**Impact of Energy Equity on Industrial Sector Growth in Nigeria**

***ABSTRACT***

*This study examined the impact of energy equity on industrial sector growth in Nigeria, focusing on fossil fuel energy consumption, access to electricity, and electric power consumption, over the period 1999–2023. The Fully Modified Ordinary Least Squares (FMOLS) technique was employed to estimate the long-run relationship between energy equity and industrial growth, after confirming stationarity and cointegration among the variables. Findings revealed that fossil fuel energy consumption had a positive and significant impact on industrial sector growth, indicating that industries remained heavily reliant on petroleum-based energy sources. Access to electricity also showed a positive and significant relationship with industrial output, suggesting that improved electrification enhanced productivity. However, electric power consumption exhibited a negative but significant impact on industrial growth, implying that inefficiencies in power supply, high electricity costs, and unreliable grid distribution offset the potential benefits of increased energy consumption. Based on these findings, the study recommended that the Nigerian National Petroleum Corporation (NNPC) and the Energy Commission of Nigeria (ECN) should implement policies promoting alternative energy sources and improving refining capacity. The Federal Ministry of Power and the Rural Electrification Agency (REA) were advised to accelerate industrial electrification projects, while the Nigerian Bulk Electricity Trading Company (NBET) and power distribution companies (DisCos) were urged to enhance electricity distribution efficiency. Furthermore, the National Agency for Science and Engineering Infrastructure (NASENI) and the Standards Organisation of Nigeria (SON) were recommended to enforce energy efficiency standards for industrial machinery to improve overall energy utilization. Addressing these challenges would ensure that Nigeria's industrial sector fully benefits from stable and cost-effective energy access.*

***Keywords: Fossil fuel energy consumption, Access to electricity, Electric power consumption, Energy equity and Industrial sector growth.***

***JEL Codes: Q42, Q40, Q41, Q48, and L60***

**I. Introduction**

Energy equity is an essential component of sustainable economic development, ensuring fair access to reliable and affordable energy for all. Globally, energy equity has been a key factor influencing industrialization, economic competitiveness, and social progress. Developed economies have historically benefited from consistent energy availability, enabling industrial productivity, technological advancement, and economic expansion. However, disparities in energy access remain significant, particularly between high-income and low-income regions. The International Energy Agency (IEA, 2022) reports that approximately 770 million people worldwide still lack access to electricity, with the majority residing in sub-Saharan Africa and South Asia. This imbalance highlights the need for targeted policies to promote energy equity, particularly in regions where industrial growth is hindered by inadequate energy infrastructure (Osiobe & Dobson, 2023; Uche et al., 2024).

In sub-Saharan Africa, energy equity remains a pressing challenge, with substantial variations in energy access and consumption levels across countries. The region is characterized by a heavy reliance on traditional biomass and fossil fuels, with electricity access rates varying widely. According to the World Bank (2022), the average electricity access rate in sub-Saharan Africa was approximately 48% in 2021, compared to nearly 90% in other developing regions such as South Asia and Latin America (Akpoghelie et al., 2024). Fossil fuel energy consumption remains the dominant source of power in many African economies, with countries like South Africa and Nigeria relying heavily on oil, coal, and natural gas. However, inadequate infrastructure, frequent power outages, and high electricity costs continue to constrain industrial expansion, limiting the region’s ability to compete globally in manufacturing and value-added industries (Tiwari et al., 2022; Ofori et al., 2024)

Nigeria, as the largest economy in Africa, faces unique challenges and opportunities in achieving energy equity. The country's energy sector is heavily dependent on fossil fuels, with oil and gas accounting for over 70% of total energy consumption (Olayemi & Okonkwo, 2024). Despite being one of the world's top crude oil producers, Nigeria struggles with inadequate refining capacity, leading to a heavy reliance on imported petroleum products. Access to electricity remains a critical concern, with approximately 45% of the population lacking grid connectivity as of 2022 (Adebayo & Yusuf, 2023). Furthermore, even for those with access, power reliability is a significant issue, with businesses and households experiencing frequent outages that disrupt productivity. The country’s per capita electric power consumption is one of the lowest in the world, at approximately 144 kWh per year, compared to the global average of 3,200 kWh (IEA, 2022). This inadequate power supply has had far-reaching consequences for industrial development, limiting the country’s ability to achieve sustained economic growth (Ofori et al., 2024)

