

RE-EXAMINING THE LINK BETWEEN FDI, ENERGY CONSUMPTION, POPULATION GROWTH AND CARBON EMISSION IN NIGERIA

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Abstract

Research on how FDI and population growth affects carbon emissions (CO₂) is essential, the pollution-haven theory is less clear because prior research has not much examined the complicated relationship between FDI, population growth and CO₂ in Nigeria. Based on this, this study re-examined the link between FDI, energy consumption and population growth on CO₂ in Nigeria. The data for the study were obtained from World Development Indicator (WDI, 2023) which covered from 1990-2023. The ARDL methods were employed to analyze the data. The findings of the study show that energy consumption has a negative effect on CO₂ emissions and is statistically significant, this can be trace to the renewable energy application in the Nigeria economy. The study recommends promotion of greener energy sources; Nigeria's government needs to review its energy strategy more. These could include taxing or regulating the use of fossil fuels, increasing energy efficiency, and providing incentives for renewable energy. The government needs to come up with ways to lessen the detrimental effects of exchange rate and foreign direct investment on Nigeria's carbon emissions, like increasing funding for research innovation and emancipation in eco-friendly industries and technologies, especially energy efficiency and renewable energy.

Keywords: Energy consumption, Population growth, Exchange rate, Carbon emission

Introduction

Global warming and climate change have become some of the most pressing issues confronting the world community in recent years. The impact of humans on the climate system is evident, and recent human-caused greenhouse gas emissions, particularly carbon emissions, are at an all-time high. Both natural and human systems have been greatly impacted by climate change. Consequently, reducing carbon emissions and creating a low-carbon economy have received a lot of attention worldwide. Economic growth and energy use are the two most significant factors associated with environmental degradation. Even though they are now major contributors to environmental pollution, most studies solely look at environmental pollution, especially CO₂ emissions, which are correlated with FDI and energy consumption. FDI and energy use by themselves might not be sufficient to account for CO₂ (Zhu et al., 2016; Yin et al., 2022). Consequently, it is necessary to consider other factors related to carbon emissions.

Even while foreign direct investment (FDI) has grown in significance, not much has been spoken about it, particularly in relation to Nigeria. In fact, the growing amount of foreign direct investment in developing nations begs the crucial question of whether it has any negative effects on the environment (Gabriel Aremo & Ayobami Ojeyinka, 2018).

Research on how FDI affects carbon emissions is therefore essential. The pollution-haven theory is less clear because prior research has not examined the complicated relationship between FDI and CO₂ or the causation between the two, despite Sub-Saharan Africa's efforts to attract FDI. According to popular wisdom, foreign direct investment (FDI) may increase CO₂ overall if environmental regulations are loosened in developing nations (Behera & Dash, 2017). The

pollution-haven hypothesis is the term used in economic theory to describe the tendency of emerging nations to disregard environmental issues to attract foreign investment through lenient or non-enforced regulations. However, when low-carbon technologies are implemented to lower carbon dioxide emissions by FDI overall or when FDI flows to concentrate on the service sector, the impact of FDI can be reversed (Adjei-Mantey & Adams, 2023; Ben Jebli et al., 2019; Gunarto, 2020; Halliru et al., 2021; Khan et al., 2022; Shahbaz et al., 2018, 2019)

The halo effect concept holds that foreign businesses employ superior management techniques and cutting-edge technologies that support a clean environment in their host nations (Udemba & Tosun, 2022). (Ali et al., 2021), total carbon emissions pose a worldwide problem due to their transboundary character, which causes extensive environmental deterioration. This problem has gotten worse because of industrialized nations' faster economic growth since the Industrial Revolution. Globally, environmental deterioration has steadily increased over the past thirty years. Greenhouse gas (GHG) emissions are among the pollutants that are greatly impacted by human-induced climate change. Notably, income levels have a significant impact on rising carbon dioxide (CO₂) emissions, impacting both the wealthy and the poor.

