Solid Mineral Production and Environmental Pollution

Dr Victor AKIDI[1*], Dr Ibeinmo Friday COOKEY[2] & Isaac Olubiyi OLADOSU[3]

[1,2]Department of Economics, Rivers State University, Nkpolu-Oroworukwo, Port Harcourt Rivers State, Nigeria.

[3]Department of Economics, University of Port Harcourt, Nigeria.

[*]Corresponding Author

DOI: https://doi.org/10.51244/IJRSI.2024.1108090

Received: 06 August 2024; Accepted: 13 August 2024; Published: 14 September 2024

ABSTRACT

The study empirically diagnosed the effects solid minerals production had on environmental pollution in Nigeria. Covering a data period of 1986 to 2022, the study utilized mining and quarrying, metal ores and coal production as forms of solid mineral production while carbon (CO_2) emission is employed as proxy for environmental pollution. Yearly time series information from the Nigeria's Apex Bank's statistical bulletin and the Development Indicators' data base of the World Bank were gathered on the variables, and were examined by applying the analytical processes of the Autoregressive Distributive Lag econometric technique. The resultant outcomes of the study established that except mining and quarrying that was integrated at level, CO_2 emission, metal ores and coal production were stable at first differencing. Particularly, the dynamic study confirmed that mining and quarrying, metal ores and coal production activities exerted positively substantial effects on carbon emission in Nigeria in the short run and long run. Premised on the results, it is concluded that solid mineral production substantially contributes to environmental pollution in Nigeria. The study recommended among others that government should ensure implementation of the mineral development plan in order to ensure environment friendly solid mineral production processes.

Keywords: Solid Mineral Production, Environmental Pollution, Mining and Quarrying, Metal Ores, Coal Production, CO_2 Emission

INTRODUCTION

Possessing abundant natural resources is great blessing for a country to boost its economy and compete on a global scale. When it comes to enhancing a country's economic progress, solid minerals are critical. Such minerals have the potential to improve national income and generate foreign currency, in addition to creating jobs and attracting investments in related businesses. The vast mineral wealth of Nigeria extends from the northern states of Jos (tin and columbite), Edo (lead), and Enugu (coal) to the states of Enugu and Ogun (limestone), and from the states of Edo and Enugu throughout the nation. Gemstones, marble, granite, gypsum, lithium, talc, silver, bitumen, coal, barite, bentonite, limestone, tantalite/columbite, iron ore, lead/zinc, gemstones, and more are among the more than 40 mineral kinds distributed throughout the nation (KPMG, 2014). Given the vast quantities of solid minerals spread out across Nigeria's various geographical zones, Edeme and Nkalu (2019) argued that mining and processing these resources could help the country's economy grow quickly, generate more income, employ more people, and alleviate poverty. Because of its importance in generating jobs and its capacity to spur fast economic development, solid mineral production is a critical sector for Nigeria's economic diversification.

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XI Issue VIII August 2024

Nevertheless, environmental contamination is a major risk associated with solid mineral production. Solid mineral extraction has substantial health and environmental implications at every level, in congruent with Ouadadi (2020). Agriculture, flora, and wildlife have all been profoundly impacted, and the mining and quarrying employees' and the general public's health is at risk. It also adds to environmental deterioration and pollution. Therefore, research on the environmental impact of solid mineral extraction has shown that the availability and extraction of natural resources, especially solid mineral resources, degrade environmental quality. That is to say, environmental contamination results from the extraction of solid minerals. The extraction and processing of solid minerals in Nigeria have resulted in environmental damage in agreement with (Odoh, Akpi, & Anyah, 2017). The extent of this damage varies. Changes to the ecological condition, contamination of the air, water, and soil, extinction of plant and animal life, deterioration of landscapes, radiation emissions, and loss of vegetation are all known results. Additionally, mineral production causes air, water, and land contamination to varied degrees, depending on the stage and size of activity. The search of solid minerals causes very little pollution, but the extraction processes, especially when done on a large scale, cause far more severe air and water pollution. This means that the extraction of limestone and other rocks for building purposes on a big scale is the single most polluting activity in the world.

There is a wide range of intensities in the mining and processing of solid minerals in Nigeria, thanks to the country's rich mineral resources. Unfortunately, many of these activities and the harm they do to the environment, ranging from degradation of land, ecological upheaval leading to pollution of air, land, and water, and to the extinction of species go unregulated. Inadequate regulatory implementation impetus or the little revenue accruing from these sources means that these disturbing situations and means to minimise them have surprisingly not been taken seriously. The revenue is so small that it does not even meaningfully contribute to Nigeria's Gross Domestic Product (GDP). The development of the solid minerals sub-sector, the improvement of solid minerals production, and the reduction of harmful environmental consequences resulting from this sector have all been priorities for succeeding administrations in Nigeria. There are a number of important statutes and executive orders pertaining to minerals and mining, including the Minerals and Mining Act of 2007, the Minerals and Mining Regulations of 2011, the Presidential Retreat on Solid Minerals in August 2013, and others. Despite their best efforts, the sector's contribution to the nation's GDP remained below 1% from 1981 to 2020, indicating that the growth in measures has been pitiful at best. The sector's impact is quite little. The contribution of solid minerals fell from 0.44 percent in 1981 to 0.15 percent in 1990, 0.08 percent in 2000, and 0.09 percent in 2010 in congruent with a study from the Central Bank of Nigeria (CBN) in 2021. Nevertheless, it increased slightly to 0.33% in 2015, 0.50% in 2018, and 0.45% in 2020, respectively. Meanwhile, the solid mineral sub-sector has persisted in its contribution to environmental pollution in Nigeria, despite the many initiatives and policies implemented by successive administrations.

Following the above stated disturbing conditions, this current study is set out to empirically examine the effects of solid minerals production on environmental pollution in Nigeria. This study specifically diagnosed:

i. the effect of mining and quarrying on environmental pollution indicated as carbon dioxide emission,

ii. the impact of metal ores production on environmental pollution measured as carbon dioxide emission, and

iii. the implication of coal production on environmental pollution indexed as carbon dioxide emission.

Furthermore, to ascertain the specific goals of this research which aim are to empirically investigate the implications of the selected components of solid minerals production on environmental contamination in Nigeria in terms of polluting the air by carbon dioxide emission, the methodological process of the autoregressive distributed lag (ARDL) approach shall be applied. This decision will be predicated on the

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XI Issue VIII August 2024

principles associated with the pre-diagnostic analyses such as the unit root and cointegration tests' outcomes of the variables for the data period of 1986 to 2022. More so, the main expected finding from this study is to investigate whether or not activities of the selected indicators of solid minerals production have over the chosen sample period significantly decreased or increased Nigeria's environmental air pollution. By so doing, the concluded report of this study shall as contribution importantly add to the existing body of empirical literature. Also, another expected important contribution of this research is that the outcome shall necessarily induce public commentators, policy analysts and makers in both domestic and international communities to intensify efforts at advocacy and making of suitable policies for mitigating possible environmental air pollutants.