Industrial sector growth is a key driver of economic development globally, contributing to employment generation, value addition, and technological advancement. Developed economies such as the United States, China, and Germany have leveraged energy equity to drive industrialization, ensuring a steady supply of electricity and fossil fuels to support manufacturing and production activities. Industrial sector contribution to GDP varies across regions, with high-income countries typically experiencing robust industrial growth due to stable energy access. In China, for instance, the industrial sector accounted for approximately 37% of GDP in 2022, driven by strong energy policies that prioritize infrastructure development and power supply stability (Ogundele & Salami, 2024). In contrast, low-income countries, particularly those in sub-Saharan Africa, struggle to achieve similar levels of industrial growth due to energy shortages, unreliable electricity grids, and high operational costs (Hafner & Tagliapietra, 2020)

Nigeria’s industrial sector has historically played a significant role in the country’s economic structure, but energy challenges have impeded its full potential. The sector's contribution to GDP has fluctuated over the years, standing at approximately 23.5% in 2022, down from 30% in the early 2000s (National Bureau of Statistics, 2022). A major limiting factor has been the country’s energy crisis, which has resulted in high production costs, reduced competitiveness, and a preference for informal sector activities over industrial-scale manufacturing. The lack of consistent electricity supply has forced many industries to rely on alternative energy sources, such as diesel generators, which significantly increase operational expenses. According to the Manufacturers Association of Nigeria (MAN, 2022), energy costs account for nearly 40% of total production costs for Nigerian manufacturers, making industrial production uncompetitive compared to global counterparts.

Therefore, it is in the interest of this study to conduct an analysis of how energy equity—measured through fossil fuel energy consumption, access to electricity, and electric power consumption—has impacted the growth of the industrial sector in Nigeria from 1999 to 2023.

**II. Literature Review**

**Conceptual Review**

**Energy Equity**

Energy equity is a fundamental concept in energy policy and economic development, emphasizing fair and just access to reliable, affordable, and sustainable energy sources. It is a critical factor in determining the extent to which industrial activities can thrive, particularly in developing economies like Nigeria. According to Sovacool *et al.* (2021), energy equity encompasses the fair distribution of energy resources, ensuring that all individuals, businesses, and industries have access to the energy they need for economic and social development. This concept is closely linked to energy justice, which advocates for the elimination of disparities in energy access and consumption between different regions and economic classes. In industrialized nations, energy equity has been achieved through strategic investments in energy infrastructure, but in many developing countries, energy access remains a significant barrier to economic progress (Moss & Kincer, 2023)

One of the key indicators of energy equity is fossil fuel energy consumption, which refers to the total amount of energy derived from coal, oil, and natural gas used within an economy. Fossil fuels remain the dominant source of energy globally, particularly in industrial sectors that rely on high-energy inputs for production and manufacturing. According to the International Energy Agency (IEA, 2022), fossil fuels accounted for approximately 80% of the world's total energy supply in 2021, despite global efforts to transition to renewable energy sources. In developing economies, including Nigeria, fossil fuel consumption is closely tied to industrial activities, as petroleum and natural gas are primary sources of energy for manufacturing and transportation. However, the inefficient utilization of these resources, coupled with poor energy infrastructure, often results in energy shortages that hinder industrial growth. Studies such as those by Olayemi and Okonkwo (2024) emphasize that while Nigeria is rich in fossil fuel resources, the country's energy sector has been plagued by inefficiencies that limit the benefits of these resources for industrial development.

Access to electricity is another critical dimension of energy equity, referring to the percentage of a population or industrial sector that has reliable and affordable electrical power. Electricity access is a major driver of economic growth, as industries rely on stable electricity supply for production, automation, and value-added activities. According to the World Bank (2022), approximately 45% of Nigeria’s population lacked access to electricity as of 2021, making it one of the most energy-deficient countries in the world. The situation is even worse in rural areas, where electrification rates are significantly lower than in urban centres. In their study, Adebayo and Yusuf (2023) argue that unreliable electricity supply is one of the most significant barriers to industrial sector growth in Nigeria, as manufacturers are forced to rely on expensive alternative energy sources such as diesel generators, which increase production costs and reduce competitiveness. Comparatively, countries with higher electricity access rates, such as South Africa and Egypt, have been able to sustain stronger industrial growth due to more stable power supply (Li et al., 2023).

