

TOWARDS ENVIRONMENTAL SUSTAINABILITY: EVALUATING THE ROLE OF ENERGY CONSUMPTION AND URBANIZATION ON CARBON EMISSION IN NIGERIA

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Abstract

Nigeria confronts a substantial challenge in reconciling emancipation with environmental changes amid rapid economic growth and an increasing population. Sequel to this, this study evaluates the role of energy consumption, FDI and urbanization on carbon emission in Nigeria. The data was obtained from World Development Indicators (WDI, 2022), ARDL techniques were employed in analyzing the data. The findings indicate a direct correlation between energy consumption and CO₂ which is statistically significant in both the near and distant future. The enhancement of foreign investment adds to the rise of carbon dioxide emissions in Nigeria. Based on the empirical data of the study, it proposes numerous policy implications regarding energy usage in Nigeria. The Nigerian government must reassess its energy policy to promote renewable energy sources. This may encompass incentives for renewable energy, enhancements in energy efficiency, and a tax or regulatory disincentive against fossil fuel consumption

Keywords: Energy consumption, FDI, Urbanization, Nigeria

INTRODUCTION

Nigeria confronts a substantial challenge in reconciling development with environmental sustainability amid rapid economic growth and an increasing population. Escalating carbon dioxide emissions, driven by increased foreign direct investment (FDI) and energy demands, are exerting mounting pressure on the nation as it strives to position itself as a regional leader in economic innovation. Population growth exacerbates these concerns, necessitating more energy production and resource consumption, often relying on conventional energy sources that contribute to environmental degradation (Salahuddin et al., 2018). Foreign direct investment (FDI) has profoundly influenced Nigeria's economic development by generating employment, enhancing infrastructure, and promoting technological advancement. Nevertheless, the prioritization of short-term financial gains by several investors poses significant environmental risks. Consequently, a conflict seems to exist between environmental sustainability and carbon emissions. Despite the irregular and sluggish nature of progress, integrating energy consumption sources presents a feasible solution to address these challenges (Halliru et al., 2021; Shahbaz et al., 2018). Communities, corporations, and policymakers find it challenging to synchronize initiatives aimed at reducing carbon emissions while ensuring economic stability. The problem is exacerbated by the scarcity of comprehensive assessments that establish a cohesive framework connecting demographic trends, foreign direct investment inflows, carbon emissions, and energy consumption patterns. This study addresses these gaps by employing advanced models, such as ARDL, to

analyse the interactions of these elements from 1990 to 2022. It aims to provide feasible solutions to guide Nigeria towards an inclusive and sustainable future.

An adaptable and evidence-driven strategy is crucial to tackle the issues identified in this research. This study integrates short-term and long-term estimations to reveal dynamic patterns and monitor temporal changes. It delineates essential linkages among population growth, foreign direct investment (FDI), carbon emissions, and energy consumption within Nigeria's distinct socioeconomic and environmental framework. A primary option is to advocate for sector-specific strategies that incorporate energy consumption into Nigeria's energy mix, thus diminishing dependence on fossil fuels and decreasing CO₂ emissions (Adjei-Mantey & Adams, 2023; Ganda, 2022; Gunarto, 2020; Saqib & Dincă, 2024). Policymakers can create incentives for firms to implement cleaner technologies, bolstered by targeted foreign direct investment that emphasizes sustainability.

LITERATURE REVIEW

A study conducted by Munir and Riaz (2020) examined the disaggregation of energy use in relation to environmental deterioration in Australia, China, and the USA, utilizing annual data from 1975 to 2018 and nonlinear ARDL (NARDL) methodology. Results indicated that oil, coal, and natural gas contribute to the long-term increase of carbon dioxide emissions. Khan et al. (2019b) employed the dynamic ARDL bound test to investigate the effects of energy consumption and economic growth on Pakistan's CO₂ emissions from 1965 to 2015. Findings indicate that variations in energy use (oil, coal, and gas) and economic development positively influence environmental deterioration in Pakistan, both temporarily and permanently.