RELATED LITERATURE REVIEW

Theoretical Literature

This study is underpinned on Environmental Kuzsnets Curve (EKC) Hypothesis, presented as discussed below:

Environmental Kuznets Curve (EKC) Hypothesis

As economic development progresses, pollution and other types of environmental degradation become more severe, thus agreeing with the Environmental Kuznets Curve (EKC) theory, which hypothesizes a reversed U-shaped association between carbon emissions and per capita income of an economy. Kuznets, an economist, proposed the idea that pollution levels are inversely proportional to income levels, and the EKC is named for him. The primary idea underpinning EKC is that pollution levels rise in tandem with a country's industrialization because rising incomes lead to more resource exploitation. Cleaner energy sources are more accessible and affordable as people's disposable income grows and their awareness of environmental issues grows. Consequently, leading to a decrease in pollutant emissions after a certain time frame. Here we see the inverted U-shape in action. The Environmental Kuznets Curve theory, first proposed by Grossman and Krueger (1991), has the form of an inverted U. Beckerman (1992) argues that affluence is the greatest weapon against environmental degradation. In the field of resource and environmental economics, the concept has been "stylized" (e.g., Cole & Neumayer, 2005). In general, the production of solid minerals is strongly associated with environmental degradation. But there are ways to dampening the impact of these two interconnected problems. One is to adopt more eco-friendly technologies. Another is to boost economic production in general and pollution levels in particular via technical advancements as well as employing government policy options. There may be future constraints on how much these connections may be severed due to scepticism about the possibility of limitless replacement or technical advancement.

Empirical Review

Investigating the driving role of solid mineral sector on the Nigeria's economic growth spanning the data series period, beginning from 1980 and ending in 2020, Nwogwugwu, Nwokoye and Ebenebe (2021) employed the Canonical Cointegrating Regression model of analysis on Nigeria's solid mineral – growth nexus. The results established substantial positive effect of solid mineral production on economic growth and that solid mineral depletion could retard economic growth. Also employing qualitative analysis, Adeniyi, Adeleke and Olabode (2013) concluded in their study that the solid mineral subsector remains crucial for deepening growth. Utilising the methodology of Autoregressive Distributed Lag (ARDL) on Nigeria's data over 1981 to 2019, Muftau and Onaopemipo (2022) generated that insubstantial positive influence is exerted on growth by solid mineral development. In similar study, Ajie, Okoh and Ojiya (2019) found long-run equilibrium relationship and that the Ordinary Least Squares diagnosis revealed increasing effect of solid mineral resources (quarrying, bauxite, metal ores, iron ore, coal etc.) on Gross Domestic Product in Nigeria. As empirically established by Edeme, Onoja and Damulak (2018), solid minerals

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XI Issue VIII August 2024

production had substantial positive implication on the economic growth (GDP per capita) of Nigeria over the sampled period 1960 to 2015, applying the Ordinary Least Squares approach. In a study to ascertaining the linkages between investment, solid minerals and economic growth, applying the multivariate vector autoregressive (VAR) model on yearly series from 1981-2016, Mbah, Mgbemena and Mbah (2019) reported insubstantial link from domestic investment to solid minerals in Nigeria, foreign direct investments directly but weakly impacted solid minerals production while foreign portfolio investments to Nigeria negatively impacted on solid minerals development.

Researching on how trade openness influenced the growth of Nigeria's solid mineral sub-sector from 1981 to 2020, Nwinyodee and Kerebana (2022) utilised Autoregressive Distributed Lag (ARDL) analysis to find that openness of trade negatively implicated on the sub-sector, likely because of crude practices. Contributions of the mineral mining sector to sustainable development and poverty reduction in Nigeria were the basis of the historical analysis by Erhun (2015). With the goal of providing solutions to enhance Nigeria's mineral mining business, which may help reduce poverty and boost development, a framework of enhanced rules, laws, and regulations for mining activities was proposed. Finding out how solid minerals have affected Nigeria's efforts to diversify its economy requires a mix of qualitative and quantitative research methods. In their 2013 study, Akongwale, Ayodele, and Udefuna demonstrated that the solid mineral subsector might have a substantial impact on Nigeria's economy. As a substitute for petroleum, a very unpredictable source of foreign currency revenues for the nation, Danmola and Wakili (2013) investigated the possibilities of solid mineral resources. In congruent with the research, the solid mineral subsector may be developed into a major source of foreign currency for the nation if all three levels of government work together. In addition to creating jobs, solid mineral development is anticipated to provide a steady supply of raw materials for local industry, generate foreign currency, and benefit emerging nations like Nigeria.

Literature Gap

After examining several studies on solid mineral production and environmental pollution in Nigeria, it was observed that there have been various studies conducted on the impact of solid mineral production on the economy, likewise the impact of environmental pollution on economic growth. However, none of these studies have conducted empirical research on the impact of solid mineral extraction on environmental contamination, particularly in the Nigerian setting. Thus, this research aimed to address such gap contribute to the existing body of literature by conducting an empirical inquiry into the impact of solid minerals extraction on environmental pollution in Nigeria over the sampled period of 1986 to 2022.

MODEL AND METHODOLOGY

For this study, the researchers utilised an ex-post facto variant research design. Additionally, this study relied mainly on library research as it utilised preexisting yearly time series data that extended from 1986 to 2022 and had been collected from the World Bank's World Development Indicators and the Central Bank of Nigeria's (CBN) yearly bulletin.

In effort to examine the specific objectives of this study suing gathered data for the variables, the model for this study is theoretically underpinned on the Environmental Kuznets Curve (EKC) Hypothesis, which posits that environmental contamination grows as society explores more natural resources (solid minerals in this case) in her drive to improve economic performance, Kuznets (1955). The primary idea is that pollution levels rise in similar direction with a country's industrialization because rising incomes lead to more resource exploration, thus, there is expectedly direct relationship between solid minerals (natural resources) production and environmental pollution in terms of carbon dioxide emission.

