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Climate Change and Fiscal Policy in Nigeria: Asymmetric Long-Run Evidence from Nonlinear ARDL and Structural Break Tests (1981–2023)

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Abstract
Using annual Nigerian data (1981–2023), this study examines the long-run and short-run nexus between climate change and fiscal policy, with climate change proxied by per-capita carbon dioxide emissions excluding land-use change (World Development Indicators) and fiscal policy proxied by the general government consumption share of GDP and net taxes on products (Central Bank of Nigeria Statistical Bulletin). Given the presence of structural change in Nigeria's macro-fiscal environment, we combine break-robust unit-root testing (Zivot–Andrews) with the autoregressive distributed lag (ARDL) bounds approach to cointegration and a nonlinear ARDL (NARDL) specification that allows asymmetric fiscal shocks. Unit-root tests indicate that the variables are integrated of order one, and bounds tests strongly support cointegration. In the baseline ARDL, the estimated error-correction term is negative and statistically significant (–1.264), implying rapid adjustment to the long-run equilibrium after shocks. Long-run elasticities suggest that a higher government consumption share is associated with lower emissions. In contrast, a higher net-tax share is associated with higher emissions, consistent with Nigeria's oil-linked tax base and the weak environmental content of most taxes. The NARDL results reveal important asymmetry: positive fiscal expansions (increases in the government consumption share) significantly reduce emissions in the long run, while fiscal contractions have smaller and statistically weaker effects. Dynamic multipliers confirm convergence to the estimated long-run effects within a decade. Robustness checks using dynamic ordinary least squares support the emissions-reducing role of government spending. The findings underscore the need to re-orient fiscal policy toward climate-compatible public spending, remove distortionary fossil-fuel subsidies, and mainstream climate risks into Nigeria's medium-term fiscal framework.

Keywords: Nigeria; climate change; fiscal policy; CO2 emissions; ARDL; nonlinear ARDL; structural breaks; CBN Statistical Bulletin; World Development Indicators.

1. Introduction

Nigeria simultaneously confronts two interlocking policy challenges: a rising exposure to climate-related shocks (floods, heat stress, drought and coastal erosion) and persistent macro-fiscal constraints tied to a narrow, oil-dependent revenue base. Climate change is not only an environmental concern; it is a macro-fiscal phenomenon that reshapes growth, inflation, public investment needs, and the sovereign risk premium, while also altering the tax base and expenditure pressures through disaster response, adaptation, and social protection (IPCC, 2022; Stern, 2006). Conversely, fiscal policy—through taxes, spending composition, and subsidy regimes which affect greenhouse-gas emissions, energy use, and the speed of structural transformation that ultimately determines Nigeria's long-run emissions path (Pigou, 1920; Andersson, 2019).

The climate–fiscal nexus is particularly salient for Nigeria for three reasons. First, Nigeria's infrastructure gap and rapid urbanization increase the marginal fiscal cost of climate resilience: roads, drainage systems, power generation and coastal protection require large, sustained public outlays. Second, fiscal space is constrained by volatile hydrocarbon revenues and recurrent expenditure pressures, making it difficult to finance adaptation without crowding out growth-enhancing investment. Third, the structure of Nigeria's tax system and energy pricing, which historically include large fossil-fuel subsidies, can unintentionally lock the economy into high-emissions technologies while also creating contingent liabilities when subsidy regimes become fiscally unsustainable.

Despite the policy importance, empirical evidence on the climate–fiscal linkage in Nigeria remains fragmented. Much of the Nigerian empirical literature treats climate change narrowly as an emissions-growth relationship, often within the environmental Kuznets curve (EKC) tradition, while fiscal variables enter only as controls or are captured by aggregate government spending without distinguishing the direction and sign of fiscal shocks. At the same time, cross-country fiscal-risk studies emphasize natural disasters and debt dynamics, but seldom provide Nigeria-specific evidence on how routine fiscal stance variables relate to the country's emissions trajectory or how asymmetries matter in the presence of structural change (Noy & Nualsri, 2011).

This paper contributes to closing these gaps by examining the relationship between climate change and fiscal policy in Nigeria using annual data (1981–2023) and advanced time-series econometric techniques designed for small samples and structural change. Climate change is proxied by per-capita CO_2 emissions excluding land-use change, consistent with a large empirical literature that uses emissions as an operational measure of climate pressure and mitigation performance. Fiscal policy is proxied by (i) the general government consumption share of GDP (a national-accounts-based measure of current public spending) and (ii) net taxes on products as a share of GDP (a broad measure of indirect taxation embedded in national accounts). These measures, sourced from the Central Bank of Nigeria's Statistical Bulletin and the World Development Indicators, have two practical advantages: they are consistently measured over a long horizon, and they capture the fiscal stance in a way that is less affected by definitional changes in budget classification.