The utilization of energy substantially impacts carbon emissions. The initial line of inquiry examines the effects of energy use on carbon emissions, supported by several studies. Khan et al. (2020) examined the causal relationship between energy use and carbon emissions in Pakistan from 1965 to 2015. Research indicated that energy use increases carbon emissions both in the short term and long term. Musah et al. (2021) examined the relationship between energy consumption and carbon emissions in North Africa from 1990 to 2018 using CS-ARDL and DCCEMG estimators. They determined that energy use greatly elevates CO₂ emissions and that there exists bidirectional causality between the two variables. Sasana and Putri (2018) examined the impact of rising energy consumption on CO₂ in Indonesia from 1990 to 2014 utilising ordinary least squares (OLS) methodology. It was determined that fossil fuels and population growth considerably contribute to the increase of CO₂ in Indonesia, whereas the use of renewable energy mitigates carbon emissions.

Furthermore, Warsame and Sarkodie (2022) investigated the impact of energy consumption and economic growth on environmental deterioration in Somalia from 1985 to 2017, utilising a non-linear autoregressive distributed lag (NARDL) model. The empirical findings demonstrated long-term co-integration among the relevant variables. Additionally, it identified unidirectional causal relationships between energy usage and environmental contamination. Furthermore, Bekun et al. (2023, 2019; Adekunle et al., 2023; Gbadebo et al., 2025) examined the relationships among energy consumption, economic advancement, and carbon dioxide emissions in South Africa from 1960 to 2016, utilising the methodology of Bayer and Hanck (2013). The results indicate long-term correlations among the study's

variables. Additionally, the relationship between energy use and economic growth is unidirectional. Rahman (2017) conducted a study examining the correlations between energy consumption, population density, economic growth, exports, and carbon dioxide emissions in 11 of the most populous Asian countries from 1960 to 2014, employing fully modified ordinary least squares (FMOLS) and dynamic ordinary least squares (DOLS) methodologies. They stated that energy consumption adversely impacts carbon dioxide (CO₂) emissions in certain countries.

Research examining the interconnections among population growth, foreign direct investment, carbon dioxide emissions, and renewable energy in developing countries, particularly Thailand, has become increasingly significant due to pressing climate change imperatives. While separate studies have examined these actors, comprehensive integrated evaluations are limited, especially for Southeast Asian regions. The growing population generates increased energy demands and emissions due to urban and industrial expansion. Urban population density propels heightened fossil fuel usage, resulting in augmented carbon emissions. The population density in urban areas facilitates the development of energy-efficient infrastructure that reduces environmental pollutants. Foreign Direct Investment serves as both a beneficial and detrimental instrument in sustainability discourse.

Foreign Direct Investment (FDI) serves as an essential tool for attracting international money and sophisticated technologies; yet it can result in detrimental environmental consequences when it endorses water-polluting sectors. The Pollution Haven Hypothesis indicates that countries with lax environmental regulations are more likely to attract foreign direct investment (FDI), resulting in increased pollution levels. Additionally, research published in the Environmental Kuznets Curve (EKC) literature reveals that FDI and economic growth initially lead to heightened environmental emissions, which subsequently decline as income rises and clean technologies mature. Contemporary experts assert that the renewable energy sector significantly benefits from the integration of renewable energy with economic development and environmental conservation.

Limited empirical research quantifies the integrative effects of population growth and foreign direct investment on carbon emissions and renewable energy uptake, particularly in Nigeria (Adamu et al., 2019; Chidiebere-Mark et al., 2022; Ganda, 2022). Present data demonstrates the necessity of conducting comprehensive study on local policies, infrastructure assessments, and socioeconomic variables. Nigeria's unique amalgamation of rapid urbanisation, tourism-driven foreign direct investment, and government-led renewable energy initiatives creates a complex scenario that transcends the capabilities of conventional forecasting models (Gökmenoğlu & Taspınar, 2016; Iqbal et al., 2023; Odugbesan & Adebayo, 2020; Tang & Tan, 2015).

Prior research neglects to examine the mechanisms via which industry sectors produce emissions and the functioning of foreign direct investment within these sectors. Executing green FDI initiatives in energy sectors results in reduced emissions, whereas FDI focused on manufacturing or extraction operations initially causes heightened emissions (Ali et al., 2021; Udemba & Tosun, 2022; Zhu et al., 2016). The impact of urban population migrations and shifts in spending patterns on emissions function differently from the consequences of rural demographic growth, despite insufficient discourse on this subject in scholarly literature. The research employs a comprehensive modelling approach to examine

the links among population, FDI, emissions, and renewable energy, while including insights from Thailand and drawing similarities with China. This work contributes to sustainability transitions research in emerging economies by providing both theoretical advancements and pertinent policy solutions. Interactions among environmental degradation, socio-economic developments, population expansion, foreign direct investment (FDI), technical progress, and economic growth have emerged as focal points of scholarly inquiry, especially in the context of sustainable development and climate resilience.

