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Energy Use and Mining Sector Performance in Nigeria

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ABSTRACT

This study examines the contribution of energy use to mining sector growth in Nigeria. The specific objectives are the effects of fossil fuel use, renewable energy use, alternative energy use, and total electricity use on mining sector value added to the gross domestic product (GDP). The time series data for each of the variables were obtained from secondary sources, including the World Bank, International Energy Agency (IEA) and Organisation of Economic Cooperation and Development (OECD) National Data Accounts. This study utilised least squares method to estimate the ARDL model. Evidence of a positive and significant effect of fossil fuel energy use on the mining sector value added in the long run. The estimated parameter showed that the mining sector value added increased by 1.607% following a percentage increase in the fossil fuel energy use. This finding suggests that the mining sector tends to rely on fossil fuels to increase output. The results further showed that the renewable energy use and alternative do not significantly affect mining sector value added in both the short and long run. This finding is not surprising as it highlights the poor transition to renewable and alternative energy sources, which undermines their significant contribution to the mining sector's growth. In addition, the results showed that total electricity use has a positive and significant effect on the mining sector value added. As observed from the corresponding coefficient, a 1% increase in total electricity use leads to a 1.68% increase in the mining sector value added. This finding indicates that access to electricity plays a significant role in promoting the growth of the mining sector. The error correction coefficient (-0.2275) shows that distortion from the long run equilibrium position can be corrected at the speed of 22.75% each year. The R-squared (0.9414) showed that 94.14% of the total variations in the mining sector value added are jointly explained by changes in fossil fuel, renewable energy, alternative energy and electricity use. Given the findings, we recommend that policymakers should reduce fossil fuel dependency as a source of energy by diversifying energy sources to create more opportunities for firms in the mining sector to boost their output and value addition to GDP.

1. INTRODUCTION

Energy use refers to the total amount of energy utilised in a given process, which is often measured in kilowatt-hours (kWh). It includes energy from combustible renewables and waste - solid biomass and animal products, gas and liquid from biomass, and industrial and municipal waste. In developing economies, growth in energy use is closely related to the growth and development of the real sector, which translates into output growth in agriculture and manufacturing activities, among others. According to the United States Energy Information Administration (2022), the total energy use by the end-use sectors includes their primary energy use, electricity sold by and purchased from the electric power sector, and electrical system energy losses.

The way energy is used, or consumed, differs based on infrastructure and geographic location. There may be variations in the amount, kind, and method of use. Given its direct relationship to global warming and climate change, energy consumption is highly relevant to geography. Indicators of energy usage that are useful are infrastructure and population density. In general, less urbanised and less populated places use more energy than more urbanised and more populated ones. Primary energy sources are those that are used in their unprocessed state. This covers nuclear energy using uranium or plutonium, fossil fuels (oil, natural gas, and coal), and renewable energy sources (wind, solar, and wave energy). Secondary sources, like electricity that travels through power lines to homes and firms, can be produced by primary sources.

Furthermore, energy plays a critical role in driving industrial activities, and among the sectors most heavily reliant on energy inputs is the mining sector. In resource-rich developing countries, including many across Africa, the mining sector not only contributes significantly to export earnings but also serves as a key driver of employment and infrastructural development. However, the growth and productivity of this sector are closely tied to the availability, cost, and reliability of energy. In many mineral-producing regions, particularly in sub-Saharan Africa, energy-related constraints remain a major bottleneck to mining sector development. High electricity tariffs, frequent power outages, limited access to grid power, and reliance on costly and polluting diesel generators have reduced operational efficiency and increased production costs. These challenges hinder competitiveness and may deter foreign direct investment in the extractive industry.

Conversely, improved energy infrastructure and the adoption of more efficient and renewable energy sources have the potential to enhance the mining sector's growth prospects, improve sustainability, and reduce environmental impact. Despite the centrality of energy in mining operations, there is a limited body of empirical research that quantitatively examines the relationship between energy use and mining sector growth, particularly in the context of economies. Understanding this relationship is critical for policymakers and investors aiming to align energy policy with industrial growth and environmental goals. In this light, we examine the impact of energy use on mining sector growth, with specific attention to how various sources of energy, including fossil fuels and renewable energy, contribute to manufacturing GDP in Nigeria between 1990 and 2023.