In addition, the empirical model for this study is a modification from Nwogwugwu, Nwokoye and Ebenebe (2021) whose study on the nexus between solid mineral development and economic growth in Nigeria

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XI Issue VIII August 2024

modelled that:

$$ECOG = \Omega_1 TEC_t + \Omega_2 CAP_t + \Omega_3 LAB_t + \Omega_4 R_t + \Omega_5 SOMP_t + \Omega_6 SOME_t + \Omega_7 SOMD_t \qquad (3.1)$$

Where ECOG is economic growth, TEC is technological change, CAP is growth rate of capital, LAB is growth rate of labour, R is solid mineral resources, SOMP is solid mineral production, SOME is solid mineral export and SOMD is solid mineral depletion. Therefore, away from their model and incorporating all the variables chosen as well as aligning with the aim and objectives of the present study, the functional specification of the model is presented as:

$$COE = f\,(M\&Q, MTO, COP) \qquad (3.2)$$

To show the linear mathematical relationship, the model can be written as;

$$COE_t = \boldsymbol{\delta_0} + \boldsymbol{\delta_1} M\&Q_t + \boldsymbol{\delta_2} MTO_t + \boldsymbol{\delta_3} COP_t \qquad (3.3)$$

Including the stochastic or error term (ε_t) in our econometric model, our model will become;

$$COE_t = \boldsymbol{\delta_0} + \boldsymbol{\delta_1} M\&Q_t + \boldsymbol{\delta_2} MTO_t + \boldsymbol{\delta_3} COP_t + \mu t \qquad (3.4)$$

The log linear model is specified below;

$$LOG\,COE_t = \boldsymbol{\delta_0} + \boldsymbol{\delta_1} LOG\,M\&Q_t + \boldsymbol{\delta_2} LOG\,MTO_t + \boldsymbol{\delta_3} LOG\,COP_t + \mu t \qquad (3.5)$$

Where: COE = CO_2 emissions, M&Q = mining and quarrying, MTO = metal ores, COP = coal production, $\boldsymbol{\delta_0}$ = constant variable or regression intercept, $\boldsymbol{\delta_1}$ **-** $\boldsymbol{\delta_3}$ = parameter estimates, μt = error term.

Technically, to enable empirical testing of the specified model, the summary statistics for checking the idiosyncratic behaviour of the variables whether or not they followed normal distribution shall be undertaken, as this will present insight to the next suitable empirical step to be taken. Particularly, when the Jarque-Bera statistics establishes mixed normality of the variables, it necessitates the conduct of unit roots tests of the individual variables. The unit roots tests shall be employed to determine the order of integration of each variable (Dickey and Fuller, 1981). To achieve this, the study applied the Augmented Dickey-Fuller (ADF) test for unit root at 5%. Decision will rely on accepting the alternative hypothesis of no unit root against the null hypothesis of unit root. The general form of ADF estimation is based on the following model:

$$\Delta Y_t = \lambda_0 + \lambda_1 + \delta Y_{t-1} + \sum_{i=1}^{n} \lambda_1 \Delta Y_{t-i} + \mu_t \qquad (3.6)$$

Where, *Y* = the time series variables under consideration, *t* = Linear time trend, Δ = First difference operator, λ_0 = Constant term, *n* = Optimum number of lags on the dependent variables and μ_t = the stochastic error term.

Following the stationarity test shall be application of the Autoregressive Distributed Lag (ARDL) model estimation technique. This is employed to determine the long-run relationship between dependent and independent variables and the short-run dynamic outputs of the model. The main reasons for using this technique stem from its applicability in small data size, easy application by employing OLS, no endogeneity problem, concurrently estimating long-run and short-run coefficients as well as the possibility of combining both I(1) and I(0) stationary variables in estimation (Pesaran, Shin & Smith 2001 and Sulaiman & Mohammad, 2010). Therefore, specification of the ARDL form of the model is presented below;

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XI Issue VIII August 2024

$$\Delta \text{LOG}(COE_t) = \delta_1 + \delta_{1i}\Delta \text{LOG}(COE_{t-1}) + \delta_{2i}\Delta \text{LOG}(M\&Q_{t-1}) + \delta_{3i}\Delta \text{LOG}(MTO_{t-1}) + \delta_{4i}\Delta \text{LOG}(COP_{t-1}) + \sum_{t=1}^{p}\beta_{1i}\Delta LOG(COE_{t-1}) + \sum_{t=1}^{q}\beta_{2i}\Delta LOG(M\&Q_{t-1}) + \sum_{t=1}^{q}\beta_{3i}\Delta LOG(MTO_{t-1}) + \sum_{t=1}^{P}\beta_{4i}\Delta LOG(COP_{t-1}) + \varepsilon_{1i} \quad (3.7)$$

Going forward, the short run dynamic parameters are arrived at by the estimation of an ECM linked with the long-run estimates. The model is stated below:

$$\Delta \text{LOG}(COE_t) = \beta_0 + \sum_{t=1}^{p}\beta_{1i}\Delta LOG(CEO_{t-1}) + \sum_{t=1}^{q}\beta_{2i}\Delta LOG(M\&Q_{t-1}) + \sum_{t=1}^{q}\beta_{3i}\Delta LOG(MTO_{t-1}) + \sum_{t=1}^{q}\beta_{4i}\Delta LOG(COP_{t-1}) + \delta ECT_{t-1} + \varepsilon_{1i} \quad (3.8)$$

Where: Δ = the difference operator and indicates the optimum lag; $\delta_1 - \delta_4$ = long-run dynamic co-efficient of the model; $\beta_1 - \beta_4$ = short-run dynamic co-efficient of the model; ε_{1i} = serially uncorrelated stochastic term with zero mean and constant variance. More so, the ECT_{t-1} defines the error correction term determined in the short-run analysis and δ measures the error coefficients, defining how fast the co-integration model adjusts from its previous period's disequilibrium to re-establish long-run stable (equilibrium) relationship. This coefficient indicator of the ECT term is theorized to appear negative and statistically significant for an acceptable result. When ECT_{t-1} appears as expected, negative and significant, it portrays that any short-run movements between the regressand and explanatory variables will reconverge to long-run stability. However, this method fraught with applicability limitation when all variables are first difference stationary in unit root tests.

Variables in the Model and Theoretical Expectation

The factors in this research are categorised as dependent and independent variables.

Dependent Variable

Carbon Emissions: Environmental pollution is the dependent variable in this study and it is proxied by carbon emissions. Carbon emissions refers to emissions that primarily come from burning fossil fuel for cars, trucks, ships, trains, planes and so on.