Population Growth and Carbon Emissions: Environmental stress is predominantly driven by rising population figures. The rise in population, especially in urban areas, results in increased energy demand, thereby causing more CO₂ emissions. Rapid urbanisation accelerates infrastructure development and industrial activities; yet, land use significantly affects the environment unless robust environmental rules are implemented to mitigate this impact.

Foreign Direct Investment (FDI) exerts various effects on environmental outcomes, as demonstrated by research. The stimulation of economic growth via technology transfer enhances investment value; however, environmental degradation arises from certain investment sectors (Zhu et al., 2016). The Pollution Haven Hypothesis posits that polluting industrial facilities are inclined to relocate to countries with lenient regulations. Environmental regulations facilitate foreign direct investment in clean energy transitions. (Ali et al., 2021)

METHODOLOGY

$$CO_2 = f(\text{GDP, FDI, UPO, EnCO, TrO}) \tag{1}$$

Expression (1) as shown below

Expression (1) illustrates that trade openness, market size, natural resources, exchange rate, inflation rate, and institutional quality all contribute to FDI inflows. Given the possible non-linearities, we convert.

$$CO_2 = \phi_0 + \phi_1 \text{GDP} + \phi_2 \text{FDI} + \phi_3 \text{UPO} + \phi_4 \text{ECO} + \phi_4 \text{TRO} + \mu \tag{2}$$

$$\Delta CO_2 = \phi_0 + \sum_{s=1}^J \phi_{1s} \Delta CO_{.2t-n} + \sum_{s=1}^J \phi_{2j} \Delta GDP_{.t-n} + \sum_{s=0}^J \phi_{3j} \Delta UPO_{.t-n}$$

$$+ \sum_{s=0}^J \phi_{4j} \Delta \text{EnCo}_{.t-n} + \sum_{s=0}^J \phi_{5s} \Delta \text{TrO}_{.t-n} + \partial_1 CO_{2t-1} + \partial_2 GDP_{t-1}$$

$$+ \partial_3 UPO_{t-1} + \partial_4 \text{EnCo}_{t-1} + \partial_5 \text{TrO}_{t-1} + \mu \tag{3}$$

$$\Delta CO_2 = \phi_0 + \sum_s^J \phi_{1j} \Delta CO_{.2t-n} + \sum_j^J \phi_{2j} \Delta GDP_{.t-n} + \sum_j^J \phi_{3j} \Delta \text{UnPO}_{.t-n} + \sum^J \phi_{4m} \Delta \text{EnCo}_{.t-n} + \sum_m^J \phi_{5m} \Delta \text{TrO}_{.t-n} + \partial_1 CO_{2t-1} + \partial_2 GDP_{t-1} + \partial_3 UPO_{t-1} + \partial_4 \text{EnCo}_{t-1} + \partial_5 \text{TrO}_{t-1} + \in ECT_{t-1} + \epsilon_t \tag{4}$$

FINDINGS AND DISCUSSION

This part constitutes the fourth portion of the research, aimed at analysing and evaluating the study's findings. Additionally, ascertaining the ideal lag length and, crucially, examining the

association between pertinent variables across both short-term and long-term horizons utilising the autoregressive distributed lag (ARDL) method test.

Table 1: Bound Testing

Test Statistic	Value	K
F-statistic	11.88620	5

Critical Value Bounds		
Significance	I0 Bound	I1 Bound
10%	2.26	3.35
5%	2.62	3.79
2.5%	2.96	4.18
1%	3.41	4.68

Source: Author’s Compilation, 2025

Table 1 reveals a significant result: the computed F-statistic (11.89) surpasses the upper threshold value at the 1% significance level (4.68). This results in a definitive rejection of the null hypothesis, confirming the existence of a long-term link between the variables. The findings indicate that carbon emissions, energy consumption, and the other variables in the study are cointegrated, indicating a long-term equilibrium relationship.