2. LITERATURE REVIEW

2.1 Theoretical Literature

This study is anchored on the energy-led growth hypothesis, which can be traced to the foundational works of Mason (1955) and Sims (1989). The theory is based on the assumption that investments and innovations in the energy sector can serve as a powerful engine for overall economic growth and development. It emphasises that by concentrating on the energy industry, through research, innovation, and infrastructure improvements, nations can not only stimulate growth within the energy sector itself but also create positive ripple effects across the entire economy, including manufacturing. By enhancing energy efficiency, embracing renewable energy sources, and committing to sustainable energy practices, countries can better meet their energy demands while also generating new job opportunities, fostering technological advancements, and minimising environmental impacts.

Advocates of the energy-led growth theory, including Mason (1955) and Erol and Yu (1987), argue that prioritizing energy development can lead to both economic prosperity and environmental sustainability over time. The theory is rooted in the belief that energy consumption is closely linked to economic growth, as energy is a key driver of economic activities. The growth hypothesis posits a one-way causality from energy use to economic growth. Abosedra, Shahbaz, and Sbia (2015) assert that energy is the lifeblood of the global economy, serving as a crucial input for producing nearly all goods and services in today's world. As a result, energy directly contributes to economic growth by creating jobs and value through the processes of extracting, transforming, and distributing energy. According to Barney & Franzi (2002), while energy constitutes less than 10% of production costs, it is responsible for driving at least half of the industrial growth in modern economies. Energy-led growth theory faces several criticisms. One major criticism is its limitation in accounting for the complex factors that contribute to economic growth. The theory tends to oversimplify the relationship between energy consumption and economic development, neglecting the multifaceted nature of growth processes. Additionally, critics argue that energy-led growth theory does not adequately consider the impact of technological advancements and innovation in shaping economic progress.

2.2 Empirical Literature

Mahdi, Mohammad, Ali and Abbas (2023) investigated the strategic management of renewable energy use in the mining sector via the Strengths, Weaknesses, Opportunities, and Threats (SWOT) method. The results indicate that despite the high potential of renewable energy in mining, much more investigation is required for the technical use of this technology in the mining industry. Using renewable energy can create new jobs, reduce environmental pollution, increase knowledge in the mining area, create a circular economy in the mining industry, and reduce mining operating costs. All mentioned factors can have a positive effect on sustainable development indicators. On the other hand, mine owners' lack of information about the positive effects of renewable energy, high investment, lack of skilled labor, and high maintenance costs can create challenges for using renewable energy in mines.

Igogo, Awuah-Offei, Newman, Lowder and Engel-Cox (2021) explored challenges, opportunities, and enabling approaches to integrate renewable energy technologies into mining operations by examining the literature, including academic work, technical reports, and data produced by international agencies. They find that despite numerous opportunities, technical issues still need to be considered, but solutions can tailor renewables to the mining industry. Further research should focus on identifying specific opportunities, technologies, and implementation strategies across the value chain of a variety of minerals with similar operational procedures.

Using the Environmental Kuznets Curve (EKC) theory, Acuña-Ascencio, Carhuamaca-Coronel and Mougenot (2024) focused on establishing the relationship between the variables of energy consumption, GDP per capita, and mineral rents and their impact on the level of pollution by CO2 emissions in the period 1971–2019. The study used statistical and econometric tools based on the ARDL dynamic model through a time series analysis starting from historical data. Based on the findings, the study concluded that the variables CEpc, PBIpc, and RM have deleterious effects, as a 1% increase in these variables increases the level of environmental pollution.

Katta, Davis and Kuma (2020) developed the disaggregated energy use and greenhouse gas (GHG) emission footprint for Canada's iron, gold, and potash mining sectors. The energy intensities for each end-user were calculated and used in a bottom-up energy-environmental model to determine the associated end-use process GHG emissions. The results were then used to develop Sankey diagrams that allow us to visualize the energy and GHG emissions flows from resource to end use by energy use sector, fuel type, and various jurisdictions in Canada. The overall energy and GHG emission intensities for iron, gold, and potash mining are 0.7, 149.8, 1.8 GJ/Mg and 33, 4922, 158 kg CO_2 eq./Mg, respectively.

