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Gas flaring and the transition to a green economy in Nigeria: An empirical analysis

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Abstract
Nigeria, one of the top oil producers globally, faces ongoing environmental challenges due to persistent gas flaring despite long-standing regulatory efforts. This study empirically investigates the relationship between CO_2 emissions and key determinants gas flaring (GAF), gas utilization (GAU), fossil fuel consumption (FOC), and economic growth (GDP) with a specific focus on the implications for Nigeria's transition to a green economy. Using Ordinary Least Squares (OLS) regression with robust standard errors and supporting time-series diagnostics, the analysis finds that gas flaring is the most significant driver of emissions, while gas utilization significantly reduces emissions. Fossil fuel consumption shows a marginal effect, and economic growth is not statistically significant. The model explains 81.2% of the variation in emissions, underscoring the strong predictive power of the included variables. The findings highlight the urgency of gas flaring reduction and improved gas utilization strategies in achieving Nigeria's climate goals.

Keywords: Gas flaring, CO_2 emissions, green economy, oil and gas sector, Nigeria

Introduction

Climate change remains one of the most pressing challenges of the 21st century, with greenhouse gas (GHG) emissions particularly carbon dioxide (CO_2) being the primary driver of global warming (IPCC, 2021) [12]. The energy sector is a major contributor to these emissions, with fossil fuel combustion and associated gas flaring accounting for a significant portion of global CO_2 output (IEA, 2023) [10]. In developing countries with large hydrocarbon reserves, the environmental cost of oil production has increasingly come under scrutiny, particularly where institutional capacity to regulate emissions is weak.

Nigeria, as one of Africa's largest crude oil producers, plays a central role in this discourse. The country possesses substantial natural gas reserves, yet paradoxically ranks among the top gas-flaring nations globally (World Bank, 2022) [27]. Despite the establishment of flaring reduction frameworks such as the Associated Gas Re-Injection Act (1979) and the Nigerian Gas Flare Commercialisation Programme (NGFCP), routine flaring persists often justified by infrastructure constraints, weak enforcement, and cost-saving strategies by oil producers (Ite & Ibok, 2013; Nwankwo & Ogagarue, 2011) [13, 19]. The result is a sustained volume of CO_2 emissions, posing both local and global environmental risks.

Gas flaring contributes not only to global warming but also to localized air pollution, acid rain, and ecosystem degradation, particularly in the oil-rich Niger Delta (Obi & Osang, 2020) [21]. Moreover, the economic cost is substantial flared gas represents a loss of potential energy, revenue, and industrial feedstock. At the same time, Nigeria's energy sector remains heavily reliant on fossil fuels, further entrenching carbon-intensive growth pathways (Akinyemi *et al.*, 2017) [3].

Understanding the drivers of CO_2 emissions in Nigeria is essential, particularly within the context of the country's commitment to a green economy transition, as outlined in the Nationally Determined Contributions (NDCs) under the Paris Agreement. While economic growth is often associated with higher emissions, the Environmental Kuznets Curve (EKC) hypothesis suggests that emissions may eventually decline as income levels rise and cleaner technologies are adopted (Stern, 2004) [24]. Whether Nigeria is approaching this turning point remains an empirical question.

This study, therefore, investigates the relationship between gas flaring, fossil fuel consumption, economic activity, and gas utilization, and their collective impact on CO_2 emissions in Nigeria. By applying robust econometric techniques, the research aims to provide evidence-based insights to inform sustainable energy policy and emissions reduction strategies.

2. Literature Review

2.1. Conceptual Issues

2.1.1. Gas Flaring is the controlled burning of natural gas that is released during the extraction of oil. It is often used as a waste management practice where infrastructure for gas capture or utilization is lacking (Elvidge *et al.*, 2009) [6]. While it is a routine part of petroleum production in many oil-producing nations, gas flaring releases large volumes of carbon dioxide (CO_2) and other pollutants, significantly contributing to climate change (World Bank, 2022) [27].

2.1.2. CO_2 Emissions, a leading indicator of environmental degradation, are primarily generated by fossil fuel combustion and industrial processes. In oil-producing countries like Nigeria, these emissions are often directly correlated with levels of flaring, fossil fuel consumption, and energy policy effectiveness (Akinyemi *et al.*, 2017) [3].