Table 2: Long run Estimation

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
CO2(-1)	-0.207008	0.190033	-1.089326	0.3121
CO2(-2)	-0.323993	0.158606	-2.042757	0.0804
CO2(-3)	-0.677301	0.165375	-4.095535	0.0046
GDP	-3.678749	2.710803	-1.357070	0.2169
GDP(-1)	3.896136	1.069461	3.643084	0.0083
GDP(-2)	2.615564	0.873703	2.993654	0.0201
GDP(-3)	2.995204	0.950611	3.150821	0.0161
ENCO	0.404602	0.265259	1.525310	0.1710
ENCO(-1)	0.000650	0.223378	0.002910	0.0678
ENCO(-2)	0.222850	0.228656	0.974607	0.0322
ENCO(-3)	-0.230743	0.215366	-1.071401	0.3195
FDI	-3.07E-09	2.45E-09	-1.251704	0.2509
FDI(-1)	-4.88E-09	3.40E-09	-1.435362	0.1943
FDI(-2)	-1.12E-08	4.28E-09	-2.609969	0.0349
FDI(-3)	3.06E-09	3.16E-09	0.967463	0.0515
UPO	-18.69362	46.42001	-0.402706	0.6992
UPO(-1)	-191.2370	94.17804	-2.030590	0.0818
UPO(-2)	373.3931	103.5871	3.604628	0.0087
UPO(-3)	-173.2406	56.59213	-3.061214	0.0183
TRO	2.59E-10	1.01E-10	2.577401	0.0366
TRO(-1)	-1.38E-10	1.02E-10	-1.353148	0.2181
TRO(-2)	-1.67E-10	9.82E-11	-1.702753	0.1324
C	859.8289	117.3715	7.325703	0.0002

R-squared	0.963741	Mean dependent var	376.4733
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Adjusted R-squared	0.849784	S.D. dependent var	27.12951
S.E. of regression	10.51476	Akaike info criterion	7.621483
Sum squared resid	773.9210	Schwarz criterion	8.695734
Log likelihood	-91.32224	Hannan-Quinn criter.	7.965145
F-statistic	8.457090	Durbin-Watson stat	2.038573
Prob(F-statistic)	0.003738		

Source: Author’s Compilation, 2025

Table 3: Short run Estimation

Cointegrating Form				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(CO2(-1))	1.001293	0.206870	4.840202	0.0019
D(CO2(-2))	0.677301	0.165375	4.095535	0.0046
D(GDP)	-3.678749	2.710803	-1.357070	0.2169
D(GDP(-1))	-2.615564	0.873703	-2.993654	0.0201
D(GDP(-2))	-2.995204	0.950611	-3.150821	0.0161
D(ENCO)	0.404602	0.265259	1.525310	0.0410
D(ENCO(-1))	0.222850	0.228656	0.974607	0.3622
D(ENCO(-2))	0.230743	0.215366	1.071401	0.3195
D(FDI)	-0.000000	0.000000	-1.251704	0.2509
D(FDI(-1))	0.000000	0.000000	2.609969	0.0349
D(FDI(-2))	-0.000000	0.000000	-0.967463	0.3655
D(UPO)	-18.693620	46.420014	-0.402706	0.6992
D(UPO(-1))	373.393070	103.587131	-3.604628	0.0087
D(UPO(-2))	173.240603	56.592125	3.061214	0.0183
D(TRO)	0.000000	0.000000	2.577401	0.0366
D(TRO(-1))	0.000000	0.000000	1.702753	0.1324
CointEq(-1)	-2.208301	0.316354	-6.980474	0.0002

Source: Author’s Compilation, 2025

After establishing the enduring bonds among the study's participants. The study examined the impact of energy consumption, foreign direct investment, urbanization, economic growth, and trade openness on carbon emissions in Nigeria. Table 2 respectively illustrates the long-term results, indicating a direct correlation between energy consumption and CO2 emissions, which is statistically significant in both the near and distant future. This demonstrates that a 1% increase in energy usage results in a 0.22% rise in carbon emissions in Nigeria. These findings correspond with analogous research performed in Nigeria (Yang et al., 2020) and Turkey (Cetin et al., 2018). Likewise, the increase in foreign direct investment positively influences carbon emissions. The enhancement of foreign investment adds to the rise of carbon dioxide emissions in Nigeria. A 1% increase in FDI resulted in a long-term growth of 0.33 in CO2 emissions. These results align with the study conducted by Pata et al. (2023). Urbanization is determined to have a positive correlation with carbon emissions in the long term. This suggests that a 1% rise in Nigeria's urbanization results in a 17.3% increase in carbon emissions over the long term. Multiple research projects indicate that urbanization contributes to environmental degradation (Suhraab et al., 2023; Cheng and Hu, 2023). Furthermore, our findings indicate that economic expansion correlates to an increase in