Methodologically, we combine three layers of inference. First, we establish the time-series properties of the variables using augmented Dickey–Fuller (ADF), Kwiatkowski–Phillips–Schmidt–Shin (KPSS), and Zivot–Andrew's break-robust unit-root tests (Zivot & Andrews, 1992). Second, we test for long-run relationships using the ARDL bounds approach of Pesaran, Shin, and Smith (2001), which is appropriate when regressors are a mixture of I(0) and I(1) and when sample sizes are moderate. Third, to capture potentially different effects of fiscal expansions and fiscal contractions—an empirically plausible feature in Nigeria given episodes of pro-cyclical consolidation and expenditure surges, we estimate a nonlinear ARDL (NARDL) model that decomposes fiscal stance changes into positive and negative partial sums (Shin, Yu, & Greenwood-Nimmo, 2014).

The empirical results are policy-relevant. We find robust evidence of cointegration between emissions, fiscal stance, and economic activity. In the baseline ARDL, the error-correction term is negative and strongly significant, indicating that short-run deviations from the long-run relationship are corrected quickly. Long-run coefficients imply that a higher government consumption share of GDP is associated with lower emissions per capita, whereas a higher net-tax share is associated with higher emissions. The NARDL specification reveals asymmetry: fiscal expansions (increases in the government consumption share) have an emissions-reducing long-run effect, while fiscal contractions have smaller and statistically weaker effects. These findings suggest that the composition and direction of fiscal adjustments matter for Nigeria's climate outcomes.

The remainder of the paper proceeds as follows. Section 2 reviews the conceptual, theoretical and empirical literature. Section 3 presents the data and econometric methodology. Section 4 reports the empirical findings, including robustness checks and dynamic multipliers. Section 5 concludes, and Section 6 provides policy recommendations.

2. Literature Review

2.1 Conceptual Review

Conceptually, climate change refers to long-run shifts in temperature, precipitation patterns, sea level, and the frequency or intensity of extreme events, largely driven by anthropogenic greenhouse-gas (GHG) emissions (IPCC, 2021, 2022). In applied macroeconomic research, climate change is operationalized through either (i) emissions-based measures (e.g., CO2 per capita), which capture mitigation performance and the carbon intensity of production and consumption, or (ii) physical-risk measures (e.g., temperature anomalies, rainfall variability or disaster indicators), which capture exposure and damage channels. Emissions and physical risks are linked: cumulative global emissions determine the trajectory of physical risks, while local mitigation and adaptation determine how those risks translate into welfare and fiscal outcomes.

Fiscal policy comprises government decisions on taxation, public spending, transfers and debt management, typically with the dual objectives of macroeconomic stabilization and resource allocation. Climate change interacts with fiscal policy through at least four channels. First, the 'damage channel' increases fiscal pressures by raising the cost of maintaining infrastructure and providing public services after climate shocks. Second, the 'adaptation channel' requires upfront public investment (e.g., resilient roads, flood control) and recurring expenditure (e.g., early warning systems), which can widen deficits if not financed sustainably. Third, the 'tax-base channel' changes sectoral output and consumption patterns, affecting revenue from commodities, VAT and corporate taxes. Fourth, the 'transition channel' reflects the fiscal implications of decarbonization policies such as carbon pricing, subsidy reform, and green public investment, which may alter energy prices, distributional outcomes, and competitiveness.

In Nigeria, these channels operate within a context of oil dependence and recurring fiscal fragility. Oil-related revenues and foreign exchange earnings have historically shaped fiscal cycles, while subsidy reforms and exchange-rate adjustments have repeatedly altered the distributional and inflationary environment. Climate change adds a new layer of fiscal risk by increasing the expected frequency of floods in riverine and coastal areas and by affecting agricultural productivity in the north through heat and water stress. Because fiscal resources are constrained, the design of climate-compatible fiscal policy in Nigeria is not simply a matter of choosing a mitigation instrument; it is also about aligning climate objectives with debt sustainability and social protection.

A growing policy literature emphasizes 'green fiscal policy'—the use of fiscal instruments to reduce emissions and support adaptation while maintaining macro-fiscal sustainability. Instruments include carbon taxes or emissions charges, removal of fossil-fuel subsidies, feebates, targeted public investment in clean infrastructure, and climate-sensitive budgeting practices that incorporate physical and transition risks into medium-term fiscal frameworks (IMF, 2019; World Bank, 2022). The core conceptual challenge is that climate policy often entails short-run fiscal and distributional trade-offs (e.g., higher energy prices), while the benefits (lower damages, improved health, technological progress) accrue in the long run. Therefore, empirical analysis that clarifies the direction, magnitude, and asymmetry of climate–fiscal relationships is valuable for policy design.