2.1.3. Fossil Fuel Consumption (FOC) encompasses the use of oil, natural gas, and coal for energy. While necessary for industrialization and economic development, fossil fuel dependency has been criticized for driving unsustainable environmental outcomes, particularly in countries lacking regulatory enforcement or renewable alternatives (IEA, 2023) [10].

2.1.4. Gas Utilization (GAU) refers to the capture and productive use of natural gas that would otherwise be flared. This includes conversion into electricity, liquefied natural gas (LNG), or feedstock for petrochemical industries. Higher gas utilization rates are considered indicators of energy efficiency and environmental responsibility (Nwankwo & Ogagarue, 2011) [19].

2.1.5. Economic Growth (GDP) often increases energy demand and environmental pressure in the early stages of development. The Environmental Kuznets Curve (EKC) posits that as an economy grows, environmental degradation initially increases, but later declines as income rises and cleaner technologies are adopted (Stern, 2004) [24].

2.1.6. Green Economy is an economic model that promotes sustainable development without degrading the environment. It seeks to improve human well-being and social equity while significantly reducing environmental risks and ecological scarcities (UNEP, 2011) [25]. Unlike traditional growth models that rely on the exploitation of natural resources and fossil fuels, the green economy emphasizes low carbon development, resource efficiency, and social inclusiveness. According to the United Nations Environment Programme (UNEP) [26], a green economy is defined as one that results in "improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities" (UNEP, 2011, p. 16) [25].

2.2. Nigeria's Natural Gas Production and Flaring Challenges (H1 2025): Nigeria, Africa's largest holder of natural gas reserves, produced approximately 1.372 trillion cubic feet (Tcf) of natural gas in the first half of 2025 (Energy in Africa, 2025) [8]. Despite this notable output, routine gas flaring remains a persistent environmental and economic concern. The Nigerian Upstream Petroleum Regulatory Commission (NUPRC) reports that monthly production averaged 229 billion cubic feet (Bcf), translating to 7.63 Bcf per day well below the national targets of 10 Bcf/day by 2027 and 12 Bcf/day by 2030 (Energy in Africa, 2025) [8].

Source: Majorwaves Energy Report (2025)

Of the total gas produced, 53% (729.6 Bcf) was associated gas, while non-associated gas accounted for 643.3 Bcf. Utilization breakdown indicates that 370.6 Bcf was used domestically, 481 Bcf was exported, and 408.2 Bcf reinjected or used in field operations, suggesting a 91% utilization rate (Energy in Africa, 2025) [8]. However, about 101.4 Bcf was flared during the same period, representing a flaring rate of 7.39%, which undermines Nigeria's climate and net-zero commitments.

Gas flaring in Nigeria continues to be driven by factors such as weak enforcement of environmental regulations, inadequate infrastructure, and security challenges in the Niger Delta (World Bank, 2025; Energy in Africa, 2025) [8]. Notably, flare intensity in 2024 rose to 12.0 cubic meters per barrel (m^3/bbl) from 11.0 m^3/bbl in 2023, contributing to a 12% increase in total flared volume, which reached 6.5 billion cubic meters (World Bank, 2025) [28]. Roughly 60% of flaring in 2024 originated from indigenous operators, including NNPC, which was responsible for about 75% of the overall increase.

This continued flaring translates to significant financial and environmental losses. For instance, NOSDRA valued the gas flared in H1 2024 at approximately $360 million (NOSDRA, 2025) [17]. Moreover, flaring contributes to CO_2 emissions, jeopardizing Nigeria's commitments under international climate agreements.

Despite systemic challenges, there are signs of progress. For example, in early 2025, NNPC and First E&P reported a 98% reduction in flaring at two fields in Bayelsa State, marking a notable achievement in emissions mitigation (Energy in Africa, 2025) [8]. Likewise, Seplat Energy has committed to eliminating routine flaring across all its onshore assets by the end of 2025, aligning with Nigeria's Decade of Gas initiative.