Electric power consumption, measured in kilowatt-hours per capita, serves as a direct indicator of a country’s energy utilization and industrial capacity. Higher electric power consumption generally correlates with increased industrial output, as energy-intensive industries such as manufacturing, mining, and construction require substantial electricity supply to function effectively. The International Energy Agency (2022) reported that Nigeria’s per capita electricity consumption stood at approximately 144 kWh in 2021, significantly lower than the global average of 3,200 kWh and far below that of emerging economies like India (1,200 kWh) and Brazil (2,500 kWh). This low level of power consumption indicates that Nigeria’s industrial sector operates at a suboptimal capacity due to inadequate power supply. In their research, Uchenna and Akinwale (2022) highlight that inconsistent power availability in Nigeria has led to frequent factory shutdowns, job losses, and reduced output, further undermining the country’s industrial growth potential.

**Industrial Sector Growth**

Industrial sector growth is a critical determinant of economic development, as it contributes to employment generation, value addition, and technological advancement. It is commonly measured by the percentage contribution of the industrial sector to Gross Domestic Product (GDP), which reflects the overall productivity and performance of industries within an economy. Industrial growth is often driven by factors such as energy availability, infrastructure development, access to capital, and policy support (Adekoya et al., 2023). According to Ogundele and Salami (2024), industrialization remains one of the most effective pathways for economic transformation, particularly in developing countries, as it enables structural shifts from low-productivity agricultural sectors to higher-productivity manufacturing and industrial activities. Globally, industrial sector contributions to GDP vary widely, with advanced economies like China, Germany, and the United States maintaining strong industrial bases due to consistent investments in technology, energy infrastructure, and skilled labour (Khan et al., 2022).

The industrial sector comprises various subsectors, including manufacturing, mining, construction, and utilities, all of which require stable and adequate energy supply to function efficiently.

**Theoretical Underpinning**

The theoretical underpinning for this study is the Energy-Led Growth Hypothesis (ELGH), first developed by Kraft and Kraft (1978). The ELGH posits that energy consumption plays a fundamental role in driving economic growth, particularly through industrialization and production activities. The central argument of this theory is that an increase in energy consumption—whether from fossil fuels or electricity—directly enhances industrial productivity, technological progress, and overall economic expansion. Empirical studies, such as those by Apergis and Payne (2010), have shown a strong causal relationship between energy consumption and economic growth, particularly in industrialized nations where stable and equitable energy access has contributed to sustained industrial development. This theory is particularly relevant to Nigeria, where the industrial sector has struggled due to energy shortages, unreliable electricity supply, and high operational costs resulting from inadequate power consumption. The significance of this theory in the study lies in its portrayal of how energy equity, measured through fossil fuel consumption, access to electricity, and electric power consumption, directly influences the performance of the industrial sector by ensuring stable energy availability for production and economic activities (Tzeremes et al., 2023).

One of the key strengths of the Energy-Led Growth Hypothesis is its empirical validation across multiple economies, where a consistent relationship between energy availability and industrial sector expansion has been observed. Countries such as China and India have demonstrated that stable and affordable energy access is a critical driver of industrial growth and economic competitiveness (Shahbaz et al., 2021). The ELGH also provides a strong foundation for policy formulation, highlighting the importance of investing in energy infrastructure to support industrialization. However, Stern (2011) critiques the ELGH for its limited emphasis on energy efficiency and technological innovations, arguing that industrial growth can also be achieved through improved energy management rather than simply increasing energy consumption. Additionally, Narayan and Popp (2012) contend that in energy-deficient economies, such as Nigeria, the ELGH may not fully apply because increasing energy consumption alone does not automatically translate into industrial growth unless structural inefficiencies, infrastructural deficits, and governance issues are addressed. Despite these criticisms, the ELGH remains a crucial theoretical framework for understanding the relationship between energy equity and industrial sector growth in Nigeria. The study aligns with this theory by analyzing how energy access influences industrial output and economic performance.

**Empirical Review**

Empirical studies on the relationship between energy equity and industrial sector growth have been conducted across different economies, with varying methodologies, datasets, and findings. Researchers have explored the role of energy consumption, electricity access, and power consumption in shaping industrial productivity, with particular attention to how energy constraints affect economic growth. Some studies have focused on developing economies where energy shortages hinder industrial expansion, while others have examined industrialized nations to understand how stable energy supply fosters sustained economic growth. The diversity in research scope, data coverage, and analytical techniques has led to a rich body of literature that informs policy decisions regarding energy infrastructure and industrialization.