Independent Variables

On the other hand, solid minerals production is the independent variable in this study and it is proxied by mining and quarrying, metal ores likewise coal production:

Mining and Quarrying: Mining and quarrying are industrial activities that involve the extraction of valuable minerals, rocks, and other geological solid materials from the environment. These activities play crucial role in the development of economies by providing raw materials for various industries. Economic theory posits that in the process of developing mining and quarrying solid resources, environmental pollution usually one consequence in Nigeria. This is mathematically represented as: $\delta_1 > 0$.

Metal Ores: Metal ores are naturally occurring rocks or solid minerals from which metallic elements or compounds can be extracted. These ores typically contain high concentrations of the desired metal, making it economically viable to extract and process the metal for various industrial applications. Metal ores serve as the primary source of raw materials for the production of metals through mining and metallurgical processes.

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XI Issue VIII August 2024

It is thus posited that the industrial activities associated with metal ores production contributes to environmental pollution. This is mathematically represented as: $\delta_2 > 0$.

Coal Production: This term pertains to the process of cutting, removing, acquiring, and extracting coal with the intention of selling, gaining profit, or utilising it for commercial purposes. In congruent with economic theory, coal extraction in Nigeria is anticipated to have contribute to environmental contamination. This is mathematically represented as: $\delta_3 > 0$.

ANALYSES RESULTS AND DISCUSSION OF UPSHOTS

Descriptive Analysis

The descriptive statistics test outcomes for the study's variables are summarized in Table 4.1 below. It presents the descriptive statistics of the research variables (CO_2 emission, mining and quarrying, metal ores and coal production) over a period of thirty-seven years from 1986 to 2022. As shown in the table, the CO_2 emission (COE) recorded over the period a mean value of 45.81 with a maximum of 54.46 and minimum of 33.15 per annum. The standard deviation of CO2 emission (COE) is 5.56 and this indicates that CO_2 emission (COE) had high deviation from the mean over the studied period. In addition, mining and quarrying (M&Q) activities recorded over the period a mean value of 6903.0 with a maximum of 9323.75 and minimum of 4391.42 per annum.

Table 4.1: Descriptive Statistics

	COE	**M&Q**	**MTO**	**COP**
Mean	45.80710	6903.001	2.784516	7.220270
Median	46.63830	6850.370	1.892308	4.580000
Maximum	54.46350	9323.750	9.664283	27.50000
Minimum	33.15260	4391.420	0.623736	1.710000
Std. Dev.	5.555995	1322.493	2.347724	6.854641
Skewness	-0.247717	0.104303	1.480698	1.653563
Kurtosis	2.364425	2.248174	4.145023	4.837989
Jarque-Bera	1.001175	0.938503	15.54146	22.06939
Probability	0.606174	0.625470	0.000422	0.000016
Sum	1694.863	255411.0	103.0271	267.1500
Sum Sq. Dev.	1111.287	62963525	198.4251	1691.500
Observations	**37**	**37**	**37**	**37**

Source: Computation by author (2023), E-views 12.0

The standard deviation of mining and quarrying (M&Q) is 1322.49 and this also indicates that mining and quarrying (M&Q) processes had high dispersion from the mean. Further, the metal ores (MTO) recorded over the period a mean value of 2.78 with a maximum of 9.66 and minimum of 0.62 per annum. The standard deviation of metal ore (MTO) is 2.35 and this indicates that metal ore (MTO) had low dispersion from the mean. Lastly, the coal production (COP) recorded over the period a mean value of 7.22 with a maximum of 27.5 and minimum of 1.71 per annum. The standard deviation of coal production (COP) is 6.85 and this indicates that coal production (COP) had low deviation from the mean.

Trend Analysis

Figure 4.1 depicts a graphic representation of the datasets of the variables being examined. These include

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XI Issue VIII August 2024

CO_2 emission (COE), mining and quarrying (M&Q), metal ores (MTO) and coal production (COP) in Nigeria from 1986 to 2022. Specifically, Figure 4.1 shows that CO_2 emission was initially low during the early period of this study but later appeared to rise shortly after and fell again. This rise and fall continued throughout the study period. As regards mining and quarrying (M&Q), the Figure shows that mining and quarrying (M&Q) is of cyclical inconsistencies in its movements. This is shown by its erratic fluctuations in upward and downward directions across the whole duration of the investigation. With respect to metal ores (MTO), a more consistent but slow level of upward movement was observed in most parts of the research period. Lastly, coal production (COP) is seen to experience slight inconsistent movement from the start period to 1999 while a more steady and consistent level of upward movement especially from 2001 was observed.

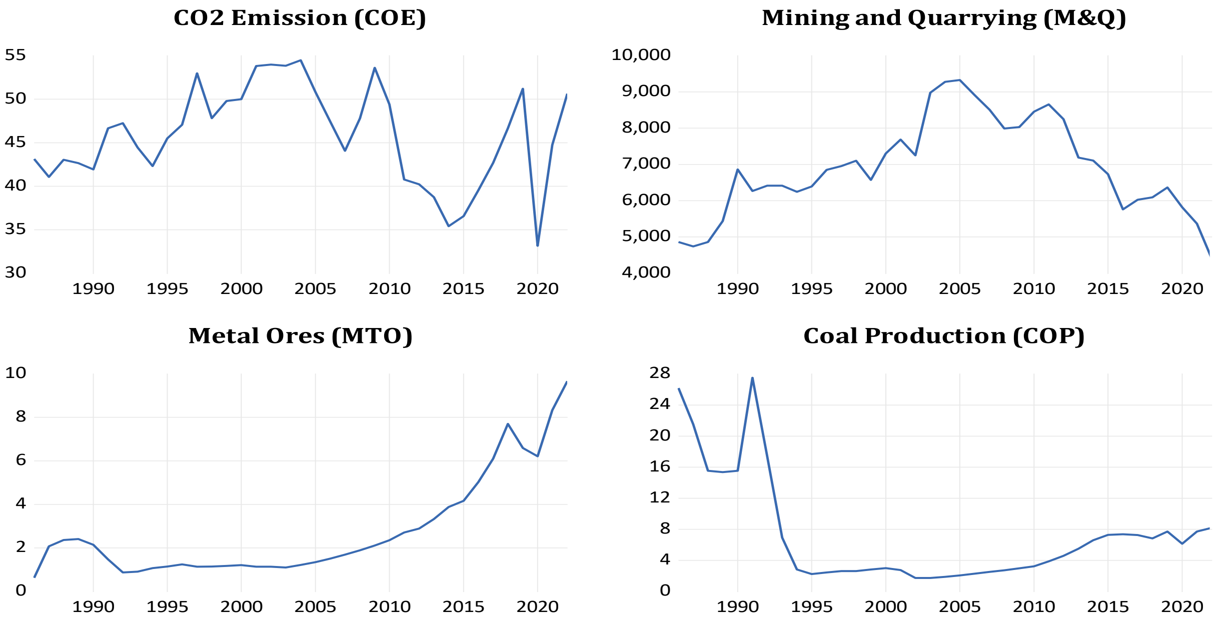


Figure 4.1: Line Graph Showing Trends in CO_2 Emission (COE), Mining and Quarrying (M&Q), Metal Ores (MTO) and Coal Production (COP)

Pre-Estimation Tests

Unit Root Test

Since testing of the unit roots of a series is a precondition to the existence of cointegration relationship, this study first employed the Augmented Dickey-Fuller (ADF) method to ascertain the stationarity status of the variables. Thus, below in Table 4.2 are the outcomes.