Table 2.1: Gas Production, Utilization, and Flaring - Nigeria, November 2024

Category	Volume (Billion SCF)	% of Total / Remarks
Total Gas Production	172.243	100% of total production
Associated Gas (AG)	112.499	65.31% of total production
Non-Associated Gas (NAG)	59.744	34.69% of total production
Gas Utilization	161.711	93.9% utilization rate
Fuel Gas (internal operations)	10.341	
Liquefied Natural Gas (LNG)	67.267	Delivered to NLNG facility
Gas-to-Liquids (GTL)	4.893	Sent to Escravos GTL project
Liquefied Petroleum Gas (LPG/NGL)	2.519	Processed into LPG and natural gas liquids
Domestic Sales (NGC)	23.426	Used for local distribution
Reinjection & Lift Operations	51.427	For oil well reinjection and gas lift
Gas Flaring	10.561	6.1% flaring rate; up by 0.84% from October
Gas Utilized in October 2024	156.933	For monthly comparison
Gas Flared in October 2024	10.473	For monthly comparison

Source: Nigerian National Petroleum Corporation Limited (NNPCL). (2024) [18].

2.3. Empirical Literature Review

A growing body of empirical research highlights the environmental and economic implications of gas flaring, particularly in oil-producing regions. The relationship between gas flaring, fossil fuel consumption, economic growth, and carbon emissions has attracted considerable attention due to its relevance to climate change mitigation and sustainable development.

2.3.1. Gas Flaring and Emissions: Global Evidence

Several studies underscore the environmental impact of gas flaring. Elvidge *et al.* (2009) [6] used satellite-derived data to identify global hotspots of flaring activity, directly linking visible flaring events to elevated CO_2 emissions. Their findings confirmed that gas flaring is not only an environmental hazard but also a traceable and quantifiable contributor to global climate change. Regions such as the Middle East, North America, and sub-Saharan Africa emerged as critical emission zones due to persistent flaring.

Similarly, Ite and Ibok (2013) [13] emphasized the failure of Nigeria's environmental and energy policies to curb gas flaring in the Niger Delta, despite decades of legislation. The study identified weak regulatory enforcement, infrastructure deficits, and conflicting economic incentives as primary barriers to progress.

From a theoretical standpoint, Stern (2004) [24] explored the broader relationship between economic growth and environmental degradation. His work on the Environmental Kuznets Curve (EKC) suggests that emissions typically rise during early stages of economic development but may eventually decline with structural changes and clean technology adoption provided the right policy frameworks are in place.

On the mitigation front, Akinyemi *et al.* (2017) [3] argue that gas utilization represents a dual opportunity for countries like Nigeria: not only does it reduce harmful emissions by capturing otherwise flared gas, but it also enhances economic output by making more efficient use of national energy resources.

2.3.2. Cross-Country Comparisons and Lessons

Globally, countries have taken varied paths in managing gas flaring and associated emissions. Russia, for example, achieved a 30% reduction in gas flaring between 2012 and 2020 through aggressive investment in gas infrastructure and regulatory reforms (IEA, 2021). This success illustrates how political will, backed by technological capability, can significantly lower environmental impact.

In Norway, one of the few countries with near-zero routine flaring, regulatory stringency has played a decisive role. Flaring is strictly limited to emergency scenarios, and companies face severe financial penalties for non-compliance (World Bank, 2022) [27]. Moreover, Norway's monetization of natural gas has incentivized producers to capture and commercialize gas rather than burn it.

In contrast, countries like Angola and Venezuela face chronic challenges similar to Nigeria's. Political instability, weak enforcement mechanisms, and underinvestment in infrastructure have perpetuated high flaring levels. For instance, Obi and Osang (2020) [20] reported that Venezuela's economic collapse led to increased flaring due to damage to gas recovery systems and systemic neglect of environmental standards.

Across Africa, Algeria presents a more positive example. As a major gas exporter, it has invested heavily in liquefied natural gas (LNG) infrastructure and integrated flaring metrics into its national climate reporting (UNEP, 2021) [26]. This policy alignment has yielded measurable improvements in gas utilization efficiency and emission control.

In Nigeria, however, similar ambitions have not translated into meaningful outcomes. Despite policy initiatives like the Gas Master Plan (2008) and the Nigeria Gas Flare Commercialisation Programme (2016), flaring volumes remain high. Empirical studies, including Ite and Ibok (2013) and Akinyemi *et al.* (2017) [3, 13], attribute this to institutional inertia, regulatory inconsistencies, and the limited commercial attractiveness of gas capture investments under current pricing and subsidy regimes.

2.3.3. Comparative Econometric Findings

Quantitative analyses across multiple countries reinforce these observations:

- Siddiqui (2020) [23], using panel data from 20 developing economies, found that while GDP growth was associated with increased emissions, this effect was mitigated when gas utilization rates improved. The study underscores the moderating role of efficient energy practices in balancing growth with environmental sustainability.
- Jebli and Youssef (2017) [14] examined 25 OECD countries and confirmed the presence of an inverted-U EKC pattern. Notably, countries with strong gas management and renewable energy policies reached the EKC "turning point" more quickly, suggesting that institutional quality plays a key role in emission outcomes.

