Mineral Production and Carbon Dioxide Emissions in Nigeria

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Abstract
This study investigated the effect of mineral production on carbon dioxide (CO2) emissions in Nigeria over the period 1989 to 2024, using mining and quarrying, crude petroleum and natural gas production, coal production, and metal ores as proxies for mineral production. Anchored on the Environmental Kuznets Curve hypothesis and estimated with the Autoregressive Distributed Lag (ARDL) bounds-testing approach, the study draws on annual time-series data sourced from the Central Bank of Nigeria Statistical Bulletin and the World Development Indicators of the World Bank. Augmented Dickey-Fuller unit root tests confirmed a mixed order of integration among the series, justifying the ARDL framework, while the bounds test confirmed a long-run cointegrating relationship among the variables. The results showed that mining and quarrying, crude petroleum and natural gas production, and coal production each exert a positive and statistically significant effect on CO2 emissions in both the short run and the long run, while metal ores exert a positive but statistically insignificant effect. Diagnostic checks confirmed that the estimated model is normally distributed, free of serial correlation and heteroscedasticity, correctly specified, and stable. The study concluded that mineral production is a significant driver of carbon emissions in Nigeria and recommends stricter enforcement of environmental regulation, incentives for cleaner extraction technologies, and diversification away from emission-intensive mineral production.

Keywords: *Mineral production, carbon dioxide emissions, ARDL bounds test, Environmental Kuznets Curve, Nigeria*

1.0 Introduction

Nigeria holds one of the largest and most varied mineral endowments in Africa, with over forty commercially viable minerals identified across more than five hundred sites in all thirty-six states and the Federal Capital Territory. As government policy increasingly looks to mineral production to diversify the economy away from oil dependence, extraction activity in mining and quarrying, crude petroleum and natural gas, coal, and metal ores has become an important source of revenue, employment, and industrial growth. Yet the same extraction processes that generate this economic value are widely implicated in environmental harm: land degradation from open-pit and artisanal mining, contamination of water bodies with heavy metals, and the release of dust and combustion gases into the atmosphere are all well documented consequences of mineral extraction in Nigeria. Among these environmental consequences, carbon dioxide emissions are of particular concern because they connect Nigeria's domestic mineral policy to its international climate commitments.

Mining, drilling, and processing activities burn fuel, flare gas, and disturb carbon sinks, all of which raise atmospheric CO2 concentrations. Despite the scale of Nigeria's mineral sector, empirical evidence quantifying how specific mineral production activities affect CO2 emissions remains limited, with much of the existing literature instead focused on the relationship between solid minerals and economic growth. This study addresses that gap by empirically estimating the short-run and long-run effects of mining and quarrying, crude petroleum and natural gas production, coal production, and metal ores on CO2 emissions in Nigeria between 1989 and 2024, using the ARDL bounds-testing approach.

2.0 Literature Review and Theoretical Framework

The study is anchored on the Environmental Kuznets Curve (EKC) hypothesis, which posits an inverted U-shaped relationship between economic activity and environmental degradation: pollution rises in the early stages of resource-based industrial expansion and declines only once income and institutional capacity for regulation reach a sufficiently high threshold. This framework is complemented by ecological economics theory, which emphasizes that extractive economic activity draws down natural capital and generates residual waste that the environment must absorb, and by limits theory, which stresses that resource extraction and pollution cannot expand indefinitely without breaching ecological thresholds.

A number of Nigerian studies have examined the solid minerals sector, but the bulk of this literature centers on the sector's contribution to economic growth, gross domestic product, or revenue diversification rather than on its environmental cost. Where environmental outcomes have been examined, studies have often relied on aggregated proxies for mineral production or have paired extraction activity with broad measures of pollution without disaggregating by mineral type. The present study extends this literature by disaggregating mineral production into mining and quarrying, crude petroleum and natural gas production, coal production, and metal ores, and by applying rigorous pre- and post-estimation diagnostics to establish the robustness of the estimated relationship with CO2 emissions.

3.0 Methodology

The study adopted an ex-post facto research design, appropriate because the phenomena under investigation had already occurred and could not be manipulated by the researcher. Annual time-series data spanning 1989 to 2024 were sourced from the Central Bank of Nigeria (CBN) Statistical Bulletin and the World Development Indicators (WDI) of the World Bank. Mineral production is proxied by mining and quarrying (MQA), crude petroleum and natural gas production (CPP), coal production (COP), and metal ores (MOS); CO2 emissions (CO2) serve as the dependent variable representing environmental degradation.