Nazir et al. (2020) investigated the economic potential of the regions from the mining sector of North Morowali, Central-Sulawesi, Indonesia, and the formulation of pro-business regional development management that aims to create synergy between the local government and mining sector entrepreneurs. This study uses a descriptive qualitative approach by taking data in the form of primary data from FGD and secondary data observations from statistical bureau data in the North Morowali, Indonesia. The analysis unit uses SWOT analysis to determine the economic potential of the North Morowali and Location Quotient (LQ) to analyze the economic potential of the mining sector. The research period covers one year (2018-2019) in North Morowali, Indonesia. All the mining products have considerable potential as a financing unit in North Morowali, while mining potential has not been maximally exploited. The absence of regulations, facilities such as road access, and optimal land and sea transportation are the causes of the difficulty of optimization and access to explore mining products comprehensively.

Madzík *et al.* (2016) investigated the relationships between progress in the energy and mining industry and the competitiveness of selected countries. The focus of the study was determined by reviewing the expert literature on the topic, which showed that not many approaches appreciate the correlations between these two areas and pay closer attention to their historical relations. The study works with historical data on the energy and mining industry in selected countries and also data on the competitiveness of those countries. Correlations were examined using bivariate correlation analysis of respective time series. This research identified historically strong correlations, for instance, between electric power consumption, land area, or forest rent and indicators of national competitiveness. The results show that the influence of energy and mining industry on competitiveness over the last 40 years has increased, particularly in the case of countries with low or medium economic development, and it has decreased in developed countries. The resulting information about the intensity of the mutual relations might be useful for the management of competitiveness and planning of strategic economic tools.

Henriksson, Söderholm and Wårell (2014) analyzed long-run electricity demand behavior in the Swedish mining industry with special emphasis on the impact of energy prices and private research and development (R & D) on electricity use. Methodologically, we estimate a generalized Leontief variable cost function using a panel data set of nine mining operations over the period 1990–2005. Since the lower boundary of a set of short-run cost functions confines the long-run cost function, we can compute the long-run own- and cross-price elasticities of electricity demand. The empirical results indicate that long-run electricity demand in the mining industry is sensitive to changes in the own price, and already in a baseline setting Swedish mining companies tend to allocate significant efforts towards improving energy efficiency, in part through private R & D. From a policy perspective, the results imply that taxes (and tax exemptions) on electricity can have significant long-run impacts on electricity use. Moreover, future evaluations of so-called voluntary energy efficiency programs must increasingly recognize the already existing incentives to reduce energy use in energy-intensive industries.

Ariza, Vargas-Prieto and García-Estévez (2020) investigated the relationship between mining-energy and inclusive development indicators of local communities. The analysis includes several dimensions of inclusive development: education, health, security, and the quality of the local public management. The study focused two regions in Colombia which are the main mining-energy producers: Cesar, which produces more than 60% of the nation's coal, and Casanare, which produces 20% of the nation's oil. The study used a panel data estimation methodology based on the indicators for all municipalities from 2000 to 2015. The results show that mining-energy municipalities had, in general, better performance in social indicators than in other non-mining-energy municipalities.

3. METHODOLOGY

3.1 Model Specification

The model for this study utilised manufacturing sector GDP as the dependent variable while energy use indicators are the independent variables. The model is specified in a functional form as:

MIV = f (FEU, REU, AEU, TOU) (1)

Where: MIV = mining sector value added, FEU = fossil fuel energy use, REU = renewable energy use, AEU = alternative energy use and TOU = total electricity use

Specifically, the autoregressive distributed lag (ARDL) model is specified below:

$$\Delta MIV_t = \alpha_0 + \sum_{i=1}^{p} \alpha_1 \Delta MIV_{t-1} + \sum_{i=1}^{q} \alpha_2 \Delta FEU_{t-1} + \sum_{i=1}^{q} \alpha_3 \Delta REU_{t-1} + \sum_{i=1}^{q} \alpha_4 \Delta AEU_{t-1} + \sum_{i=1}^{q} \alpha_5 \Delta TOU_{t-1} + \beta_1 MIV_{t-1} + \beta_2 FEU_{t-1} + \beta_3 REU_{t-1} + \beta_4 AEU_{t-1} + \beta_5 TOU_{t-1} + \varepsilon_t \quad (2)$$