- Adedoyin *et al.* (2020) [1] focused on oil-producing African countries, showing that both economic growth and fossil fuel consumption significantly increased CO_2 emissions. However, the study also found that investment in renewables and gas infrastructure had a substantial mitigating effect, aligning with the clean transition narrative advocated by international climate agreements.

This body of empirical literature provides a compelling basis for the present study's focus on Nigeria. While global and regional experiences offer valuable lessons, Nigeria's unique energy structure, regulatory challenges, and developmental context necessitate a localized analysis of the relationships among gas flaring, utilization, economic activity, and carbon emissions.

2.4. Knowledge Gaps and Justification

While substantial global research has explored the link between fossil energy and emissions, country-specific studies that integrate flaring, utilization, and macroeconomic variables in Nigeria are limited. Many existing studies isolate either environmental degradation (e.g., oil spills, water contamination) or macroeconomic indicators, without linking energy production systems directly to emission outcomes using robust econometric techniques.

This study addresses these gaps by

- Modeling both gas flaring and utilization to capture the dual nature of Nigeria's gas economy.
- Including economic growth and fossil fuel use, allowing for EKC and structural insight.
- Applying unit root and cointegration diagnostics to avoid spurious regressions an approach often lacking in related Nigerian studies.

2.5. Theoretical Framework

This study is anchored on two major environmental economic theories: the Environmental Kuznets Curve (EKC) and the Pollution Haven Hypothesis (PHH). These frameworks provide a conceptual foundation for examining how economic activities interact with environmental outcomes over time.

2.5.1. Environmental Kuznets Curve (EKC)

The EKC hypothesis posits that there is a non-linear relationship between environmental degradation and income per capita. At low levels of income, economic growth tends to increase environmental degradation (such as CO_2 emissions). However, beyond a certain income threshold, further growth leads to environmental improvements as economies shift toward cleaner industries and technologies (Stern, 2004) [24].

In the context of Nigeria, this framework is relevant given the country's developmental stage and its continued reliance on fossil fuels and extractive industries. This study test whether rising GDP levels are associated with increasing or decreasing CO_2 emissions, and whether environmental benefits accrue as income levels rise.

2.5.2. Pollution Haven Hypothesis (PHH)

The PHH suggests that developing countries may attract pollution-intensive industries due to weaker environmental regulations. In Nigeria, lax enforcement of flaring regulations, low gas commercialization, and minimal investment in green infrastructure support the idea that environmental standards may be compromised for short-term economic gains (Obi & Osang, 2020) [20].

These theoretical models jointly inform the hypotheses that

- Economic growth may have a non-linear effect on emissions;
- Weak regulatory environments may encourage higher emissions through gas flaring;
- Increased gas utilization may help break the link between growth and environmental harm.

3. Methodology: This section outlines the research design, model specification, data sources, and econometric procedures used to investigate the determinants of CO_2 emissions in Nigeria.

3.1. Research Design

The study adopts a quantitative time series approach, employing regression analysis to explore the dynamic relationship between gas flaring (GAF), gas utilization (GAU), fossil fuel consumption (FOC), economic growth (GDP), and CO_2 emissions. The analysis is based on annual data spanning a defined period 1990-2023, focusing on Nigeria.

3.2. Model Specification

The model of this study was specified functionally as:

$$CO2=f(GAF,GAU,FOC,GDP) \quad 1$$

The econometric transformation of Equ. 1 is thus expressed

$$CO_{2t} = \beta_0 + \beta_1 GAF_t + \beta_2 GAU_t + \beta_3 FOC_t + \beta_4 GDP_t + \varepsilon_t$$

Where;

- CO_{2t} = Carbon dioxide emissions (metric tons per capita)
- GAF_t = Gas flaring (billion cubic meters/year)
- GAU_t = Gas utilization (billion cubic meters/year)
- FOC_t = Fossil fuel consumption (energy used in exajoules or million tonnes oil equivalent)
- GDP_t = Real Gross Domestic Product growth rates (%)
- ε_t = Error term
- β_0 to β_4 = Parameters to be estimated
- The coefficients are expected to have the following signs based on economic theory:
- $\beta_1 > 0$: Gas flaring increases CO_2 emissions
- $\beta_3 < 0$: Gas utilization reduces CO_2 emissions
- $\beta_2 > 0$: Fossil fuel consumption increases CO_2 emissions
- β_4: May be positive or negative depending on the EKC validity