Additionally, transportation-related pollution, deforestation, and the exploitation and burning of fossil fuels like coal, petroleum, and natural gas all contribute to rising CO₂. (Tang & Tan, 2015), CO₂ emissions account for more than 60% of global warming among these greenhouse gas emissions. The rationale for using VECM is as follows: first, we use the annual data framework to study CO₂ emissions and other moving variables in the Nigerian context because it offers more informative data, more variability, more degrees of freedom, and therefore greater estimation efficiency than concentrating on multiple countries (Adamu et al., 2019; Ali et al., 2021; Chidiebere-Mark et al., 2022; Ganda, 2022; Gökmenoğlu & Taspınar, 2016; Iqbal et al., 2023; Mai, 2023; Odugbesan & Adebayo, 2020; Saqib & Dincă, 2024; Tang & Tan, 2015; Udemba & Tosun, 2022; Zhang et al., 2023; Zhu et al., 2016). Considering this, it seems logical to revisit the factors that influence CO₂ emissions in the Nigerian context using the annual data framework. This approach can also characterize the full conditional distribution of the dependent variable: as a result, it gives us a more comprehensive understanding of the variables influencing pollution emissions.

LITERATURE REVIEW

According to the literature evaluation, three study clusters can be used to broadly categorize the links between CO₂ emissions, FDI, economic growth, and energy use. First, the validity of the ECK hypothesis is tested by empirical research on the connection between CO₂ emissions and economic growth. To confirm the validity of the pollution haven hypothesis, the second and third studies concentrate on the energy CO₂ nexus and the FDI–pollution nexus, respectively. However, there aren't many studies accessible for ASEAN nations.

Under the umbrella of the environmental Kuznets curve (EKC) hypothesis, several studies have examined the connection between economic growth and environmental pollution since the groundbreaking work of Grossman and Krueger (1995). These studies include those conducted by Suri and Chapman (1998), Dinda and Coondoo (2006), Managi and Jena (2008), and Zhu et al. (2012). Recent research, however, seems to offer conflicting empirical findings on EKC's validity. For instance, Lean and Smyth (2010) investigate the connection between CO₂ and economic growth in five ASEAN nations using a panel vector error correction model analysis of the EKC.

The empirical findings, which are based on annual data from 1980 to 2006, indicate that, overall, there appears to be evidence in favor of the EKC hypothesis in the ASEAN-5. However, Narayan and Narayan (2010) contend that the EKC hypothesis is not supported in any of the nations (Indonesia, Malaysia, the Philippines, and Thailand) based on a comparison of long-run and short-run income elasticity. Similarly, using annual data from 1971 to 2008, Chandran and Tang (2013) examine the EKC hypothesis for the ASEAN-5 countries using the cointegration and Granger causality approaches. They conclude that the ASEAN-5 economies cannot be explained by the inverted U-shaped EKC hypothesis. Additionally, Heidari et al. (2015) use a smooth transition regression model to examine the connections between economic development, energy use, and carbon emissions. The validity of the EKC theory in the ASEAN nations is further supported by the empirical findings.

Regarding the relationship between energy consumption and CO₂, Lean and Smyth (2010) discover a strong long-term correlation between emissions and power usage in each of the ASEAN-5 nations. According to the Granger causality panel, only short-term unidirectional Granger causation exists between emissions and electricity use. However, using both supply-side and demand-side frameworks, Bloch et al. (2012) examine the relationship between coal consumption and emissions in China. Their findings show that there is bi-directional causality between coal consumption and pollutant emissions over both the short and long term. In all five ASEAN nations, Saboori and Sulaiman (2013) also discover a bi-directional Granger causation between energy use and CO₂.

Governments and academics have taken notice of and supported renewable energy as a potent alternative energy source to lower CEI and advance sustainable development. Renewable energy has grown in importance for meeting energy demand and reducing carbon emissions among governments and politicians as environmental degradation and carbon emissions gain more attention (Assi et al., 2021). Scholars have also carried out a substantial amount of pertinent research. As an illustration, replacing fossil fuels with clean energy can successfully lower CEI (Dong et al., 2018; Mohsin et al., 2021). Using a sample of 25 developing countries from 1990 to 2018, it was found that using renewable energy can successfully minimize CEI (Rahman et al., 2022). Renewable energy also inhibits CEI, according to China's provincial panel statistics (Zheng et al., 2021). Clear energy use can lower CEI in high-carbon nations, according to another study (Pata & Kumar, 2021; Shabir et al., 2022). Between 2000 and 2020, the deployment of renewable energy in Asian economies helped to lower the CEI over the long run (Du, 2023).