2.2 Theoretical Review

The theoretical foundations of the climate–fiscal nexus begin with the economics of externalities. Greenhouse-gas emissions impose social costs that are not fully reflected in market prices; the Pigouvian solution is to internalize the marginal external damage through corrective taxation or regulation (Pigou, 1920). In this framework, a carbon tax equal to the social cost of carbon induces firms and households to reduce emissions where abatement costs are lowest. When implemented effectively, carbon pricing can achieve emissions reductions at lower welfare cost than many command-and-control policies, and it can generate revenue that may be recycled to reduce distortionary taxes or finance social transfers.

A second theoretical lens is the environmental Kuznets curve (EKC), which posits an inverted-U relationship between environmental degradation and income: at early stages of development, emissions rise with income due to industrialization and energy use; at higher income levels, structural change, cleaner technologies, and stronger institutions reduce emissions (Grossman & Krueger, 1995; Dinda, 2004). Although the EKC is not a universal law, it motivates empirical models that incorporate scale effects (economic activity), composition effects (sectoral change), and technique effects (technology and regulation). Fiscal policy can influence each channel: public investment in clean energy affects technique, taxes and subsidies influence the composition of production, and countercyclical spending affects scale.

A third lens focuses on macro-fiscal dynamics and stabilization. In Keynesian frameworks, government spending and taxation affect aggregate demand, output and employment in the short run. Over the medium term, the composition of spending shapes productivity and private investment. If fiscal expansions finance resilient infrastructure, they may reduce climate-related damages and future fiscal pressures. Conversely, if spending is directed toward energy-intensive projects without environmental safeguards, it may raise emissions. Theoretical ambiguity, therefore, motivates empirical estimation rather than reliance on sign predictions.

Climate-related fiscal risks can also be studied within sovereign debt sustainability frameworks. Climate shocks act as stochastic disturbances to output and the tax base, while also raising expenditure needs. When shocks are persistent (e.g., long-run temperature increases) or when adaptation needs are large, debt dynamics can worsen unless fiscal policy adjusts or concessional financing expands. This perspective links climate risk to fiscal reaction functions and highlights the importance of fiscal space, credibility, and the cost of borrowing.

Finally, nonlinearities and asymmetries are theoretically plausible in the climate–fiscal relationship. Fiscal expansions and contractions may not be symmetric because (i) budget rigidities make expenditure cuts different from spending increases, (ii) mitigation investments may only occur during expansions, and (iii) political economy constraints can create threshold effects. To capture such features in small-sample time series, Shin et al. (2014) extend the ARDL framework by decomposing regressors into positive and negative partial sums, enabling separate long-run and short-run effects. This nonlinear ARDL (NARDL) approach aligns with Nigeria's experience of episodic fiscal consolidations, oil-driven spending cycles, and policy regime changes, and therefore provides a suitable econometric representation for the present study.

2.3 Empirical Review

The empirical literature on climate change and fiscal policy spans several interconnected research streams, including the macroeconomic impacts of climate-related disasters, the relationship between economic growth and carbon emissions, and the effectiveness of fiscal instruments in environmental management. This review synthesises findings from cross-country comparative studies, country-specific analyses, and policy evaluation research to establish the theoretical and empirical foundation for examining climate change and fiscal policy in Nigeria.

Early cross-country evidence established that the relationship between natural disasters and economic growth varies systematically with institutional quality and development levels. Skidmore and Toya (2002) employed panel regression techniques across countries to demonstrate that the disasters-growth nexus is conditional on institutional characteristics, a finding reinforced by Toya and Skidmore (2007), who showed through cross-sectional, and panel analyses that higher levels of development and stronger institutions significantly reduce the adverse impacts of disasters. Noy (2009) extended this line of inquiry by focusing specifically on developing countries, finding that disasters reduce economic output, and that governance quality plays a crucial role in shaping resilience outcomes.

The fiscal dimensions of climate shocks have received substantial attention in the literature. Lis and Nickel (2010) analysed European data using panel fiscal regressions and found that extreme weather events significantly worsen budget balances. Melecky and Raddatz (2011) broadened this analysis globally, demonstrating through panel estimation that disasters weaken fiscal stance, particularly in poorer states where fiscal buffers are limited. Noy and Nualsri (2011) decomposed these fiscal effects for developing countries, documenting that government spending typically rises while revenues fall in the aftermath of disasters, creating a dual pressure on fiscal balances. Becerra et al. (2014) examined the international response to these fiscal pressures, finding that while aid flows respond to disaster shocks, they do not fully offset the economic and fiscal losses experienced by affected countries.

Research on the persistence and magnitude of disaster impacts has yielded nuanced findings. Cavallo et al. (2013) employed synthetic control methods to demonstrate that only very large disasters produce persistent negative effects on GDP, suggesting that smaller events may be absorbed without long-term consequences. However, Fomby et al. (2013) showed through panel event studies that disaster impacts are highly heterogeneous and depend critically on disaster type. Hsiang and Jina (2014) provided evidence that cyclones reduce long-run income levels, indicating that certain disaster types produce lasting economic damage that extends well beyond the immediate shock period.