Where: α_0 = constant parameter to be estimated, α_1 – α_5 = short-run parameters to be estimated, β_1 - β_5 = long-run multipliers, p = optimal lag operator for each of the dependent variables, q = optimal lag operator of the independent variables, Δ = first difference operator, ε_t = error terms

3.2 Data and Variable Description

Mining sector growth defines the net contribution of the mining industry to a country's GDP. It is calculated as the difference between the total output (gross production) of the mining sector and the intermediate inputs used in the production process. It was measured as a percentage of GDP. The energy use is measured by fossil fuel energy use, renewable energy use, alternative energy use and total electricity use. Annual time series data were utilised in this study. Specifically, the data on service sector value added were obtained from the World Bank and the Central Bank of Nigeria Statistical Bulletin. Similarly, data on the energy use indicators were obtained from the World Bank, International Energy Agency (IEA) and Organisation of Economic Cooperation and Development (OECD) National Data Accounts. The datasets spanned from 1990 to 2023.

3.3 Data Analysis Techniques

In this study, we utilized the least squares method to estimate the ARDL models. It's important to note that the ARDL differs from the error correction mechanism (ECM), which is rooted in the work of Engel and Granger (1987). According to Hassler and Wolters (2006), the ARDL has gained traction in econometrics literature largely because it allows for the cointegration of nonstationary variables, which is akin to an error correction process. For the ARDL to be effectively estimated, the variables need to exhibit a structure of I(0), I(1), or a mix of both. This means that one of the first steps in working with the ARDL model is to determine the order of integration for each series using a unit root test. This step is crucial to ensure that none of the series are I(2), which would render the procedure invalid. Additionally, our data analysis included descriptive statistics, covering aspects like mean distribution, standard deviations, and the normal distribution of each variable throughout the study period. We also employed the augmented Dickey-Fuller (ADF) test, introduced by Dickey and Fuller (1981), for the unit root test, alongside the bounds cointegration test.

4. RESULTS AND DISCUSSION

4.1 Unit Root Test

The results of the ADF unit root test are presented in Table 1

Table 1: ADF Unit Root Test Result

Variable	ADF stat. at levels	ADF stat. at 1st diff.	Critical Value at 5%	Order of Integration
MIV	-0.4760	-6.9015***	-2.9604	I(1)
FEU	-2.7280	-5.8578***	-2.9604	I(1)
REU	-1.7160	-5.6900***	-2.9604	I(1)
AEU	-2.4903	-8.1275***	-2.9604	I(1)
TOU	-2.9633**	-	-2.9604	I(0)

Source: Computed from E-views Software

Note: *, ** and * denote Significant at 10%, 5% and 1% levels respectively**

The results show Total electricity use is stationary at levels given that the ADF statistics at levels is greater than the corresponding critical value at 5% level. Consequently, the null hypothesis of unit root is rejected at the 5% critical value. The implication of this result is that total electricity use is integrated of order zero I (0). On the other hand, the results show that mining sector value added, service sector value added, fossil fuel energy use, renewable energy use, and alternative energy use are non-stationary at levels, given that their ADF statistics at levels are less than the associated critical value at the 5% significance level. However, they were found to be stationary at first difference, indicating that they are integrated of order one (1). Overall, the results show that the variables are mixed integrated, which conforms to the previous result of Erdal, Erdal, and Esengün (2008) and Samuel, Rosemary, Inim, Ededem, and Ndubuaku (2021). The evidence of mixed integration in the series provided the statistical requirement for the application of bounds cointegration test.

4.2 Cointegration Test

The cointegration test results are reported in Table 2.

