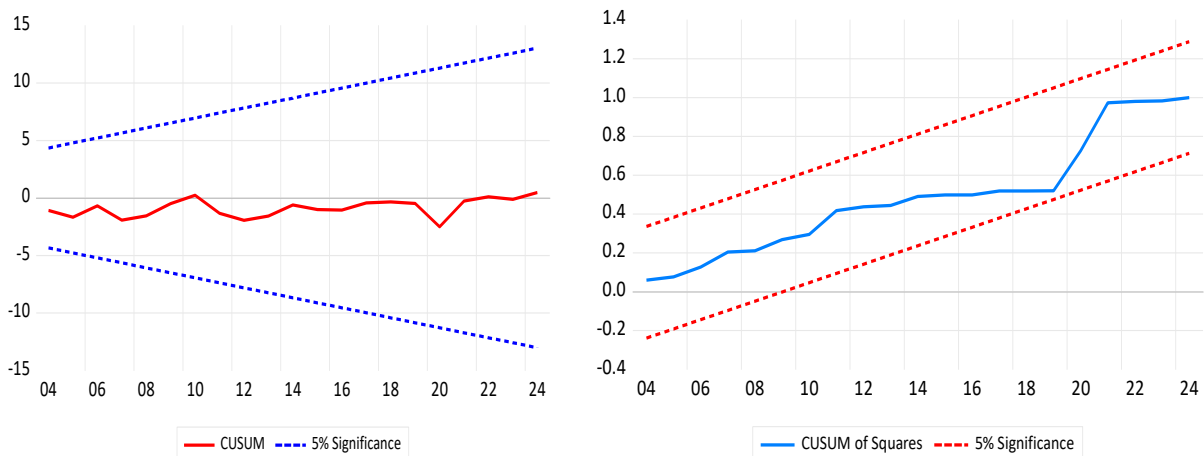


Figure 6: CUSUM and CUSUM of Squared Results

Table 7 presents the residual diagnostic tests used to evaluate the reliability and adequacy of the Dynamic ARDL model. The tests include the ARCH LM, Breusch-Godfrey LM, Ramsey RESET, and Jarque-Bera normality tests. The decision rule states that probability values greater than 0.05 indicate absence of diagnostic problems and confirm model adequacy and stability. The ARCH LM test produced a probability value of 0.7104, which exceeds 0.05, indicating the absence of heteroskedasticity in the residuals. This suggests that the error variance is constant over time and that the estimated coefficients are reliable. Similarly, the Breusch-Godfrey LM test reported a probability value of 0.4205, confirming the absence of serial correlation and indicating independently distributed residuals.

The Ramsey RESET test yielded a probability value of 0.0956, which is greater than 0.05, indicating that the model is correctly specified and free from functional form misspecification or omitted variable bias. Furthermore, the Jarque-Bera normality test produced a probability value of 0.8366, confirming that the residuals are normally distributed and suitable for valid statistical inference and hypothesis testing. From figure 7, (CUSUM and CUSUM of Squares), the recursive residuals remain within the upper and lower critical boundaries throughout the sample period. This indicates that the estimated parameters are stable and do not suffer from structural instability. The result therefore confirms the reliability and consistency of the Dynamic ARDL estimates over time.

5. Conclusion

This study investigated the relationship between CO₂ emissions, human capital development, gross fixed capital formation, natural resource rent and economic growth in Nigeria from 1981 to 2024 using the Dynamic ARDL approach. The results confirm the existence of a stable long-run relationship among the variables. In particular, the findings show that human capital development and natural resource rent are key drivers of economic growth in Nigeria, while inefficient capital formation significantly hinder growth. CO₂ emissions were found to have only a weak and statistically insignificant effect on economic performance. The study therefore concludes that Nigeria's economic growth is largely driven by human capital improvements and resource-based revenues, rather than physical capital accumulation or environmental pressures. However, inefficiency in capital investment and persistent inflation remain major constraints to sustainable growth

In conclusion, the diagnostic results confirm that the Dynamic ARDL model is stable, properly specified, free from serial correlation and heteroskedasticity, and characterized by normally distributed residuals. Consequently, the estimated results are robust and suitable for policy analysis and interpretation. Based on the findings of this study, the following recommendations are proposed:

1. The fact that CO₂e is not significant does not entail that it is not important in the growth mode. Nigeria can pursue environmental sustainability alongside growth through technology driven production models.
2. Since human capital promotes growth, Governments at all levels should increase investment in education, healthcare, vocational training, and skills acquisition to enhance productivity and long-run economic growth.
3. Government should set up community-level and technology-driven capital project monitory system for communities to monitor and report the quality of capital projects implemented to ensure growth-enhancing outcomes.
4. Government should continue to ensure that natural resource earnings should are efficiently invested in productive sectors such as infrastructure, education, and healthcare rather than recurrent expenditure to achieve steady economic growth.