Kima and Seok (2022), the autoregressive distributed lag (ARDL) model were used to examine the impact of foreign direct investment (FDI) inflows on carbon emissions in Korea over a one-year period between 1971 and 2015. According to their findings, FDI has a major impact on CO₂ emissions. Blanceo et al. (2013) used panel Granger causality to examine how foreign investment affected CO₂ emissions in Latin America between 1980 and 2007. They mentioned an incentive for FDI to raise emissions. Kisswani and Zaitouni (2021) employed the ARDL model to evaluate the correlations between FDI and carbon dioxide emissions for four Asian countries using time series data from 1971 to 2014. They concluded that the pollution halo theory was validated in Malaysia and Singapore, whereas the pollution haven hypothesis was only present in the Philippines. In addition, Teng et al. (2021) used the Pooled Mean Group (PMG) to analyze the impact of foreign direct investment (FDI), energy consumption, economic development, globalization, and institutional quality on CO₂ for a dataset spanning ten economies from 1985 to 2018. Research has shown that while renewable energy contributes to improving environmental

quality, economic expansion and foreign direct investment have a favorable impact on environmental degradation. In a similar vein, Shahbaz et al. (2018) used bootstrapping bound test and novel SOR approaches to analyze the factors that govern France's pollution from 1955 to 2016. They discovered that while energy innovation helps to lessen the effects, foreign direct investment boosts environmental pollution.

Furthermore, Ali et al. (2019) used an autoregressive distributed lag model to investigate the impact of urbanization in Pakistan on carbon emissions from 1972 to 2014. The findings showed that urbanization reduces carbon emissions over the long run. Furthermore, Ali et al. (2017) highlighted how urbanization affected Singapore's CO₂ emissions between 1970 and 2015 using ARDL. They discovered that Singapore's urbanization had no negative impact on the country's environmental quality. If not, carbon emissions will fall. (Keshavarzian & Tabatabaienasab, 2022; Viphindrarti et al., 2020; Yang et al., 2020) also examined the relationship between urbanization, energy consumption, and CO₂ emissions in Malaysia. Their results indicate that urbanization exhibits positive elasticity in its early phases but shifts to negative inelasticity as it intensifies. The dynamic panel threshold approach was also used by Lee et al. (2023) to examine how urbanization affected China's carbon emissions between 1996 and 2018. They concluded that more people moving from rural to urban areas increases emissions of carbon dioxide. Using the ADRL bound test, Wang et al. (2021) investigated the causal relationship between urbanization and carbon emissions in OECD nations across time. Their results demonstrated that, despite variations in the resources available to each nation, the detrimental effects of urbanization on carbon emissions are typically similar in industrialized countries. Anwar et al. (2020) employed the fixed effect method to examine the factors influencing carbon emissions using panel data from nations in far east Asia from 1980 to 2017. They proposed that the main causes of environmental contamination are trade openness, economic expansion, and urbanization. Sufyanullah et al. (2022) used the autoregressive distributed lag model (ARDL) to determine the effects of Pakistan's urbanization on CO₂ over the years 1975 to 2018 because of the country's recent increase in urbanization. The association between the variables was shown by the ARDL results, and urbanization contributes to increased environmental contamination.

METHODOLOGY

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

According to expression (1), carbon emission (CO₂) is explained by a combination of FDI, urbanization, GDP and exchange rate. Considering the possible non-linearities, we convert

Expression (1) as shown below

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

$$\begin{aligned} \Delta CO_2 = & \phi_0 + \sum_{s=1}^J \cdot \phi_{1s} \Delta CO_{.2t-n} + \sum_{s=1}^J \cdot \phi_{2j} \Delta GDP_{.t-n} + \sum_{s=0}^J \cdot \phi_{3j} \Delta UPO_{.t-n} + \sum_{s=0}^J \cdot \phi_{4j} \Delta EnCo_{.t-n} \\ & + \sum_{s=0}^J \cdot \phi_{5s} \Delta EXRt_{.t-n} + \partial_1 CO_{2t-1} + \partial_2 GDP_{t-1} + \partial_3 UPO_{t-1} + \partial_4 EnCo_{t-1} \\ & + \partial_5 EXRt_{t-1} + \mu \end{aligned} \tag{3}$$

$$\begin{aligned} \Delta CO_2 = & \phi_0 + \sum_{s=1}^J \cdot \phi_{1j} \Delta CO_{.2t-n} + \sum_{j=1}^J \cdot \phi_{2j} \Delta GDP_{.t-n} + \sum_{j=1}^J \cdot \phi_{3j} \Delta UnPO_{.t-n} + \\ & \sum_{m=1}^J \cdot \phi_{4m} \Delta EnCo_{.t-n} + \sum_{m=1}^J \cdot \phi_{5m} \Delta EXRt_{.t-n} + \partial_1 CO_{2t-1} + \partial_2 GDP_{t-1} + \partial_3 UPO_{t-1} + \\ & \partial_4 EnCo_{t-1} + \partial_5 EXRt_{t-1} + \epsilon ECT_{t-1} + \epsilon_t \end{aligned} \tag{4}$$