Table 2: Bounds cointegration test results

MIV FEU REU AEU TOU				
F-Bounds Test		Null Hypothesis: No levels relationship		
Test Statistic	Value	Signif.	I (0)	I (1)
F-statistic	5.5619	10%	2.2	3.09
K	4	5%	2.56	3.49
		2.5%	2.88	3.87
		1%	3.29	4.37

Source: E-views Software 12

The result show that the computed F-statistics (5.5619) is greater than the upper bound critical value (3.49) at the 5% significance level. Indicating that the null hypothesis of no long run relationship exist among the variables is rejected. Thus, the existence of long-run relationship among mining sector value added and energy use is established. This finding is in accordance with the recent findings of Kurniawan, Nugroho, Fudholi, Purwanto, Sumargo, Gio, and Wongsonadi (2024) and David, Noah, and Agbalajobi, (2016).

4.3 Model Estimation

The least squares method was employed to estimate the ARDL models. The results are presented in Table 3.

Table 3: ARDL results for model

Dependent Variable: MIV				
Selected Model: ARDL(1, 1, 0, 1, 3)				
Cointegrating Form				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(FEU)	0.103845	0.478713	0.216926	0.8305
D(REU)	-0.408488	0.367236	-1.112333	0.2792
D(AEU)	-6.599437	8.458775	-0.780188	0.4444
D(TOU)	-0.063941	0.123606	-0.517294	0.6106
D(TOU(-1))	0.148962	0.114538	1.300547	0.2082
CointEq(-1)	-0.22759**	0.092314	-2.465443	0.0229
Long Run Coefficients				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
FEU	1.60666***	0.551993	2.910652	0.0031
REU	-1.794804	1.915631	-0.936926	0.3600
AEU	46.610845	57.950134	0.804327	0.4307
TOU	1.68780***	0.491433	3.434449	0.0026
C	262.6367	209.726374	1.252283	0.2249
Adjusted R-squared	0.941421		Prob(F-statistic)	0.0000

Source: E-views Output (2024)

Note: *, ** and * denote significant at 1%, 5% and 10% levels respectively**

The results showed that fossil fuel energy use has a positive and significant effect on the mining sector value added in the long run. This finding agrees with the a priori expectations, which predict that fossil fuels largely drive the mining sector. It is also consistent with the findings of Lin and Atsagli (2017) who reported that the use of fossil fuels is critical to the development of the real sector including the mining sector value added to the GDP. The implication of this finding is that the mining sector tends to rely on fossil fuels to increase output. The results further showed that renewable energy use and alternative energy use have no significant effect on mining sector value added in both the short and long run. This finding is in tandem with the results of Igogo *et al.* (2021) and Pollack and Bongaerts (2020) who report that the transition to renewable and sustainable energy including alternative and nuclear power has not significantly contributed to the growth of the mining sector. This further indicates that the firms in the mining sector in Nigeria have optimized the opportunities associated with the energy mix in the country to foster long-term growth and development.

Interestingly, the results showed that total electricity use has a positive and significant effect on the mining sector value added. This finding conforms to the theoretical expectation which highlights the potential of electricity access and usage in driving the development of the real sector including the mining sector value added in developing economies. In comparison, the significant positive contribution of electricity to the mining sector growth corroborates the findings of Ateba, Prinsloo and Gawlik (2019), and Lin and Zhu (2021) who reported that access to electricity plays a critical role in driving the growth of mining sector. This finding highlights the effectiveness of electricity in fostering the value chain in the mining sector. The error correction coefficient (-0.2275) shows that distortion from the long run equilibrium position can be corrected at the speed of 22.75% each year. The R-squared (0.9414) showed that 94.14% of the total variations in the mining sector value added are jointly explained by changes in fossil fuel, renewable energy, alternative energy and electricity use. The statistical significant of this model is further highlighted by the probability value (0.0000) of the F-statistic which is less than 0.05. This finding indicates that the energy use indicators (fossil fuel, renewable energy, alternative energy and electricity use) are jointly significant in influencing the mining sector value added.