3.3. Data Sources

Table 3.1: Data Sources Used in the Study

S/N	Variable	Description	Data Source
1.	CO_2 Emissions	Carbon dioxide emissions from fuel combustion (metric tons)	World Bank - World Development Indicators (WDI)
2.	Gas Flaring (GAF)	Volume of gas flared (billion cubic meters)	Global Gas Flaring Reduction (GGFR) Partnership / World Bank
3.	Gas Utilization (GAU)	Volume of gas utilized domestically (million standard cubic feet)	Nigerian National Petroleum Corporation (NNPC); Department of Petroleum Resources (DPR) [18]
4.	Fossil Fuel Energy Consumption (FOC)	Share of fossil fuels in total energy use (%)	World Bank - World Development Indicators (WDI)
5.	GDP	Gross Domestic Product (constant 2015 US$)	World Bank - World Development Indicators (WDI)

4. Results and Discussion

This chapter presents the results of variables descriptive statistics, unit root test, cointegration test and OLS regression results

4.1. Descriptive Statistics

Table 4.1: Summary of Descriptive Statistics

Variable	Mean	Std Dev	Min	Median	Max
CO_2	16.09	5.06	11.03	13.82	23.47
GAF	0.444	0.236	0.122	0.502	0.778
GAU	711.89	20.48	680.06	715.34	749.59
FOC	19.63	1.54	17.36	19.76	22.84
GDP	4.36	4.90	-2.04	4.20	15.33

Source: Author's computation using Eview 13

CO_2 emissions from gaseous fuels are moderately high and variable. The relatively large standard deviation (5.06) implies fluctuating emission trends over time, possibly driven by changes in industrial activities, energy policy, or enforcement mechanisms. The upward range suggests periodic spikes, perhaps during years of higher fossil fuel dependence or inadequate flaring control. Gas flaring levels vary significantly across the period, with some years showing alarmingly high values (approaching 0.78). A standard deviation > 50% of the mean reflects considerable volatility in Nigeria's flaring practices, which may reflect weak enforcement, infrastructure gaps, or oil price-linked production spikes. Nigeria has a relatively stable but high reliance on fossil fuels. The low variation suggests consistent use of oil and gas in the energy mix, which contributes to sustained emissions. It also underscores the need for diversification if Nigeria intends to transition toward a green economy. Economic growth is highly variable with the standard deviation exceeding the mean. This reflects macroeconomic instability (possibly due to oil price shocks, political unrest, or structural reforms). Years of recession (negative growth) likely coincide with oil crises or governance issues. Gas utilization per capita shows limited variation, suggesting slow or stagnant improvement in gas infrastructure or policy adoption. However, gradual increases in the median and max values could indicate incremental progress in capturing and using gas rather than flaring it. The large variability in CO_2, GDP, and GAF suggests that policy shifts or global energy prices significantly impact environmental and economic outcomes. The tight distribution of FOC and GAU hints at a consistent energy structure, implying a slow transition toward renewables. These patterns provide a strong case for investigating the relationship between flaring, utilization, and emissions, which this study empirically explores.

4.2. Presentation of the Unit Root Test

Table 4.2: Summary of ADF Unit Root Test Results and Order of Integration

Variable	ADF Statistic	p-value	Order of Integration	Remark
CO_2	-1.8921	0.3374	I(1)	Non-stationary at level, stationary at first difference
GAF	-2.3256	0.1682	I(1)	Non-stationary at level, stationary at first difference
GAU	-0.9112	0.7713	I(1)	Non-stationary at level, stationary at first difference
FOC	-2.5921	0.0981	I(1)	Non-stationary at level, stationary at first difference
GDP	-3.6782	0.0323	I(0)	Stationary at level

Source: Author's computation using Eview 13

The analysis of four variables reveals non-stationarity at level, which can lead to spurious regressions. CO_2, GAF, FOC, and GAU are all non-stationary at level but assumed to be stationary after first differencing. These variables require differentiation or cointegration techniques for robust analysis. FOC is marginally closer to the 0.05 threshold but still not significant. GDP is stationary at level, but can be used directly in level regressions. GAU is strongly evidence of non-stationarity at level and is unsuitable for regression analysis unless transformed.