FINDINGS AND DISCUSSION

Analyzing and assessing the study's results is the aim of this portion, which makes up the fourth section of the research. Additionally, figuring out the ideal lag length and above all using the autoregressive distributed lag (ARDL) method test to examine the association between pertinent variables across both short and long periods.

Table 1: Bound Testing

Test Statistic	Value	k
F-statistic	16.23873	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

A strong result is shown in Table 1: at the 1% significance level (4.68), the computed F-statistic (16.23) is more than the upper bound critical value. As a result, the null hypothesis is robustly rejected, confirming that there is a long-term link between the variables. The findings imply that

energy use, carbon emissions, and other study variables are cointegrated and share a long-term equilibrium.

Table 2: Long run Estimation

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
CO2(-1)	0.054995	0.168372	0.326627	0.7550
CO2(-2)	0.137597	0.173507	0.793035	0.4580
CO2(-3)	-0.147596	0.165008	-0.894481	0.4055
CO2(-4)	-0.209966	0.139882	-1.501028	0.1840
ENCO	-0.140556	0.160847	-0.873851	0.0158
ENCO(-1)	-0.125651	0.122282	-1.027555	0.3438
GDP	0.514666	1.582781	0.325166	0.7561
GDP(-1)	1.631617	2.783311	0.586214	0.5791
GDP(-2)	2.831432	0.798067	3.547865	0.0121
GDP(-3)	3.439935	1.216997	2.826577	0.0301
FDI	-2.95E-09	2.07E-09	-1.423300	0.2045
FDI(-1)	-6.83E-09	2.42E-09	-2.826183	0.0301
FDI(-2)	2.04E-09	2.43E-09	0.838184	0.4340
FDI(-3)	5.21E-09	2.57E-09	2.030724	0.0886
EXR	-0.159859	0.086289	-1.852613	0.1134
EXR(-1)	-0.301586	0.075422	-3.998671	0.0071
EXR(-2)	-0.163253	0.360685	-0.452619	0.6667
EXR(-3)	-0.286932	0.281718	-1.018510	0.3477
UPO	-87.38139	271.6611	-0.321656	0.7586
UPO(-1)	-332.9400	463.5507	-0.718239	0.4996
UPO(-2)	592.2681	217.6640	2.721020	0.0346
UPO(-3)	-186.8804	43.17318	-4.328622	0.0049
C	743.2014	115.8085	6.417505	0.0007
R-squared	0.978864	Mean dependent var		378.3477
Adjusted R-squared	0.901366	S.D. dependent var		25.55635
S.E. of regression	8.026229	Akaike info criterion		7.013977
Sum squared resid	386.5221	Schwarz criterion		8.098384
Log likelihood	-78.70267	Hannan-Quinn criter.		7.353600
F-statistic	12.63084	Durbin-Watson stat		2.847493
Prob(F-statistic)	0.002303			

Source: Author's Compilation, 2025

Table 3: Short run Estimation

Cointegrating Form				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(CO2(-1))	0.219965	0.331127	0.664294	0.5312
D(CO2(-2))	0.357563	0.215211	1.661450	0.1477
D(CO2(-3))	0.209966	0.139882	1.501028	0.1840
D(ENCO)	-0.140556	0.160847	-0.873851	0.4158
D(GDP)	0.514666	1.582781	0.325166	0.0561
D(GDP(-1))	-2.831432	0.798067	-3.547865	0.0121
D(GDP(-2))	-3.439935	1.216997	-2.826577	0.0301
D(FDI)	-0.000000	0.000000	-1.423300	0.2045
D(FDI(-1))	-0.000000	0.000000	-0.838184	0.4340
D(FDI(-2))	-0.000000	0.000000	-2.030724	0.0886
D(EXR)	-0.159859	0.086289	-1.852613	0.1134
D(EXR(-1))	0.163253	0.360685	0.452619	0.6667
D(EXR(-2))	0.286932	0.281718	1.018510	0.0477
D(UPO)	-87.381386	271.661127	-0.321656	0.7586
D(UPO(-1))	592.268087	217.664011	-2.721020	0.0346
D(UPO(-2))	186.880389	43.173182	4.328622	0.0049
CointEq(-1)	-1.164971	0.405238	-2.874783	0.0282