A distinct but related literature has examined the direct relationship between temperature variation, climate change, and economic outcomes. Dell et al. (2012) used panel methods to analyse temperature shocks globally, finding that higher temperatures significantly reduce economic growth in poor countries but have minimal effects in wealthy nations. Burke et al. (2015) advanced this research by documenting nonlinear temperature-growth relationships, demonstrating that the damages from warming are not proportional but instead accelerate at higher temperature levels. Kahn et al. (2019) synthesised cross-country panel evidence showing that warming lowers long-run growth prospects, with effects that compound over time and disproportionately affect countries in warmer climates that already face development challenges.

Substantial empirical work has explored the determinants of carbon emissions within the environmental Kuznets curve (EKC) framework and related approaches. Time-series cointegration studies of individual countries have established foundational relationships between economic activity, energy use, and emissions. Ang (2007) demonstrated for France that energy consumption and economic output are primary drivers of CO2 emissions, a pattern Ang (2008) replicated for Malaysia using similar cointegration techniques. Jalil and Mahmud (2009) found evidence supporting the EKC hypothesis in China, suggesting that emissions initially rise with development before eventually declining. Shahbaz et al. (2012) employed autoregressive distributed lag (ARDL) and causality analysis for Pakistan, confirming that energy consumption drives CO2 emissions and that policy interventions can influence the EKC relationship.

Panel cointegration studies spanning multiple countries have generally confirmed these relationships across broader samples. Apergis and Payne (2010) documented cointegration among energy consumption, economic growth, and CO2 emissions in Commonwealth of Independent States countries. Narayan and Narayan (2010) found similar cointegration relationships in a panel of developing countries, while Pao and Tsai (2010) showed that energy consumption is the dominant driver of CO2 emissions in BRIC countries (Brazil, Russia, India, and China).

For Nigeria specifically, recent studies have examined the determinants of carbon emissions using various econometric approaches. Zubair et al. (2020) employed ARDL and vector autoregression (VAR) models to establish relationships among income, trade, foreign direct investment, and CO2 emissions in Nigeria. Odugbesan and Adebayo (2020) advanced this analysis by applying both symmetric and asymmetric models, revealing that key economic and policy drivers affect Nigeria's CO2 emissions asymmetrically, with increases and decreases in explanatory variables producing different magnitudes of impact on emissions.

Empirical evaluations of fiscal policy interventions for environmental management have produced evidence of effectiveness across multiple contexts, though outcomes depend on policy design and institutional factors. Lin and Li (2011) analysed Nordic countries using panel econometric methods and found that carbon taxes significantly reduce CO2 emissions. Martin et al. (2014) employed micro-econometric techniques to show that carbon taxation reduces emissions intensity in European manufacturing sectors. Andersson (2019) used difference-in-differences estimation to demonstrate that Sweden's carbon tax successfully reduced transport sector emissions. Best et al. (2020) synthesised panel evidence from high-income economies, concluding that carbon pricing mechanisms lower emissions growth rates. Bayer and Aklin (2020) applied synthetic control methods to European Union Emissions Trading System (EU ETS) countries, finding that the EU ETS reduced CO2 emissions despite relatively low carbon prices during the study period.

The effectiveness of broader government spending on environmental outcomes has been shown to depend critically on governance quality and spending composition. López et al. (2011) demonstrated through cross-country panel analysis that government spending improves environmental outcomes primarily when governance is strong, suggesting that institutional quality mediates the environmental impacts of fiscal policy. Halkos and Paizanos (2013) refined this understanding for OECD countries by showing that the environmental effects of public spending depend significantly on the composition of expenditures rather than merely aggregate spending levels. Fredriksson and Millimet (2002) examined the political economy of environmental policy in the United States, revealing that political incentives and strategic interactions shape environmental policy adoption and stringency.

The literature collectively establishes that climate change and natural disasters impose high macroeconomic and fiscal costs, particularly in developing countries with limited institutional capacity and fiscal buffers. Economic growth and energy consumption are reliably linked to carbon emissions, though these relationships may exhibit nonlinearities and asymmetries. Fiscal policy instruments, particularly carbon pricing and strategically allocated public spending, can effectively mitigate emissions when implemented within supportive institutional environments. However, significant gaps remain in understanding these dynamics in the Nigerian context, where institutional challenges, dependence on fossil fuel revenues, and vulnerability to climate shocks create a distinctive policy environment that warrants targeted empirical investigation.

Empirical research on the climate–fiscal nexus can be grouped into three complementary strands. The first examines how climate-related shocks and disasters affect macroeconomic and fiscal outcomes such as public spending, revenue, and debt. The second evaluates how fiscal instruments—especially carbon pricing and expenditure composition—affect emissions. The third focuses on country-specific determinants of emissions, including Nigeria, and provides evidence on nonlinearities and policy interactions.