Model Specification

The functional form of the model is specified as:

$CO2 = f\,(MQA, CPP, COP, MOS)$

which, expressed in linear econometric form with a stochastic error term, becomes:

$CO2t = \beta 0 + \beta 1MQAt + \beta 2CPPt + \beta 3COPt + \beta 4MOSt + \mu t$

The a priori expectation is that β1, β2, β3, and β4 are all greater than zero, reflecting the theoretical expectation that mineral production activities raise, rather than lower, CO2 emissions. The long-run and short-run ARDL specifications follow the standard error-correction representation of

Pesaran, Shin, and Smith (2001), allowing the short-run dynamics and the speed of adjustment to long-run equilibrium to be estimated jointly with the long-run coefficients.

Estimation Technique

Given that the study's variables exhibit a mixed order of integration, the Autoregressive Distributed Lag (ARDL) bounds-testing approach of Pesaran, Shin, and Smith (2001) is adopted, since it accommodates a combination of I(0) and I(1) series without requiring all variables to be integrated of the same order. Prior to estimation, the Augmented Dickey-Fuller (ADF) test is used to determine the order of integration of each series. The ARDL bounds test is then used to establish whether a long-run cointegrating relationship exists, after which the short-run and long-run coefficients are estimated. Model adequacy is assessed using the Jarque-Bera normality test, the Breusch-Godfrey serial correlation LM test, the Breusch-Pagan-Godfrey heteroscedasticity test, the Ramsey RESET functional form test, and the CUSUM stability test.

4.0 Results and Discussion

Table 1: Descriptive Statistics

Statistic	CO2	MQA	CPP	COP	MOS
Mean	46.137	6955.889	6922.330	6.153	3.196
Median	46.995	6855.610	6832.305	4.225	2.000
Maximum	54.464	9323.750	9294.050	27.500	9.120
Minimum	33.153	4391.420	4231.900	1.710	0.870
Std. Dev.	5.522	1301.972	1287.140	5.405	2.688
Observations	36	36	36	36	36

Source: Author's computation (2025), E-Views 12.0.

Table 4.1 presented the descriptive statistics of the study variables over the 1989–2024 period. CO2 emissions averaged 46.14 (metric tons per capita equivalent index) with a standard deviation of 5.52, indicating moderate dispersion around the mean. Mining and quarrying and crude petroleum and natural gas production show the widest dispersion, each with means above 6,900 and standard deviations exceeding 1,280, reflecting the volatility of Nigeria's extractive output over the study period. Coal production and metal ores, by contrast, recorded comparatively low means, though coal production's Jarque-Bera statistic indicates a marked departure from normality

Table 2: Unit Root Test

Variable	ADF (Level)	ADF (1st Diff.)	5% Critical Value	Order of Integration
LOG(CO2)	-2.973937	—	-2.948404	I(0)
LOG(MQA)	-1.060965	-6.460233	-2.948404 / -2.951125	I(1)
LOG(CPP)	-1.337575	-6.687628	-2.948404 / -2.951125	I(1)
LOG(COP)	-1.614437	-3.378069	-2.948404 / -2.951125	I(1)
LOG(MOS)	-3.556388	—	-2.948404	I(0)

Source: Author's computation (2025), E-Views 12.0.

The Augmented Dickey-Fuller test results in Table 2 showed that CO2 and metal ores (MOS) are stationary at level, I(0), while mining and quarrying (MQA), crude petroleum and natural gas production (CPP), and coal production (COP) are stationary only after first differencing, I(1). This mixed order of integration justifies the choice of the ARDL bounds-testing approach over conventional cointegration methods that require all series to be integrated of the same order.

Table 3: Bounds Cointegration Test

Significance Level	I(0) Bound	I(1) Bound
10%	2.20	3.09
5%	2.56	3.49
2.5%	2.88	3.87
1%	3.29	4.37

Computed F-statistic: 7.583030 (unrestricted intercept, no trend, k = 4). Source: Author's computation (2025), E-Views 12.0.

Table 3 presented the results of the ARDL bounds cointegration test. The computed F-statistic of 7.583030 exceeds the upper bound critical values of 3.09, 3.49, 3.87, and 4.37 at the 10%, 5%, 2.5%, and 1% significance levels respectively. The null hypothesis of no cointegration is therefore rejected, confirming a long-run equilibrium relationship among CO_2 emissions, mining and quarrying, crude petroleum and natural gas production, coal production, and metal ores.