Source: Author's Compilation, 2025

following the identification of the individuals' long-term partnerships. The study reexamines the relationship between Nigeria's carbon emissions and energy consumption, foreign direct investment, urbanization, economic growth, and exchange rates. The long-term results, as shown in Table 2, show that energy consumption has a negative relationship with CO2 emissions and is

statistically significant. This shows that Nigeria's carbon emissions fall by 0.41% for every 1% increase in energy usage. These findings are consistent with related research carried out in South Africa by Adekunle et al. (2023; 2022) and Bekun et al. (2023). In a similar vein, increasing FDI has a detrimental effect on carbon emissions. Nigeria's carbon dioxide emissions have decreased because of increased foreign investment. Over time, CO2 emissions rose by 0.68% for every 1% increase in foreign direct investment. These results align with studies conducted by (Pata et al., 2023). Long-term urbanization is found to have a positive correlation with carbon emissions. This shows that a 1% rise in Nigeria's urbanization will eventually result in a 5.92% increase in carbon emissions. Numerous research, like those by Suhrab et al. (2023) and Cheng and Hu (2023), have suggested that urbanization exacerbates environmental degradation. Additionally, the findings indicate that economic expansion in Nigeria is a contributing factor to rising carbon dioxide emissions. Over time, CO2 emissions rise by 2.83% for every 1% increase in the nation's economic growth. Nonetheless, research indicates that the exchange rate has no influence on carbon emissions; Zhang et al. (2017) and Akhayere et al. (2023) also discovered that trade openness lowers carbon emissions.

Table 3 presents the short-term results, which show that energy use has a negative effect on carbon emissions. In the short term, a 1% increase in energy consumption will result in a 0.14% rise in carbon emissions. Foreign investment inflow has a neutral and very important impact on CO2 emissions. This suggests that a 1% increase in foreign direct investment will immediately offset a 0.0% short-term increase in carbon emissions. Additionally, urbanization quickly raises carbon dioxide levels in Nigeria. In the short term, a 1% rise in urbanization will result in a 5.9% increase in CO2 emissions. Carbon emissions are positively correlated with economic activity, and an increase of 1% will result in a 0.51% decrease in carbon dioxide. The results also showed that there is no short-term correlation between the exchange rate and carbon emissions. Additionally, the short-term effects of the explanatory factors on CO2 emissions are examined using the error correction model (ECT). Convergence rather than divergence is indicated by the statistically significant negative ECT coefficient. Every year, the model corrects for about 116% of short-term imbalances in CO2 emissions.

Heteroskedasticity Test: ARCH

F-statistic	4.344476	Prob. F(1,26)	0.0471
Obs*R-squared	4.008813	Prob. Chi-Square(1)	0.0453

Source: Author's Compilation, 2025

Table 5: Heteroskedasticity Test: ARCH

F-statistic	1.975697	Prob. F(2,4)	0.2531
Obs*R-squared	14.41136	Prob. Chi-Square(2)	0.0007