A consistent finding is that disasters and extreme events tend to weaken fiscal balances by simultaneously raising expenditures (relief, reconstruction, social spending) and eroding revenues through output losses. Using cross-country evidence, Skidmore and Toya (2002) and Toya and

Skidmore (2007) highlight the role of development and institutions in reducing damages, implying that fiscal exposure is not purely climatic but also institutional. Noy (2009) documents sizable macroeconomic losses from disasters in developing countries, with resilience shaped by governance and openness. Focusing more directly on fiscal aggregates, Lis and Nickel (2010) find that extreme weather events can worsen budget balances. Melecky and Raddatz (2011) show that disasters can deteriorate fiscal stances, especially where insurance markets are thin. Noy and Nualsri (2011) provide evidence that the fiscal effects of disasters can be persistent—an important result for debt sustainability.

Beyond disasters, a second set of studies links temperature and climate variability to macroeconomic performance, which in turn affects fiscal capacity. Dell et al. (2012) find that higher temperatures reduce growth in poorer countries, implying medium-term erosion of the tax base. Burke et al. (2015) show nonlinear temperature damages to output, suggesting that fiscal risks rise more than proportionally with warming. Hsiang and Jina (2014) and Kahn et al. (2019) highlight persistent income effects of climate shocks and warming, supporting the view that climate change is a long-horizon fiscal issue. These macro findings complement disaster studies by emphasizing that even in the absence of headline events, gradual climate change can weaken the revenue base.

Fiscal policy instruments and emissions. A large empirical literature evaluates whether fiscal instruments can reduce emissions. Carbon pricing has received the most rigorous causal evaluation. Lin and Li (2011) find that carbon taxes in the Nordic countries reduce per-capita emissions, though effect sizes differ by design. Andersson (2019) uses a quasi-experimental design to show that Sweden's carbon tax significantly reduced transport emissions. Complementary evidence indicates that cap-and-trade can also deliver reductions: Bayer and Aklin (2020) find that the EU Emissions Trading System reduced emissions even during periods of low prices, which they attribute to expectations and complementary policies. At the micro level, Martin et al. (2014) provide evidence that carbon taxation influences manufacturing emissions intensity. Cross-country evidence also suggests that carbon pricing is more effective when policy is broad-based and stringent (Best et al., 2020).

A second empirical theme emphasizes spending composition and institutions. Halkos and Paizanos (2013) show that the environmental effect of government expenditure depends on what governments spend on, with productive or environmentally oriented spending more likely to improve environmental outcomes. López et al. (2011) argue that governance quality mediates the link between fiscal spending and environmental quality; in low-governance settings, additional spending may not translate into better environmental outcomes. Political-economy evidence also suggests that fiscal incentives and government structure shape environmental regulation (Fredriksson & Millimet, 2002).

Nigeria and emissions determinants. Nigeria-focused studies typically examine emissions determinants using cointegration and causality methods. Zubair et al. (2020) apply ARDL and VAR approaches and highlight the roles of economic activity and energy-related factors in Nigeria's emissions dynamics. Odugbesan and Adebayo (2020) show that symmetric models may miss important nonlinearities, finding asymmetric effects of key drivers on emissions. More broadly, a large time-series and panel literature links emissions to energy use and income across countries (Ang, 2007, 2008; Jalil & Mahmud, 2009; Narayan & Narayan, 2010; Pao & Tsai, 2010), underscoring that fiscal policy can affect emissions indirectly through energy pricing, investment and structural change.

3. Methodology

3.1 Data and Variable Definitions

We employ annual time-series data for Nigeria covering 1981–2023. Fiscal variables were obtained from the Central Bank of Nigeria (CBN) Statistical Bulletin. The two fiscal-stance indicators were selected: government final consumption expenditure as a share of GDP, and net taxes on products as a share of GDP, both at current market prices. These variables served as proxies for the spending and revenue components of fiscal policy. Real gross domestic product (GDP) at 2010 constant prices is obtained from the CBN Statistical Bulletin and included as a control for the overall scale of economic activity. The climate variable is per-capita CO_2 emissions (excluding land-use change, in metric tons CO_2 per capita), obtained from the World Bank's World Development Indicators (WDI).

3.2 Econometric Model and Estimation Strategy

We begin by examining the time-series properties of each variable using unit-root tests. In particular, we apply the augmented Dickey–Fuller (ADF) test (Dickey and Fuller 1979) and the KPSS test (Kwiatkowski et al. 1992). To account for potential structural breaks, we also use the Zivot–Andrews' test (Zivot and Andrews 1992), which endogenously identifies a single break in the intercept or trend. Having confirmed that none of the variables is integrated of order two (I(2)), we proceed with the ARDL bounds-testing approach to cointegration (Pesaran et al. 2001).