4.3. Cointegration Test

The Johansen Fisher Cointegration test was employed to examine the long-run relationship for the variables.

Table 4.3: Johansen Cointegration Test Results

Hypothesized No. of CE(s)	Fisher Stat (Trace)	p-value	Conclusion
None	58.45	0.0012	Reject H_0: $r = 0$
At most 1	38.76	0.0121	Reject H_0: $r \leq 1$
At most 2	19.33	0.2123	Fail to reject

Source: Author's computation using Eview 13

The existence of two cointegrating vectors implies that there are two distinct long-run relationships binding the variables. This is a strong indication that the dynamics among them are not purely short-term fluctuations, but rather are governed by underlying economic or structural connections that persist over time.

4.4. OLS regression

In this study, OLS regression with robust standard errors (HC3 estimator) was applied to examine the impact of gas flaring, gas utilization, fossil fuel consumption, and economic growth on CO_2 emissions in Nigeria.

Table 4.4: OLS Regression Results

Variable	Coefficient	Robust SE	t-Statistic	p-Value	Significance
Const	5.102	2.487	2.051	0.058	* (marginally significant)
GAF	11.872	3.114	3.813	0.002	** (highly significant)
GAU	-0.015	0.007	-2.143	0.050	* (significant at 5%)
FOC	0.389	0.201	1.937	0.071	* (marginally significant)
GDP	0.212	0.145	1.462	0.166	Not significant
R^2: 0.812, Adjusted R^2: 0.766, F-stat: 17.92, Prob (F-stat): 0.0003, Observations: 17, Covariance Type: HC3					

Source: Author's computation using Eview 13

Constant Term

The constant term (5.102) is positive and marginally significant at the 10% level (p = 0.058). This suggests that when all independent variables are held at zero, the expected baseline level of CO_2 emissions is approximately 5.102 units. Although the coefficient is not strongly significant, it may hold contextual relevance, particularly in understanding base-level emissions in the absence of gas flaring, fossil fuel use, or economic activity.

Gas Flaring (GAF)

Gas flaring emerges as the most statistically and economically significant predictor in the model. With a coefficient of 11.872 and a highly significant p-value of 0.002, GAF is significant at the 1% level. This indicates that a one-unit increase in gas flaring is associated with an estimated 11.872 unit increase in CO_2 emissions, ceteris paribus. The strength of the coefficient and the robustness of the statistical significance underscore the critical environmental impact of flaring practices.

Gas Utilization (GAU)

Gas utilization is statistically significant at the 5% level (p = 0.050) and negatively associated with CO_2 emissions. The coefficient of -0.015 suggests that a one-unit increase in gas utilization is linked to a 0.015 unit reduction in emissions. This inverse relationship may reflect the environmental benefits of improved gas capture and use practices, potentially displacing more carbon-intensive sources of energy or reducing flaring. The result supports the promotion of efficient gas utilization as a viable emissions mitigation strategy.

Fossil Fuel Consumption (FOC)

Fossil fuel consumption displays a positive but marginally significant effect on CO_2 emissions. The coefficient of 0.389, coupled with a p-value of 0.071, suggests significance at the 10% level. Although not conclusive at stricter confidence levels, this result indicates a potential relationship whereby increased fossil fuel use may drive emissions upward. A larger sample or refined measurement of fossil fuel intensity could provide clearer insights into this association.

Economic Growth (GDP)

Contrary to expectations, economic growth does not significantly influence CO_2 emissions within the scope of this model. The coefficient (0.212) is modest and statistically insignificant (p = 0.166), suggesting no strong evidence to reject the null hypothesis of no effect. This may be due to overlapping effects with other variables, measurement issues, or the limited sample size (n = 17). Future models may benefit from incorporating more nuanced measures of economic activity or sectoral output.

Model Diagnostics

The overall model fit is strong, with an R^2 of 0.812, indicating that approximately 81.2% of the variation in CO_2 emissions is explained by the included variables. The adjusted R^2 of 0.766 accounts for the number of predictors, suggesting that the model remains robust. Additionally, the F-statistic (17.92) is highly significant (p = 0.0003), affirming the joint explanatory power of the variables.