Table 4: ARDL Short-Run and Long-Run Estimates

Variable (Long-Run)	Coefficient	Std. Error	t-Statistic	Prob.
LOG(MQA)	0.606929	0.109486	5.543450	0.0002
LOG(CPP)	0.735426	0.181848	4.044173	0.0023
LOG(COP)	0.264065	0.041762	6.323110	0.0001
LOG(MOS)	0.081710	0.130850	0.624457	0.5463
Constant	4.659203	1.540833	3.023821	0.0128

CointEq(-1) = -0.256934 (Std. Error 0.033750; t = -7.612920; Prob. 0.0000). R^2 = 0.803283; Adjusted R^2 = 0.770118; Durbin-Watson stat = 2.824520. Source: Author's computation (2025), E-Views 12.0.

Table 4 showed that the estimated short-run and long-run coefficients of the ARDL model, with LOG(CO2) as the dependent variable. In the long run, mining and quarrying, crude petroleum and natural gas production, and coal production all exert a positive and statistically significant effect on CO_2 emissions ($p < 0.05$), consistent with the a priori expectation that mineral extraction activity raises carbon emissions. A one-unit increase in mining and quarrying is associated with a 0.61 unit increase in CO_2 emissions in the long run; a one-unit increase in crude petroleum and natural gas production is associated with a 0.74 unit increase; and a one-unit increase in coal production is associated with a 0.26 unit increase. Metal ores exert a positive but statistically insignificant effect ($p = 0.5463$), suggesting that, unlike the other three mineral categories, metal ore extraction has not been a significant driver of CO_2 emissions over the study period. The short-run estimates mirror this pattern in sign and significance for the contemporaneous terms of mining and quarrying, crude petroleum and natural gas production, and coal production.

The error correction coefficient of -0.256934 is negative, statistically significant, and correctly signed, indicating that approximately 26 percent of any deviation from long-run equilibrium is corrected within one year. The adjusted R-squared of 0.770118 indicates that mineral production variables jointly explain about 77 percent of the variation in CO_2 emissions, while the Durbin-Watson statistic of 2.824520 indicates the absence of serial autocorrelation in the model residuals.

Table 5: Post-Estimation Diagnostics

Test	Null Hypothesis	Statistic	Prob.
Jarque-Bera Normality	Residuals normally distributed	1.445560	0.4854
Breusch-Godfrey LM	No serial correlation	2.732610	0.1246
Breusch-Pagan-Godfrey	Homoscedasticity	1.046922	0.4929
Ramsey RESET	Correct functional form	3.385034	0.0989

Source: Author's computation (2025), E-Views 12.0.

All four diagnostic tests fail to reject their respective null hypotheses at the 5 percent level, indicating that the model residuals are normally distributed, free of serial correlation, and homoscedastic, and that the model's functional form is correctly specified. The CUSUM stability test further shows that the cumulative sum of recursive residuals remains within the 5 percent critical bounds throughout the sample period, confirming the stability of the long-run coefficients.

Discussion of Findings

The results provided a strong empirical support for the view that mineral production is a significant driver of carbon emissions in Nigeria. Mining and quarrying, crude petroleum and natural gas production, and coal production each raise CO_2 emissions significantly in both the short run and the long run, consistent with the ecological economics premise that resource extraction draws down environmental capital and generates residual atmospheric waste. The insignificant effect of metal ores may reflect the comparatively smaller and less energy-intensive scale of metal ore extraction relative to petroleum, gas, and coal activities in Nigeria over the study period. These findings align with the broader literature linking fossil-fuel-based extraction to rising carbon emissions, while extending that literature by disaggregating mineral production into its component categories for the Nigerian case.

5.0 Conclusion and Recommendations

This study examined the effect of mineral production on carbon dioxide emissions in Nigeria between 1989 and 2024 using the ARDL bounds-testing approach. The findings show that mining and quarrying, crude petroleum and natural gas production, and coal production each have a positive and statistically significant effect on CO_2 emissions, while metal ores exert a positive but insignificant effect. The study concludes that mineral production, particularly fossil-fuel-linked extraction, is a significant contributor to carbon emissions in Nigeria.

Recommendation

Based on these findings, the study recommends that:

(i) the Nigerian government strengthen enforcement of existing environmental protection laws, including the Environmental Impact Assessment Act and the National Environmental Standards and Regulations Enforcement Agency Act, with stricter monitoring of extraction activity;

(ii) policymakers incentivize the adoption of cleaner and more energy-efficient extraction and processing technologies through tax rebates or green financing, particularly in the petroleum, gas, and coal sub-sectors;

(iii) government expand investment in non-extractive sectors such as agriculture, manufacturing, and renewable energy to reduce the economy's carbon intensity;

(iv) regulators strengthen community-based environmental monitoring to improve accountability in mining regions. Future research could extend this analysis using panel data across African countries or quarterly data to capture short-term dynamics more precisely.

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