Table 4.2: Augmented Dickey-Fuller (ADF) Test Results

	At Levels		**At 1st Difference**			
Variables	**ADF**	**Mackinnon Critical Value @ 5%**	**ADF**	**Mackinnon Critical Value @ 5%**	**Decision**	**Order of Integration**
COE	-1.70803	-2.94840	-5.25539	-2.95113	1st Difference Stationary	I(1)
M&Q	-2.96282	-2.94840	-	-	Level Stationary	I(0)
MTO	-1.64775	-2.94840	-5.22817	-2.95113	1st Difference Stationary	I(1)
COP	-2.03901	-2.94840	-3.35006	-2.95113	1st Difference Stationary	I(1)

Source: Computation by author (2023), E-views 12.0

Table 4.2 presents the summary results of the ADF Unit root tests carried out on all the variables in our model. The unit root test established that, mining and quarrying (M&Q) attained stability at level. This is because the test statistic value of mining and quarrying is above the Mackinnon critical value at 5% level of significance at level. This further indicates that this variable is stationary at order zero [i.e., I(0)]. On the other hand, CO_2 emission (COE), metal ores (MTO) and coal production (COP) attained stability after first differencing. This is because their test statistic values are above the Mackinnon critical value at 5% level of significance at first difference. This further indicates that theses variables are integrated at order one [i.e., I(1)]. In conclusion, having achieve mixed stationarity in the variables (meaning stationary at order zero and stationary at order one), it was necessary to use the Autoregressive Distributed Lag (ARDL) method to estimate the long-term relationship between the variables and the ECM.

Lag Selection Criteria

The lag selection criteria result is presented in Table 4.3 below.

Table 4.3: Lag Selection Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	145.9759	NA	2.15e-09	-8.604599	-8.423204	-8.543565
1	258.2062	190.4515	6.37e-12	-14.43674	-13.52977*	-14.13157
2	280.6038	32.57830*	4.53e-12*	-14.82447*	-13.19192	-14.27517*
3	294.0061	16.24526	6.01e-12	-14.66704	-12.30891	-13.87360

Source: Computation by author (2023), E-views 12.0

The lag selection criteria result as displayed above, revealed that the majority of the criteria determined a lag of two to be most appropriate lag length for the ARDL model estimation. More specifically, the optimum lag length as selected in Table 4.3 above implies Final Predictor Error (FPE), Akaike Information Criterion (AIC), Hannan-Quinn (HQ) Criterion selected lag two most suitable but only Swharz Criterion (SC) selected lag one. Therefore, lag two as selected will serve as the selection foundation for the ARDL model estimation conducted in this research.

ARDL Bounds Cointegration Test

Table 4.4: ARDL Bounds Cointegration Test

Significance	I(0) Bound	I(1) Bound
10%	2.37	3.20
5%	2.79	3.67
2.5%	3.15	4.08
1%	3.65	4.66
Computed F-statistic: F_{CO2}(M&Q MTO COP) = 5.894586 **Note:** Critical Values are cited from Pesaran *et al*. (2001), Table CI (iii), Case 111: Unrestricted intercept and no trend for K = 3.		

Source: Computation by author (2023), E-views 12.0.

Table 4.4 showed the output of ARDL Bounds correlation test. It shows that there are cointegration between solid mineral production indicators (mining and quarrying, metal ores, and coal production) and environmental pollution indicator (carbon dioxide emission), which emphasize the relevance and significance of the long run analysis. Specifically, the computed F – statistic value; F_{CO2}(M&Q MTO COP) is 5.894586. The obtained F-statistic value (5.894586) exceeds the critical values of 3.20, 3.67, 4.08, and 4.66 at significance levels of 10%, 5%, 2.5%, and 1% correspondingly. Therefore, the null hypothesis that there is no cointegration is rejected, providing confirmation for the existence of cointegration between carbon dioxide emission, metal ores, mining and quarrying, and coal production. Thus, the confirmation of long-term relations among the variables has led to the need to estimate the strength of the link between the dependent and independent variables utilising the Autoregressive Distributed Lag (ARDL) model.

Model Estimation

Autoregressive Distributive Lag (ARDL) Long-Run Dynamics

The dynamic relationship between solid minerals production and environmental pollution in Nigeria was estimated by utilising ARDL method. The results are presented in Table 4.5:

Table 4.5: Estimated Long-Run Co-efficient of ARDL

Variable	Co-efficient	Std. Error	t-Statistic	Prob.*
Dependent Variable = LOG(COE)				
LOG(M&Q)	5.698320	1.522351	3.743105	0.0010
LOG(MTO)	7.920736	2.782949	2.846166	0.0089
LOG(COP)	0.143724	0.066765	2.152691	0.0416
C	9.398462	3.871422	2.427651	0.0231

NB: *P<0.01, **p<0.05, ***P<0.01 ARDL(1,2,2,1) selected owing to Akaike Information Criterion Source: Computation by author (2023), E-views 12.0.

Interpretation of Long-Run ARDL Model Results

The long-run estimate's output showed in Table 4.5 revealed that mining and quarrying positively and substantially influenced CO_2 emission in Nigeria. This is evidenced by the positive co-efficient value (5.698320) of mining and quarrying and its p-value (0.0010), which is less than 0.05. This implies that an increase in the mining and quarrying activities by one percent will lead to 5.698320 percent increase in CO_2 emission in the long run. Furthermore, the long-run estimate's outcome of the ARDL model revealed that metal ores had substantial positive long-run impact on CO_2 emission in Nigeria. This is evidenced by the positive co-efficient value (7.920736) of metal ores and its p-value (0.0089), which is less than 0.05. This implies that a percentage rise in metal ores production activities lead to 7.920736 percent increase in CO_2 emission in the long run. In addition, the **e**stimated ARDL model established that coal production had substantial positive long-run impact on CO2 emission in Nigeria. This is evidenced by the positive co-efficient value (0.143724) of coal production and its p-value (0.0416), which is less than 0.05. It suggests that one percent increase in coal production activities lead to 0.143724 percent increase in CO_2 emission in the long run.