carbon dioxide emissions in Nigeria. A 1% rise in the country's economic growth results in a 3.9% increase in CO₂ emissions in the long term. Findings indicate that trade without barriers positively affects carbon emissions, as evidenced by Zhang et al. (2017) and Akhayere et al. (2023), who discovered that trade openness decreases carbon emissions.

The results of the short term are presented in Table 3, demonstrating that energy use positively influences carbon emissions. Carbon emissions will rise by 0.4% because of a 1% increase in energy usage in the short term. The impact of foreign investment inflow on CO₂ emissions is neutral and statistically significant. This indicates that a 1% increase in FDI will have a neutral effect on carbon emissions, remaining at 0.0% in the short term. Furthermore, urbanization rapidly increases carbon dioxide emissions in Nigeria. A 1% rise in urbanization will result in a 3.73% increase in CO₂ emissions in the short term. Economic activity is inversely correlated with carbon emissions, with a 1% increase resulting in a 2.6% decrease in carbon dioxide levels. The data indicated that trade openness is uncorrelated with carbon emissions in the short term. Additionally, the error correction model (ECM) is employed to examine the short-term effects of the explanatory factors on CO₂ emissions. The ECT coefficient is negative and statistically significant, indicating convergence instead of divergence. The model rectifies roughly 220% of annual short-term discrepancies in CO₂ emissions.

Table 4: Breusch-Godfrey Serial Correlation LM Test

F-statistic	2.729171	Prob. F(2,5)	0.1580
Obs*R-squared	15.65738	Prob. Chi-Square(2)	0.0004

Source: Author's Compilation, 2025

Table 5: Heteroskedasticity Test: ARCH

F-statistic	0.919469	Prob. F(1,27)	0.3461
Obs*R-squared	0.955054	Prob. Chi-Square(1)	0.3284

Source: Author's Compilation, 2025

Figure 1: CUSUM

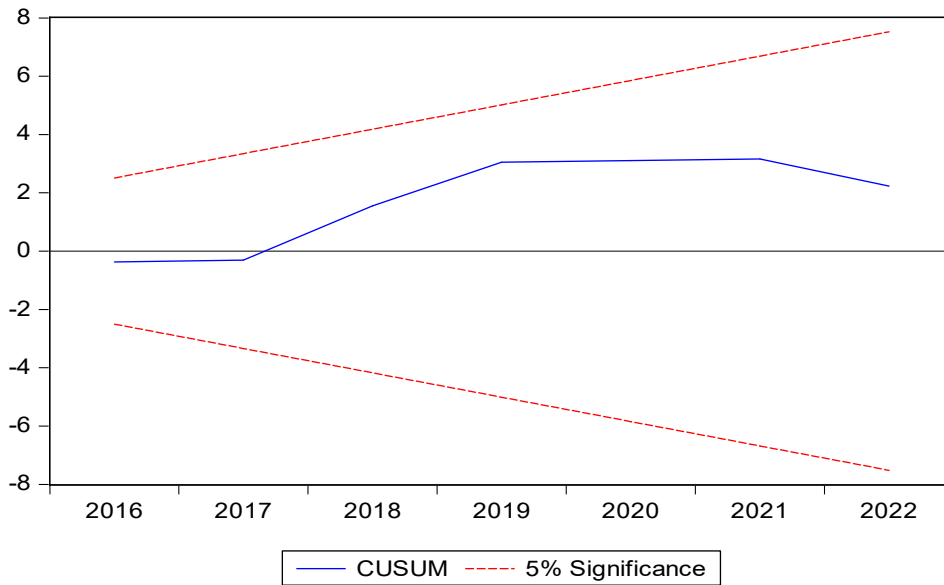
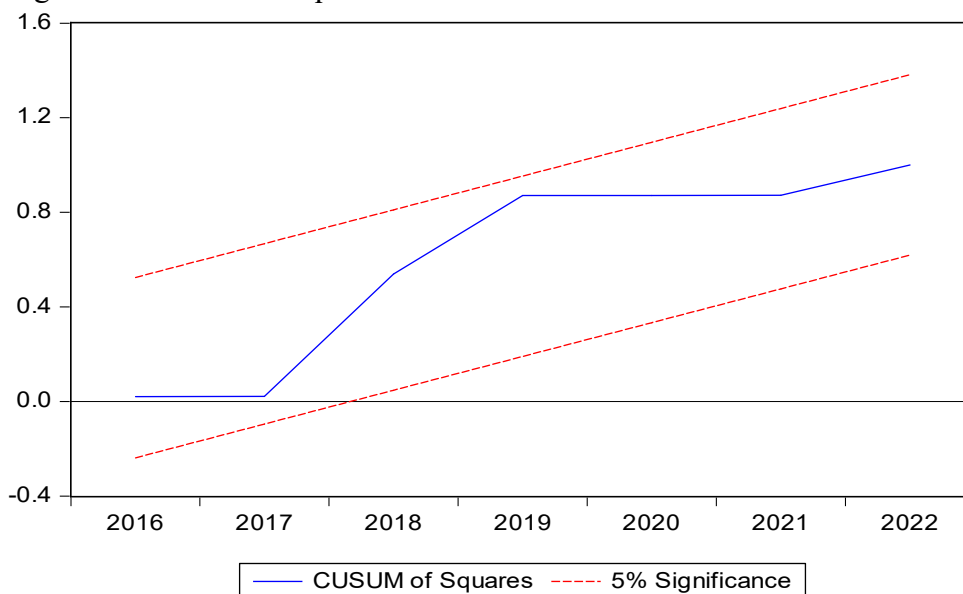