The baseline conditional ARDL model is specified as:

$$\ln CO2_t = \alpha_0 + \sum_{i=1}^{p} \phi_i \ln CO2_{t-i} + \sum_{j=0}^{q_1} \beta_j \ln RGDP_{t-j} + \sum_{j=0}^{q_2} \gamma_j \ln GOV_{t-j} + \sum_{j=0}^{q_3} \delta_j \ln TAX_{t-j} + \varepsilon_t,$$

Lag orders were selected by the Akaike information criterion (AIC), with a maximum lag of four given the annual frequency and sample size. Following Pesaran *et al.* (2001), we re-parameterize equation (1) as an unrestricted error-correction model (UECM) and perform an F-test on the joint significance of the lagged level variables to test for cointegration.

To allow for asymmetric fiscal effects, we adopt the nonlinear ARDL (NARDL) specification of Shin *et al.* (2014). We decompose changes in ln(GOV) into positive and negative cumulative sums:

$$\ln GOV_t^{+} = \sum_{k=1}^{t} \max(\Delta \ln GOV_k, 0), \quad \ln GOV_t^{-} = \sum_{k=1}^{t} \min(\Delta \ln GOV_k, 0).$$

The NARDL model replaces ln{GOV} in equation (1) with $\ln GOV^{+}$ and $\ln GOV-$ allowing separate long-run and short-run coefficients for fiscal expansions (positive changes in GOV) and fiscal contractions (negative changes). We test for long-run asymmetry via a Wald test. After estimation, we carry out diagnostic tests to validate the model:

- **Serial correlation:** Ljung–Box Q-test on the residuals.
- **Heteroskedasticity:** Breusch–Pagan test.
- **Normality:** Jarque–Bera test.
- **Stability:** CUSUM and CUSUMSQ tests.

As a robustness check, we estimate dynamic ordinary least squares (DOLS) following Stock and Watson (1993). The DOLS regression includes leads and lags of the first differences of the regressors and is estimated with heteroskedasticity-and autocorrelation-consistent (HAC) standard errors to address potential endogeneity and serial correlation.

4. Empirical Findings

4.1 Descriptive Statistics

Descriptive statistics. Table 2 reports summary statistics for the main variables. Average per-capita CO2 emissions are low in levels (mean ≈ 0.72 tCO2e per capita), reflecting Nigeria's relatively low industrial emissions per person over much of the sample, though with notable variation. The government consumption share of GDP averages 3.91%, and net taxes on products average 1.09% of GDP. Real GDP (2010 constant prices) displays strong growth over the sample, consistent with structural transformation and population growth.

Table 2. Descriptive statistics

Variable	Mean	Std	Min	max
co2_pc	0.720	0.125	0.499	0.964
gov_gdp	3.913	2.820	0.911	9.448
tax_gdp	1.086	0.189	0.981	1.925
Rgdp	39902.538	21651.617	16211.491	77936.100

4.2 Unit-Root and Structural Break Tests

Stationarity and structural breaks. Table 3 summarizes ADF and KPSS tests. For all variables in levels, the ADF fails to reject a unit root at conventional levels, while the KPSS rejects stationarity, implying non-stationarity. In first differences, the ADF strongly rejects a unit root and KPSS fails to reject stationarity, indicating that the variables are integrated of order one, I(1). Zivot–Andrews tests (Table 4) identify statistically meaningful breaks for lnCO2 and lnGOV, consistent with major policy and structural changes in Nigeria (e.g., the early-2000s reform period and changes in oil-sector dynamics). These findings justify using cointegration methods that accommodate structural change.

Table 3. Unit-root tests (ADF and KPSS)

Variable	ADF stat	ADF p	KPSS stat	KPSS p
('ln_CO_2_pc', 'Level')	-1.627	0.469	0.858	0.010
('ln_CO_2_pc', 'First diff')	-3.667	0.005	0.268	0.100
('ln_gov_gdp', 'Level')	-1.505	0.531	0.653	0.018
('ln_gov_gdp', 'First diff')	-6.770	0.000	0.098	0.100
('ln_tax_gdp', 'Level')	1.995	0.999	0.754	0.010
('ln_tax_gdp', 'First diff')	-8.228	0.000	0.304	0.100
('ln_rgdp', 'Level')	-0.792	0.821	0.926	0.010
('ln_rgdp', 'First diff')	-4.102	0.001	0.270	0.100

Table 4. Zivot–Andrews unit-root test with one endogenous break (intercept model)

Variable	ZA stat	ZA p	Break year	Selected lag
ln_CO_2_pc	-4.998	0.029	2005.000	0.000
ln_gov_gdp	-7.068	0.000	2003.000	0.000
ln_tax_gdp	-2.498	0.985	2009.000	3.000
ln_rgdp	-3.248	0.819	2001.000	2.000

4.3 Cointegration and Long-Run Estimates

Cointegration (ARDL bounds test). Using an ARDL specification with lags selected by AIC (maximum four), the Pesaran et al. (2001) bounds test strongly rejects the null of no long-run relationship. The computed F-statistic is 8.194, exceeding the 1% upper-bound critical value (Table 5). The associated upper-bound p-value is 0.00004. We therefore conclude that lnCO2, fiscal stance, and economic activity are cointegrated over 1981–2023.