Interpretation of Short-Run ARDL Model Results

The short-run estimates of the ARDL model as shown in Table 4.6 below revealed that in the current period, mining and quarrying activities had positively and substantially influenced CO_2 emission into the environment. This is evidenced by the positive co-efficient value (33.01912) of this variable and its p-value (0.0180) which is less than 0.05. Also, at lag one year, mining and quarrying has a positive and substantial effect on CO_2 emission. This is proven by the positive co-efficient value (51.54651) of mining and quarrying and its p-value (0.0055) which is less than 0.05 at lag one. This implies that there will be a substantial increase in CO_2 emission given an increase in the mining and quarrying activities in the short run.

Furthermore, the short-run estimates of the ARDL model revealed that metal ores in the current period had substantially positive short-run impact on CO_2 emission in Nigeria. This is revealed by the positive co-efficient value (32.84667) of metal ores and its p-value (0.0153) which is less than 0.05.

Autoregressive Distributive Lag (ARDL) Short-Run Dynamics

Table 4.6: ARDL Error Correction Result

Variable	**Co-efficient**	**Std. Error**	**t-Statistic**	**Prob.**
Dependent Variable = LOG(COE)				
DLOG(M&Q)	33.01912	12.68369	2.603274	0.0156
DLOG(M&Q(-1))	51.54651	16.91533	3.047325	0.0055
DLOG(MTO)	32.84667	12.57896	2.611239	0.0153
DLOG(MTO(-1))	-0.007317	0.060306	-0.121325	0.9044
DLOG(COP)	50.94893	16.76529	3.038953	0.0057
CointEq(-1)*	-0.606303	0.127204	-4.766384	0.0001
Adjusted R^2 = 0.552447; Durbin-Watson stat = 1.970279				

NB: *P<0.01, **p<0.05, ***P<0.01 ARDL(1,2,2,1) selected owing to Akaike Information Criterion Source: Computation by author (2023), E-views 12.0.

Thus, there is a substantial increase in environmental contamination due to CO_2 emission given an increase in metal ores production activities in the current year. On the other hand, in the previous year, activities of metal ores production had significant negative short-run impact on CO_2 emission. This is seen from the negative co-efficient value of -0.007317 and its p-value of 0.0153 which is less than 0.05. Therefore, a percentage rise in metal ores production evidenced low CO2 emissions. Furthermore, the short-term analysis outcome of the ARDL model established a substantially positive link between coal production (COP) activities and CO2 emissions in the Nigerian environment. This is supported by the substantial positive co-efficient value (50.94893) of coal production (COP) and its p-value (0.0057) which is below the level of 0.05. That is, in the short-term, one percent increase in coal production (COP) activities resulted in a 50.94893 percent rise in CO2 emissions.

Furthermore, the short-term dynamic co-efficient results associated with the long-term outcomes generated from the ECT are shown in Table 4.6. The indicators of the short-term dynamic interactions align with those of the long-term results. The calculated error correction co-efficient of -0.606303, with a p-value of 0.0001, is statistically substantial, has the right sign, and suggests a rapid adjustment to equilibrium after shock. This indicates that over 61% of imbalances resulting from the shock in the previous year return to the long-term equilibrium in the current year. The Adjusted R-squared value of 0.552447 as shown in table 4.6 indicates that the estimated model is a good fit. This value suggests that approximately 55 percent of the variation in CO2 emissions (environmental concerns) is explained by the systematic changes in the explanatory variables (mining and quarrying, metal ores, and coal production), while the remaining 45 percent is attributed to other determining factors exogeneous of the model. Finally, the Durbin-Watson statistic value (1.970279), confirms that there is no issue of serial autocorrelation.

Post Diagnostic Tests

The diagnostic tests are performed to assess the accuracy of the model, ensuring that it aligns with the common assumptions of Ordinary Least Square (OLS) analysis, including serial correlation, heteroscedasticity, functional form, normality, and so on. Nevertheless, the outcomes of the diagnostic examinations are reported below:

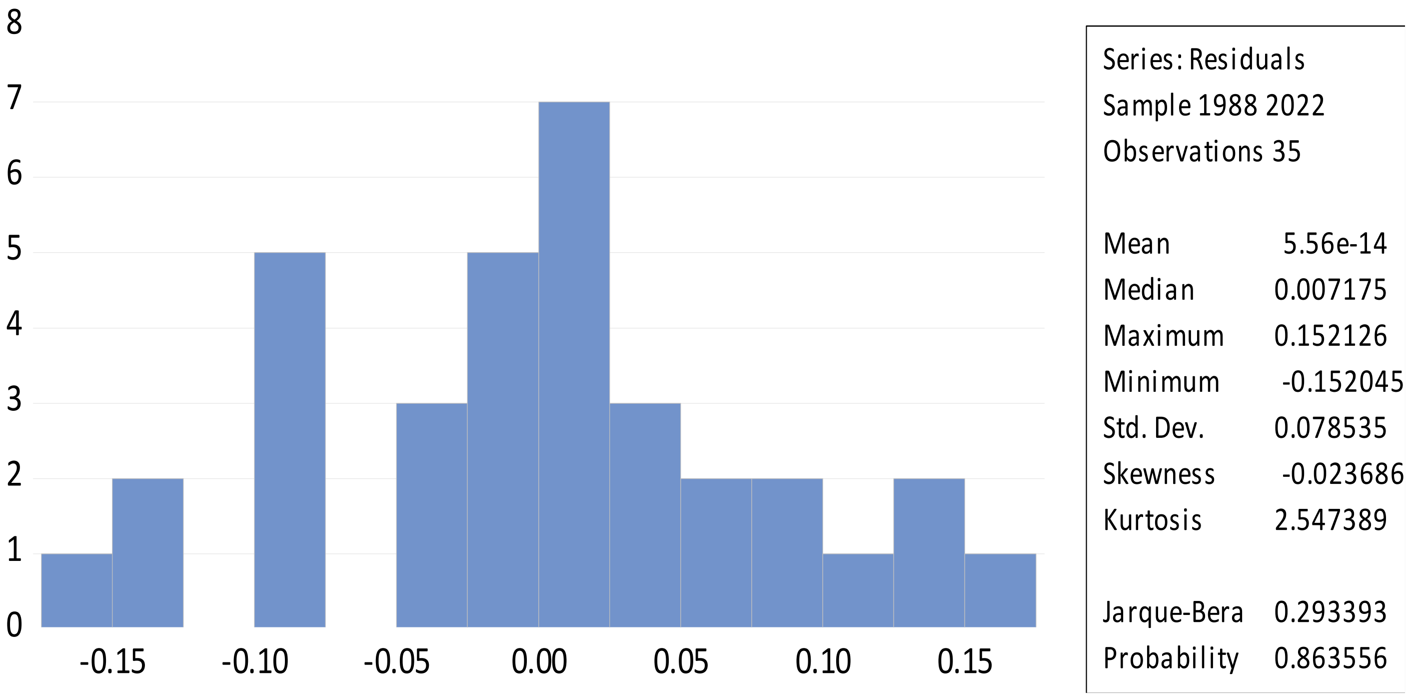
Table 4.7: Post-Diagnostic Tests' Results