Figure 2: CUSUM of Squares



Tables 4 and 5, along with Figures 1 and 2, illustrate the outcomes of the diagnostic testing. The time series data exhibit no indications of serial correlation, heteroskedasticity, or model specification problems. The investigation refuted the null hypothesis concerning a diagnostic issue. The CUSUM and CUSUM of squares tests, illustrated in Figures 1 and 2, indicate that the model structure is robust.

CONCLUSION

The study examined the influence of energy consumption, foreign investment inflows, and urbanisation on carbon emissions in Nigeria from 1990 to 2021 using the ARDL bounds testing approach. The empirical findings of the study indicate that energy usage negatively correlates with CO₂ emissions and is statistically significant in both the short and long term. A 1% increase in energy usage results in a 22% rise in carbon emissions in Nigeria over the long term. Likewise, the increase in foreign direct investment positively influences carbon emissions. The enhancement of foreign investment adds to the rise of carbon dioxide

emissions in Nigeria. A 1% increase in foreign direct investment results in a long-term growth of 0.033 in CO₂ emissions.

Urbanisation is determined to have a positive correlation with carbon emissions over the long term. This implies that a 1% rise in Somalia's urbanisation results in a 17.3% increase in carbon emissions in the long term. Furthermore, our data indicate that economic expansion correlates to an increase in carbon dioxide emissions in Nigeria. A 1% increase in the nation's economic growth results in a 3.9% rise in CO₂ emissions over the long term. The data demonstrates a direct correlation between trade openness and carbon emissions. A 1% increase in trade openness will result in a 2.5% growth in CO₂ emissions over the long term. Concerning Granger causality, it was determined that bidirectional causal links exist between GDP and CO₂ emissions, urbanization, and foreign direct investment (FDI). Unidirectional causality exists from carbon emissions to energy consumption, from foreign investment to carbon emissions, from urbanization to carbon dioxide, and from trade openness to carbon. Based on the empirical data of the study, it proposes numerous policy implications regarding energy usage in Nigeria. The Nigerian government must reassess its energy policy to promote renewable energy sources. This may encompass incentives for renewable energy, enhancements in energy efficiency, and a tax or regulatory disincentive against fossil fuel consumption. The government must devise strategies to mitigate the adverse impacts of foreign direct investment and trade on carbon emissions in Nigeria, including enhancing investment in research and development of environmentally sustainable technologies, particularly in energy efficiency and renewable energy. Moreover, governments may implement measures to foster sustainable urban development, encompassing the promotion of public transportation, the augmentation of green spaces, and the advocacy of energy-efficient construction methods. The government should provide incentives such as tax reductions or subsidies to corporations in Nigeria.

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