Source: Author's Compilation, 2025

Figure 1: CUSUM

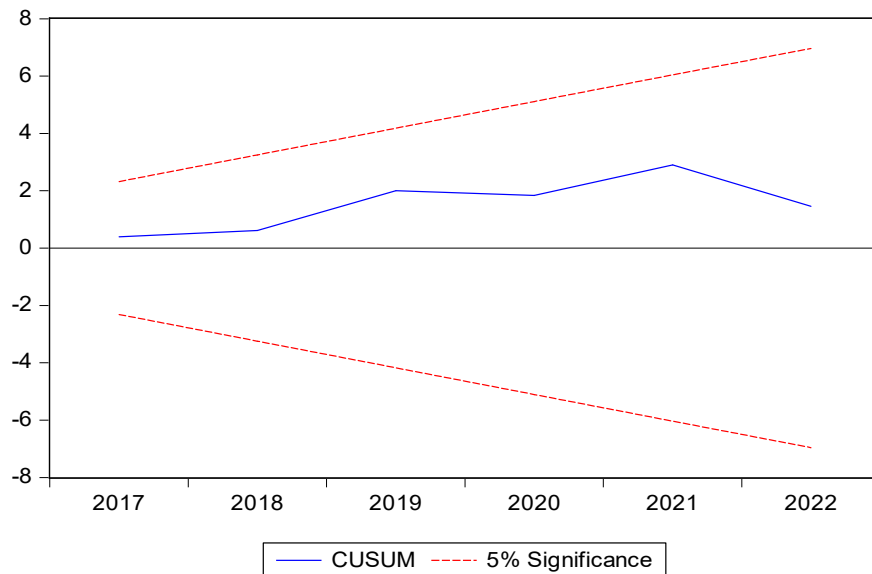
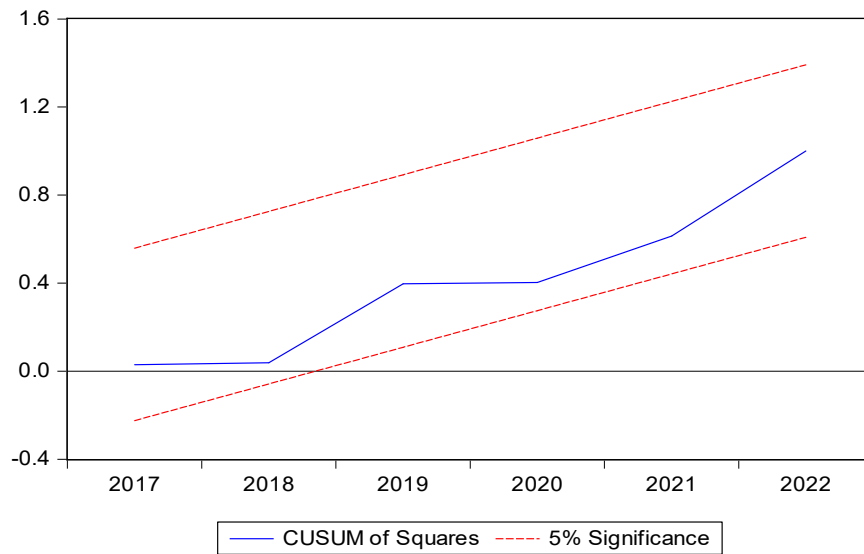


Figure 2: CUSUM of Squares



Diagnostic test findings are also shown in Table 4, Table 5, and Figures 1 and 2. There are no indications of heteroskedasticity, serial correlation, or problems with model specification in the time series data. Nevertheless, the investigation disproved the diagnostic problem null hypothesis. The model structure is still stable according to the CUSUM and CUSUM of squares tests, which are displayed in Figures 1 and 2.

CONCLUSION

Using the ARDL bound test, the study reexamines how Nigeria's carbon emissions are affected by energy consumption, foreign investment inflows, exchange rates, and urbanization throughout the years 1990–2023. The study's empirical findings demonstrate that energy use has a negative correlation with CO₂ and is statistically significant in the short and long term.

Furthermore, carbon dioxide emissions in Nigeria are rising quickly due to urbanization. Over time, a 1% increase in urbanization will result in a 0.59% increase in CO₂. Conversely, there is a clear relationship between economic activity and carbon emissions. Carbon dioxide levels will drop by 0.28% for every 1% rise in economic activity. The findings establish an unfavorable link between trade openness and carbon emissions. A 1% rise in exchange rate will lead to a 0.0% neutrality of CO₂ in the long run. Nonetheless, the report makes several policy recommendations on Nigerian energy usage based on actual data. First, to promote greener energy sources, Nigeria's government needs to review its energy strategy. These could include taxing or regulating the use of fossil fuels, increasing energy efficiency, and providing incentives for renewable energy. Second, the government needs to come up with ways to lessen the detrimental effects of trade and foreign direct investment on Nigeria's carbon emissions, like increasing funding for research innovation and emancipation in eco-friendly industries and technologies, especially energy efficiency and renewable energy. Policymakers may also take steps to create more sustainable cities, such as encouraging public transportation, improving green areas, and supporting energy-efficient building practices. Additionally, the government ought to provide businesses with incentives like tax breaks or subsidies.

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