Test	**Null Hypothesis**	**Test Type**	**F-stat.**	**Prob.**
Serial Correlation Test	Serial correlation does not exist	Breusch-Godfrey LM Test	0.690472	0.5119
Heteroscedasticity Test	Homoscedasticity exists	Breusch-Pagan-Godfrey	1.646393	0.3275
Functional form Test	Model is stable	Ramsey RESET	0.003197	0.9554

Source: Computation by author (2023), E-views 12.0

The outcome of the Breusch-Godfrey Serial Correlation LM test in Table 4.7 indicates that the probability value (0.5119) is above the significance level of 0.05. This suggests that we cannot reject the null hypothesis of no serial correlation. Therefore, it is necessary to accept the null hypothesis, which leads to the conclusion that the model does not have a problem of serial correlation. Outcome of the Breusch-Pagan-Godfrey heteroskedasticity test in Table 4.7 indicates that the probability value (0.3275) is above the significance 0.05 benchmark. Thus, suggesting that the null hypothesis of homoscedasticity cannot reject. Therefore, it is necessary to accept the null hypothesis, which necessitates the conclusion that the model exhibits homoscedasticity. Also, suggesting that relevant variables were included and model correctly specified, the Ramsey RESET test result in Table 4.7 indicates with a probability value (0.9554) which is above the significance level of 0.05. This necessitates the conclusion that the null hypothesis of accurate specification of the model cannot reject. This indicates that the functional form of the model is suitable.

Figure 4.2: Normality Test

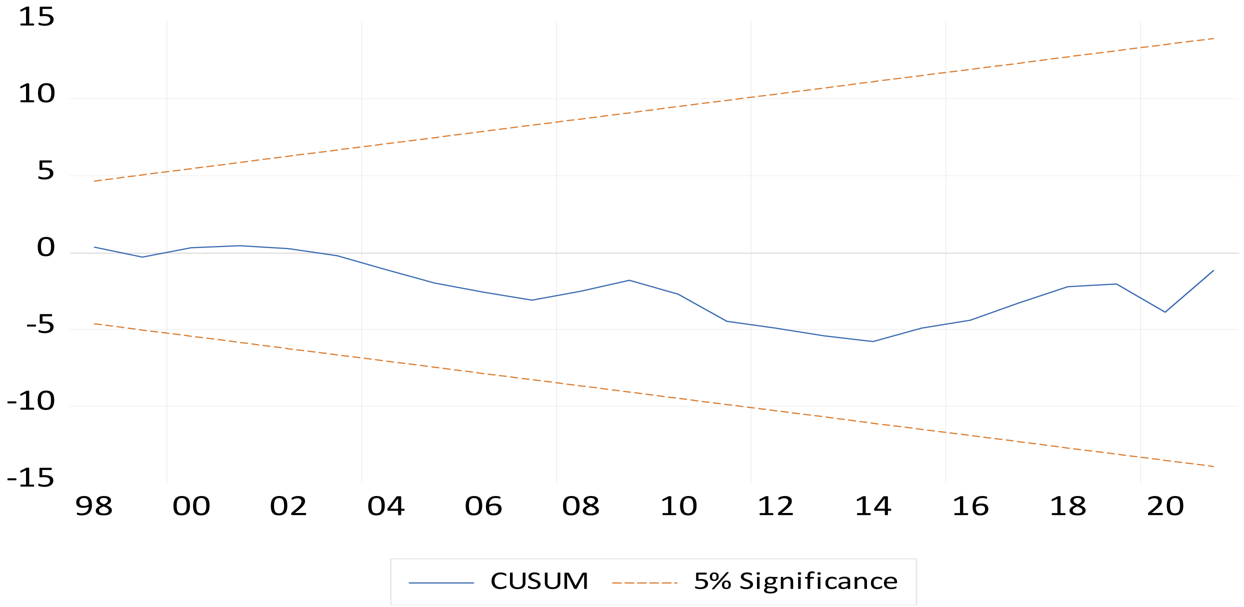


Source: Computation by author (2023), E-views 12.0.

The Jarque Bera test result in Figure 4.2 indicates that the probability value (0.863556) is above the significance level of 0.05. Therefore, we cannot reject the null hypothesis that the data follows a normal distribution. Therefore, it is necessary to accept the null hypothesis, which leads to the conclusion that the model's variables are normally distributed.

Figure 4.3: CUSUM Stability Test

To determine how stable the long-run coefficients are with respect to the short-run dynamics, the CUSUM diagnostic test was conducted. The CUSUM line did not go over the lower and upper 5% critical limit, which is in agreement with the stability test results shown in Figure 4.3 below.



Source: Computation by author (2023), E-views 12.0

Thus, this implies that the long-run coefficients of the regressors that impact environmental pollution in Nigeria remain stable. In conclusion, the diagnostic tests have shown that our results are trustworthy as they have successfully passed all the post model estimate diagnostics of serial correlation, heteroscedasticity, function shape, normalcy, and stability. Therefore, the model's estimates are robust and suitable for conclusions and policy recommendation.

Discussion of Findings

Utilising the econometric estimation approach of Autoregressive Distributed Lag (ARDL) and the E-Views 12 statistical software, this research experimentally analysed time series data for 1986 to 2022 for assessing the influence of solid minerals production on environmental pollution in Nigeria. To start with, the study's outcomes showed that mining and quarrying substantially induced CO2 emissions in Nigeria during the sampled period. This suggests that, in both the short and the long terms, mining and quarrying are major contributors to Nigeria's CO2 emissions. Muftau and Onaopemipo (2022) found that solid mineral development, such as mining and quarrying, had a beneficial impact on economic growth in the research region, which is consistent with our result. The second important takeaway from this research is that metal ore production activities substantially induced CO2 emissions in Nigeria. This suggests that, both in the short and long terms, metal ores are a substantial contributor to CO_2 emissions in Nigeria during the study period. Odoh, Akpi, and Anyah (2017) also discovered that metal ores, a proxy for mining exploration and processing and have damaged the environment in Nigeria to varied degrees, and the finding of the current study in in line with theirs. Finally, this study established that coal production substantially and positively affects CO2 emissions in Nigeria. That is, in both the short and long terms, coal production has been a major contributor to Nigeria's CO2 emissions. This confirms what Aigbedion and Iyayi (2017) have discovered: that coal production is a major source of pollution in Nigeria's ecosystems.