Table 5. ARDL bounds test for cointegration (Case 3: unrestricted intercept, no trend)

Variable	F-statistic	p-value (upper)	I(0) 10%	I(1) 10%	I(0) 5%	I(1) 5%	I(0) 1%	I(1) 1%
Bounds test	8.194	0.000	2.457	3.516	2.877	4.010	3.780	5.050

Baseline ARDL long-run relationship. Table 6 reports long-run elasticities from the cointegrated ARDL. The long-run elasticity of emissions with respect to the government consumption share is negative and statistically significant (-0.124, p=0.000), implying that increases in the government consumption share are associated with lower per-capita emissions. The long-run coefficient on net taxes on products is positive and significant (0.594, p<0.001), suggesting that Nigeria's tax base—strongly linked to product taxes and oil-related activity—may be associated with higher emissions rather than discouraging them. The long-run coefficient on real GDP is negative (-0.185, p<0.001); this pattern is consistent with decoupling in per-capita emissions during periods when real output grows, but energy use per capita grows more slowly, and it reinforces the value of controlling for structural change and fiscal composition.

Table 6. Long-run elasticities from baseline ARDL

Variable	Long-run coef	Std. error	z	P
ln_rgdp	-0.185	0.038	-4.823	0.000
ln_gov_gdp	-0.124	0.021	-5.958	0.000
ln_tax_gdp	0.594	0.214	2.774	0.006

Error-correction dynamics and diagnostics. The estimated error-correction term (ECT) is -1.264 ($p<0.001$), indicating strong mean reversion: deviations from the long-run equilibrium are corrected rapidly in subsequent periods. Diagnostic tests (Table 8) indicate no evidence of residual autocorrelation (Ljung–Box), heteroskedasticity (Breusch–Pagan), or instability (CUSUM). Overall, the baseline model appears well specified for inference.

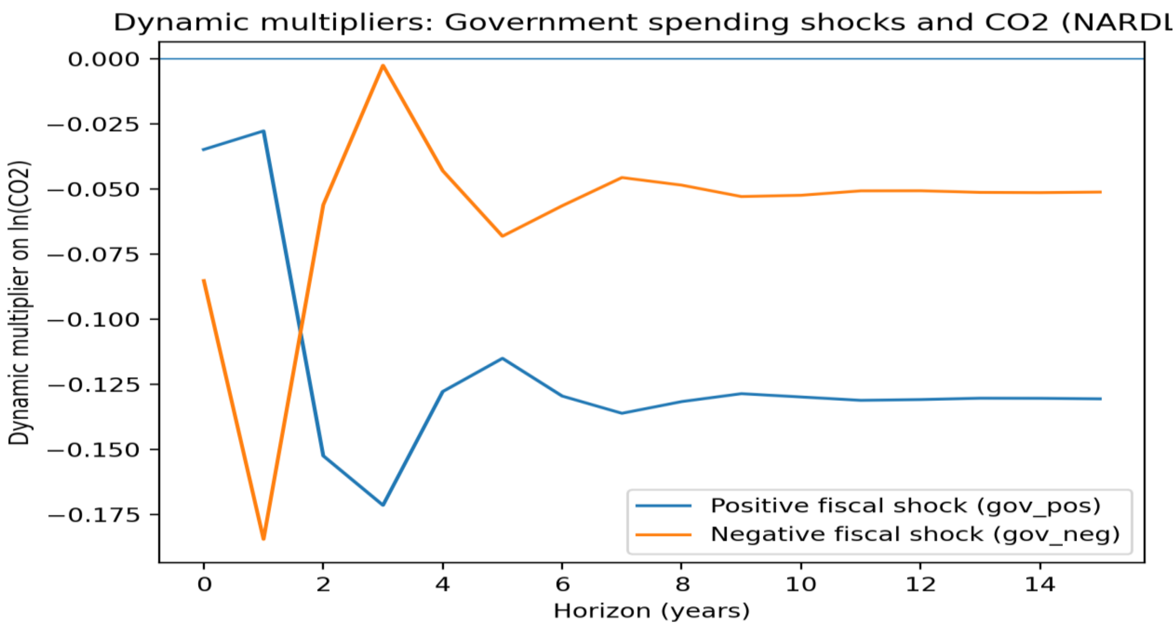
Table 7. Long-run effects from NARDL (asymmetric government spending)

Variable	Long-run coef	Std. error	z	p
ln_rgdp	-0.020	0.120	-0.167	0.867
gov_pos	-0.130	0.029	-4.476	0.000
gov_neg	-0.051	0.037	-1.400	0.162
ln_tax_gdp	0.510	0.210	2.428	0.015

4.4 Dynamic Multipliers and Robustness

Nonlinear ARDL and fiscal asymmetry. Table 7 reports NARDL long-run coefficients after decomposing fiscal stance into positive and negative changes in lnGOV. Positive fiscal shocks (fiscal expansions) have a statistically significant emissions-reducing effect (-0.130, p=0.000), while the effect of negative fiscal shocks is smaller in magnitude and not statistically significant at conventional levels (-0.051, p=0.162). This suggests that the climate implications of fiscal policy in Nigeria are asymmetric: expansions can facilitate cleaner outcomes—potentially through public provision of infrastructure, regulation or energy services—whereas contractions do not generate commensurate emissions reductions. Figure 1 plots dynamic multipliers, showing that the impact of a positive fiscal shock converges to its long-run effect within roughly a decade.