Table 4: Post-estimation test results

Test Type	Test Statistic	Probability value
Breusch-Godfrey Serial Correlation LM Test	6.296	0.0981
White heteroskedasticity test	11.666	0.3080
Ramsey RESET	1.4675	0.2568

Source: E-views Output (2024)

It is evident from the post-estimation test results that there is no serial correlation in the model at the 5% level. This is because the probability value (0.0981) of the Breusch-Godfrey serial correlation LM test result is greater than 0.05. Consequently, the null hypothesis of no serial correlation is accepted. Similarly, it is evident from the results that the variance of the residuals is constant over the study period given that the White heteroskedasticity test result is associated a probability value of 0.3080 which is greater than 0.05. This provides the basis for accepting null hypothesis of homoscedasticity in the residuals. The post-estimation test results further showed that the model is properly specified at the 5% significance level, given that the probability value (0.2568) of the Ramsey RESET result is greater than 0.05. Overall, the findings from the post-estimation test provided enough evidence for the reliability of the estimated ARDL model.

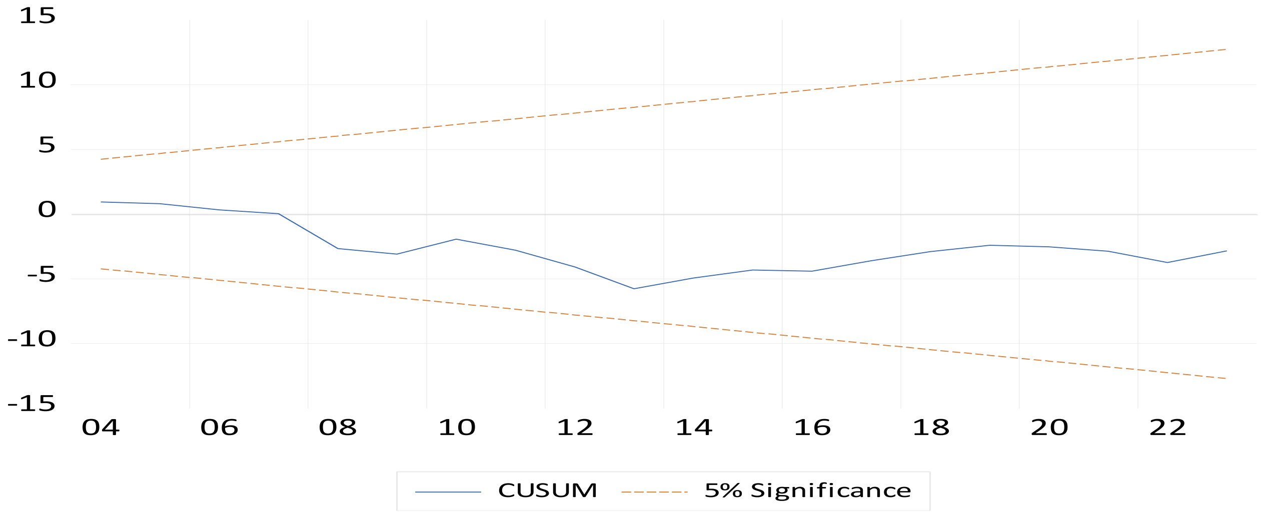

Figure 1: Cumulative sum (CUSUM) graph

As previously noted, the CUSUM graph was employed in this study to ascertain the stability of the estimated ARDL model. It is evident from the results that the CUSUM graph lies within the two critical bound lines at the 5% significance level. This implies that the estimated parameters are constant over the study period.

5. CONCLUSION AND REMARKS

The study highlights the critical role of energy use in shaping the performance and growth of the manufacturing sector. Empirical evidence shows that fossil fuel use affected the mining sector value added positively in the long run. This finding could be linked to the large dependence of the mining sector on fossil fuels, especially diesel, for increased productivity and value addition to GDP. The results further showed that renewable energy use affected the mining sector value added negatively. This finding suggests that the transition to renewable energy has not yielded positive benefits for the productive real sector. In addition, the results showed that the effect of renewable energy use on service sector value added is positive and significant. Evidence of a positive and significant effect of alternative energy use on the mining sector was established in the long run. Given the findings, we recommend that policymakers reduce fossil fuel dependency as a source of energy by diversifying energy sources to create more opportunities for firms in the mining sector to boost their output and value addition to GDP.

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