CONCLUSION AND RECOMMENDATIONS

Concluding Remark

Activities for exploring solid minerals in Nigeria have resulted in diverse levels of environmental damage, including ecological degradation, pollution of air, water, and soil, destruction of soil biodiversity, loss of vegetation, landscape deterioration, and emission of radiation, all of which contribute to environmental pollution. This research conducted an empirical analysis to investigate the impact of solid minerals production on environmental pollution in Nigeria. The empirical outputs revealed that mining and quarrying activities, metal ores and coal production activities significantly impacted on CO2 emissions in Nigeria. Following this result, the researchers concluded that the production of solid minerals in Nigeria had substantially impacted on environmental pollution.

Policy Recommendations

Inferred from the results of this empirical investigation, the following policy recommendations are put forward:

1. Since the study established that mining and quarrying contributes to environmental pollution by way of CO2 emissions, the government should among others ensure implementation of emission control measures, stricter environmental regulations and encourage use of sustainable quarrying practices to mitigate emission.
2. Having revealed that metal ores production activities impact the environment by adding to CO_2 emission, it is recommended that operators should endeavour to employ air pollution control devices like air filters and cyclones that captures and remove particulate matter (dust) and carbons, apply energy efficient initiative among others as ways to reduce emission.
3. In addition, since this study has also shown that coal production induces CO_2 emissions, policy makers and industry operators should encourage use of pre-combustion and post-combustion measures such as cleaning coal, desulfurization, etc. as such help to reduce coal production effect on the environment in Nigeria.

REFERENCES

1. Adeniyi, I. O., Adeleke, M. O., & Olabode, O. A. (2013). Legal Regime for Exploring Solid Minerals for Economic Growth in Nigeria. *Journal of Canadian Social Science, 9*(5), 67-77.
2. Aigbedion, I., & Iyayi, S. E, (2017). Environmental effect of mineral exploitation in Nigeria. *International Journal of Physical Sciences, 2*(2), 033-038.
3. Ajie, C. O., Okoh, S. A., & Ojiya, E. O. (2019). The impact of solid minerals resources on economic growth in Nigeria: an ols and causality approach. *International Journal of Humanities, Art and Social Studies (IJHAS), 4*(1), 43-57.
4. Akongwale, S., Ayodele, O. S., &Udefuna, P. N. (2013). Economic Diversification in Nigeria: Any role for solid mineral development? *Mediterranean Journal of Social Sciences, 4*(6), 691-703.
5. Beckerman, W. (1992). Economists, scientists and environmental catastrophe. *Oxford Economic Papers, 24*(5), 237-244.
6. Cole, M. A., & Neumayer, E. (2005). *Environmental policy and the environmental Kuznets curve: can developing countries escape the detrimental consequences of economic growth?* In P. Dauvergne (Ed.), International Handbook of Environmental Politics: 298-318. Cheltenham and Northampton: Edward Elgar.
7. Danmola, R. A., & Wakili, A. M. (December 1, 2013). *Solid mineral resources: Alternative source of revenue for the Nigerian economy*. Retrieved from https://hdl. handle.net/10520/ EJC148713.

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XI Issue VIII August 2024

8. Dickey, D. A. & Fuller, W. A. (1981). Likelihood ratio statistics for autoregressive time series with a unit root. *Econometrica, 49*, 1057-1072.
9. Edeme, R. K., & Nkalu, N. C. (2019). Predicting the effects of economic diversification on solid mineral development in Nigeria. *Journal of Contemporary Research in Business, Economics and Finance, 1*(4), 56-61.
10. Edeme, R. K., Onoja, T. C., & Damulak. D. D. (2018). Attaining sustainable growth in Nigeria: Any role for solid mineral development? *Academic Journal of Economic Studies, 4*(1), 105-110.
11. Erhun, M. O. (2015). The contribution of the minerals and mining industry to poverty alleviation and sustainable development in Nigeria: A legal perspective. *Journal of Energy Technologies and Policy, 5*(8), 96-109.
12. Grossman, G. M. & Krueger, A. B. (1991) Environmental impacts of the North American Free Trade Agreement. *NBER Working paper,* 3914.
13. KPMG (2014). *Nigerian mining sector brief*. Published by KPMG Nigeria. p.19.
14. Kuznets, S. (1955). Economic growth and income inequality. *An economic Review,* 45(1); 1-28.
15. Mbah, C.C., Mgbemena, E., & Mbah, S. (2019). Investments and solid mineral development in Nigeria. *Global Journal of Education, Humanities and Management Sciences, 1*(2), 156-169.
16. Muftau, A. A., & Onaopemipo R. O. (2022). The influence of solid mineral development on economic growth in Nigeria. *African Journal of Economics and Sustainable Development, 5*(2), 38-54.
17. Nwinyodee, L. N., & Kerebana, T. K. (2022). Trade openness and solid mineral sub-sector growth in Nigeria. *International Journal of Development and Economic Sustainability, 10*(4), 26-36.
18. Nwogwugwu, U. C., Nwokoye, E. S., & Ebenebe, O. E. (2021). The nexus between solid mineral development and economic growth in Nigeria. *International Journal of Research in Engineering, IT and Social Sciences, 11*(6), 1-10.
19. Odoh, C. K., Akpi, U. K., & Anyah, F. (2017). Environmental impacts of mineral exploration in Nigeria and their phytoremediation strategies for sustainable ecosystem. *Global Journal of Science Frontier Research: H Environment & Earth Science, 17*(3), 19-30.
20. Ouadadi, S. (2020). Environmental and health impacts of mining in Nigeria: A review. *Research Inventory: International Journal of Engineering and Science, 10*(7), 27-31.
21. Pesaran, M. H., Shin, Y.& Smith, R. J. (2001). Bound testing approaches to the analysis of level relationships. *Journal of Applied Econometrics, 16(3), 289-326.*
22. Sulaiman, D. M. & Muhammad, U. (2010). The bound testing approach for co-integration and causality between financial development and economic growth in case of Pakistan. *European Journal of Social Sciences, 13, 525-531.*