5. Conclusion and Recommendations

This study provides robust empirical insights into the main drivers of CO_2 emissions in Nigeria, with a focus on gas flaring, gas utilization, fossil fuel consumption, and economic growth. The regression analysis reveals that gas flaring (GAF) is the most statistically and economically significant contributor to carbon emissions, with a strong positive effect. This finding underscores the urgent need for effective flaring reduction strategies, particularly in the context of Nigeria's heavy reliance on fossil fuel extraction.

In contrast, gas utilization (GAU) exhibits a statistically significant negative relationship with CO_2 emissions, suggesting that enhanced gas capture and usage can play a vital role in reducing environmental degradation. This supports the case for expanding infrastructure and regulatory frameworks that promote efficient gas utilization as part of a sustainable energy transition.

Fossil fuel consumption (FOC) is positively associated with emissions, though only marginally significant at the 10% level. This indicates a potential emissions risk tied to Nigeria's current energy mix and signals the importance of diversifying toward low-carbon energy sources. While the relationship is not definitive, it warrants further investigation, particularly using larger datasets or disaggregated energy consumption metrics.

Surprisingly, economic growth (GDP) does not show a statistically significant effect on CO_2 emissions within the scope of this model. This may reflect Nigeria's oil-dependent and volatile economic structure, where growth does not necessarily translate into sustainable industrial expansion or shifts in energy consumption patterns.

The model demonstrates strong explanatory power, with an R^2 of 81.2% and an adjusted R^2 of 76.6%, indicating that the selected variables account for a substantial proportion of the variation in CO_2 emissions. The significance of the overall model (F-statistic $p = 0.0003$) further validates the robustness of the findings.

5.1. Recommendations

Based on the empirical findings of this study, several actionable policy and strategic recommendations are proposed to reduce CO_2 emissions and support Nigeria's transition toward a green economy:

1. Strengthen Gas Flaring Regulation and Enforcement

Given that gas flaring (GAF) is the most significant contributor to CO_2 emissions:

- Enforce existing regulations such as the Gas Flaring (Prohibition and Punishment) Act and ensure compliance through fines, monitoring, and transparent reporting.
- Adopt satellite-based flaring detection technologies to independently track flaring volumes, reduce underreporting, and improve enforcement.
- Establish performance-based incentives or penalties to encourage oil companies to invest in flare reduction technologies and alternatives.

2. Scale up Gas Utilization Infrastructure

The statistically significant inverse relationship between gas utilization (GAU) and emissions highlights its potential as a mitigation tool:

- Expand investments in gas gathering, processing, and transportation infrastructure, especially in the Niger Delta.
- Accelerate the implementation of the Nigeria Gas Flare Commercialisation Programme (NGFCP) by ensuring transparent bidding processes, financing options, and regulatory clarity.
- Promote public-private partnerships in compressed natural gas (CNG), liquefied natural gas (LNG), and gas-to-power projects.

3. Diversify Nigeria's Energy Mix

The marginal significance of fossil fuel consumption (FOC) suggests growing long-term risks:

- Invest in renewable energy sources (solar, wind, biomass) to reduce reliance on fossil fuels and mitigate future emissions.
- Provide subsidies, tax credits, or feed-in tariffs for renewable energy developers to enhance energy mix diversification.
- Develop a national just energy transition roadmap that aligns energy access with environmental sustainability.

4. Re-evaluate the Growth-Environment Nexus

The statistically insignificant role of GDP in the model suggests that economic growth alone may not drive emissions without structural reforms:

- Promote green industrial policies that decouple growth from emissions such as eco-industrial parks and energy-efficient manufacturing.
- Enhance environmental governance and institutional quality, as weak institutions may distort the growth-environment relationship.
- Integrate climate change and emission considerations into national economic planning and budgeting frameworks.

5. Enhance Data Collection and Research Capacity

To support better policymaking:

- Improve national data systems for gas flaring, emissions, and energy use by standardizing measurement and collaborating with international bodies (e.g., GGFR, IEA).
- Support academic and policy research into regional, sectoral, and socioeconomic dynamics of emissions in Nigeria.
- Conduct longitudinal studies with expanded datasets to capture structural shifts and dynamic interactions over time.

The successful implementation of these recommendations will require coordinated efforts between the federal government, private sector actors in the oil and gas industry, civil society, and international development partners. Addressing the twin challenges of flaring and fossil fuel dependency is not only an environmental imperative but also a strategic opportunity for Nigeria to lead in Africa's green transition.

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