Figure 1. Dynamic multipliers of positive vs negative government spending shocks on ln(CO2) (NARDL)



Robustness (DOLS). As a robustness check, DOLS estimates with HAC standard errors confirm the negative long-run relationship between the government consumption share and emissions. The DOLS elasticity on lnGOV is –0.104 ($p<0.001$), close to the ARDL magnitude. The tax coefficient is negative but statistically insignificant in DOLS, indicating that the tax–emissions relationship is sensitive to specification and dynamic structure. Taken together, robustness results strengthen confidence in the central finding that fiscal expansions (as proxied by the government consumption share) are associated with lower long-run emissions in Nigeria.

Table 8. Model diagnostics (baseline ARDL residuals)

Variable	Statistic	p-value
Ljung–Box Q(2)	1.460	0.482
Breusch–Pagan	3.953	0.984
Jarque–Bera	4.761	0.093
CUSUM (OLS residuals)	0.282	1.000

Table 9. Robustness: DOLS long-run coefficients (HAC standard errors)

Variable	coef	std_err	p
ln_rgdp	-0.129	0.039	0.001
ln_gov_gdp	-0.104	0.028	0.000
ln_tax_gdp	-0.105	0.105	0.316

5. Conclusion

This study investigated the relationship between climate change and fiscal policy in Nigeria using annual data for 1981–2023 and a suite of advanced time-series methods. Using per-capita CO2 emissions as a proxy for climate pressure and national-accounts based fiscal stance indicators, we find robust evidence of a long-run cointegrating relationship. The baseline ARDL and the nonlinear ARDL both indicate that government consumption as a share of GDP is negatively associated with emissions in the long run, and that the short-run dynamics adjust rapidly toward the long-run equilibrium.

The nonlinear results further show that fiscal expansions and contractions are not symmetric: increases in the government consumption share have a clearer emissions-reducing long-run effect, whereas fiscal contractions have weaker and statistically less robust effects. This asymmetry is important for policy because it suggests that climate outcomes can improve not only through tighter budgets or reduced demand, but also through the composition and direction of public spending—especially when fiscal expansions are used to finance climate-compatible infrastructure and institutional capacity.

Several caveats apply. Emissions are an imperfect proxy for physical climate damages, and national accounts fiscal proxies do not fully capture climate-specific expenditures or off-budget liabilities. Future work could extend the analysis by integrating physical-risk indicators (temperature and rainfall anomalies, flood events) and by separating ‘green’ from ‘brown’ spending using functional budget classifications. Nevertheless, the results provide evidence that Nigeria’s fiscal stance is meaningfully related to its emissions trajectory, and that nonlinearities matter for inference.

6. Policy Recommendations

The results have practical implications for Nigeria’s climate strategy and fiscal framework. The following recommendations emerge:

1. **Mainstream climate objectives into the medium-term fiscal framework (MTFF).** Incorporate climate spending needs, disaster contingencies and transition risks into fiscal forecasts, with published sensitivity analyses.
2. **Rebalance public spending toward climate-compatible infrastructure.** Prioritize resilient transport, drainage, coastal protection and clean energy; apply climate screening to project appraisal to avoid carbon-intensive lock-in.
3. **Strengthen the 'green content' of taxation.** Shift gradually from reliance on product taxes toward environmental pricing instruments (carbon-equivalent excises, feebates) with transparent revenue recycling to protect vulnerable households.
4. **Accelerate fossil-fuel subsidy reform with compensation.** Pair subsidy removal with targeted transfers and energy-efficiency programs to mitigate distributional impacts while preserving fiscal space for adaptation investment.
5. **Improve institutions and measurement.** Expand climate-tagging of budget items, improve emissions accounting, and strengthen monitoring/enforcement in high-emitting sectors (oil and gas flaring, transport).
6. **Mobilize climate finance without jeopardizing debt sustainability.** Increase concessional financing and results-based grants for adaptation and develop credible green bond frameworks tied to measurable mitigation outcomes.
7. **Build automatic stabilizers for climate shocks.** Enhance social protection systems and develop disaster-risk financing mechanisms (insurance, catastrophe bonds) to reduce ad hoc post-shock fiscal expansions.

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