References

- Azam, M., Khan, A. Q., Abdullah, H. B., & Qureshi, M. E. (2016). The impact of CO₂ emissions on economic growth: evidence from selected higher CO₂ emissions economies. *Environmental Science and Pollution Research*, 23(7), 6376-6389.
- Auty, R. (1993). *Sustaining Development in Mineral Economies: the Resource Curse Thesis*. Routledge, London.
- Bambi, P. D. R., & Pea-Assounga, J. B. B. (2025). Unraveling the interplay of research investment, educational attainment, human capital development, and economic advancement in

- technological innovation: A panel VAR approach. *Education and information technologies*, 30(3), 3309-3341.
- Effiong, M. O., & Panicker, M. (2026). Assessing the nexus of carbon emissions and agricultural growth in Nigeria (2000-2022). *African Journal of Food, Agriculture, Nutrition & Development*, 26(1).
- Ehigiamusoe, K. U., Ramakrishnan, S., Babalola, S. J., Samsurijan, M. S., & Rahmat, S. R. (2024). Analysis of the moderating roles of human and physical capital on the impact of foreign aid on economic growth in Nigeria. *SAGE Open*, 14(1), 21582440241238630.
- Garza-Rodriguez, J., Almeida-Velasco, N., Gonzalez-Morales, S., & Leal-Ornelas, A. P. (2020). The impact of human capital on economic growth: The case of Mexico. *Journal of the Knowledge Economy*, 11(2), 660-675.
- Hidayat, M., Rangkutty, D. M., Ferine, K. F., & Saputra, J. (2024). The Influence of Natural Resources, Energy Consumption, and Renewable Energy on Economic Growth in ASEAN Region Countries. *International Journal of Energy Economics and Policy*, 14(3), 332-338.
- Ishfaq, M., Rasool, A., Asghar, M. M., Karim, S., & Ahmad, R. (2024). Impact of Natural, Physical and Human Capital Formation on Economic Growth in Pakistan: An ARDL Analysis. *Journal of Asian Development Studies*, 13(3), 222-233.
- Jordan, S., & Philips, A. Q. (2018). Dynamic simulation and testing for single-equation cointegration models. *The R Journal*, 10(2), 248–276.
- Khan, Z., Hossain, M. R., Badeeb, R. A., & Zhang, C. (2023). Aggregate and disaggregate impact of natural resources on economic performance: role of green growth and human capital. *Resources Policy*, 80, 103103.
- Lucas, R. E. (1988). On the mechanics of economic development. *Journal of Monetary Economics*, 22(1), 3–42.
- Ma, L., Gan, Y., & Huang, P. (2025). Higher education investment, human capital, and high-quality economic development. *Finance Research Letters*, 71, 106419.
- Matousek, R., & Tzeremes, N. G. (2021). The asymmetric impact of human capital on economic growth. *Empirical Economics*, 60(3), 1309-1334.
- Meziane, S., & Brahim, B. (2026). Aggregate and disaggregate natural resources impacts on environmental sustainability: An Asymmetric NARDL analysis. *Resources Policy*, 113, 105830.
- Otim, J., & Mutumba, G. S. (2025). Carbon emissions, economic governance and economic growth. *Next Research*, 2(2), 100200.
- Okoh, J. I., Oyeranmi, A. O., Adamu, M. A., & Agbadua, O. B. (2022). Human Capital Development and Manufacturing Sector Performance in Nigeria.

- Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics*, 16(3), 289–326.
- Pomi, S. S., Sarkar, S. M., & Dhar, B. K. (2021). Human or physical capital, which influences sustainable economic growth most? A study on Bangladesh. *Canadian Journal of Business and Information Studies*, 3(5), 101-108.
- Rehman, A., Ma, H., Ozturk, I., & Ulucak, R. (2022). Sustainable development and pollution: the effects of CO2 emission on population growth, food production, economic development, and energy consumption in Pakistan. *Environmental Science and Pollution Research*, 29(12), 17319-17330.
- Romer, P. M. (1990). Endogenous technological change. *Journal of Political Economy*, 98(5, Part 2), S71–S102.
- Sachs, J. D., & Warner, A. M. (1995). Natural resource abundance and economic growth. *NBER Working Paper No. 5398*.
- Shahbaz, M., Song, M., Ahmad, S., & Vo, X. V. (2022). Does economic growth stimulate energy consumption? The role of human capital and R&D expenditures in China. *Energy Economics*, 105, 105662.
- Singh, Sanjeet, Gagan Deep Sharma, Magdalena Radulescu, Daniel Balsalobre-Lorente, and Pooja Bansal. "Do natural resources impact economic growth: An investigation of P5+ 1 countries under sustainable management." *Geoscience Frontiers* 15, no. 3 (2024): 101595.
- Tabash, M. I., Mesagan, E. P., & Farooq, U. (2022). Dynamic linkage between natural resources, economic complexity, and economic growth: Empirical evidence from Africa. *Resources Policy*, 78, 102865.
- Uddin, M. R., Sadik, N., & Rahman, M. M. (2025). Globalization, physical capital, and human capital nexus with economic growth: evidence from BIMSTEC. *Research in Globalization*, 10, 100284.
- Wasti, S. K. A., & Zaidi, S. W. (2020). An empirical investigation between CO2 emission, energy consumption, trade liberalization and economic growth: A case of Kuwait. *Journal of Building Engineering*, 28, 101104.
- Wegari, H. L., Whakeshum, S. T., & Mulatu, N. T. (2023). Human capital and its impact on Ethiopian economic growth: ARDL approach to co-integration. *Cogent Economics & Finance*, 11(1), 2186046.