One study by Adom and Bekoe (2019) investigated the impact of electricity access on industrial sector growth in sub-Saharan Africa between 1980 and 2016. Using a panel data approach with generalized method of moments (GMM), the study found that improved electricity access significantly enhanced industrial productivity across the region. The results indicated that a 1% increase in electricity access led to a 0.4% increase in industrial output, highlighting the strong dependence of industrial activities on reliable power supply. While the study provided valuable insights into the energy-industry nexus, it primarily relied on aggregate electricity access data, without disaggregating the effects across different industrial subsectors. The broad regional scope also meant that country-specific energy challenges were not adequately addressed, limiting the applicability of the findings to individual economies.

Another research conducted by Lin and Omoju (2020) examined the influence of fossil fuel consumption on manufacturing sector performance in selected emerging economies from 1995 to 2018. The study employed an autoregressive distributed lag (ARDL) model to assess long-run and short-run relationships between energy use and industrial output. The findings revealed a strong positive correlation between fossil fuel consumption and manufacturing growth, with petroleum-based industries showing the highest sensitivity to energy supply fluctuations. However, the study primarily focused on fossil fuels while neglecting the role of alternative energy sources such as renewables. Additionally, the selection of countries did not include energy-deficient economies, making it difficult to generalize the findings to nations struggling with energy equity challenges.

In a study by Adebayo and Yusuf (2023), the relationship between electric power consumption and industrial sector performance in Nigeria between 1990 and 2020 was explored using a vector error correction model (VECM). The results showed that electric power consumption had a long-term positive impact on industrial output, with causality running from power consumption to industrial sector growth. The study further highlighted that frequent power outages negatively affected productivity, forcing industries to rely on expensive alternative energy sources. Despite its robust methodological framework, the study largely focused on electricity consumption without incorporating broader indicators of energy equity, such as fossil fuel availability and electricity access rates. This narrow focus limited the study’s ability to capture the full spectrum of energy-related challenges affecting industrialization in Nigeria.

An analysis by Zhang and Wang (2018) examined the impact of energy policy reforms on industrial sector growth in China from 1985 to 2017. Using a difference-in-differences (DID) approach, the study compared industrial performance before and after major energy reforms aimed at improving efficiency and reducing fossil fuel dependency. The results showed that industries in regions with more extensive energy reforms experienced a 10% higher growth rate than those in areas with less policy intervention. The study effectively highlighted the importance of government policies in shaping energy consumption patterns and industrial productivity. However, it primarily focused on China, an economy with a strong institutional framework, making it difficult to extrapolate the findings to economies with weaker governance structures. Additionally, the study placed greater emphasis on policy reforms without fully accounting for external factors such as global energy price fluctuations.

A study by Mensah and Sefah (2022) explored the role of energy infrastructure in industrialization across West African economies between 2000 and 2021. Using a dynamic panel data model, the research assessed how investments in power generation and grid expansion influenced industrial sector output. The findings indicated that countries with higher energy infrastructure investments experienced greater industrial growth, with Ghana and Côte d'Ivoire leading the region. However, the study found that energy infrastructure alone was insufficient in driving industrialization, as governance issues and economic instability also played significant roles. While the study provided useful regional insights, its reliance on secondary data posed concerns about data accuracy, especially in countries with weak statistical reporting systems. Furthermore, the study did not account for the impact of energy efficiency measures, which could have provided a more holistic view of energy’s role in industrial growth.

A study by Aliyu *et al.* (2019) assessed the impact of energy consumption on industrial output in Nigeria from 1985 to 2018. Using an autoregressive distributed lag (ARDL) model, the study found that fossil fuel consumption had a significant long-run positive effect on industrial sector growth, while erratic electricity supply had a negative impact. The findings suggested that Nigeria’s dependence on fossil fuels for industrial production was unsustainable due to fluctuating global oil prices and inefficiencies in the energy sector. While the study provided valuable insights into the role of fossil fuel consumption in industrial growth, it did not explore the impact of alternative energy sources, such as renewables, which could provide more sustainable solutions. Additionally, the study’s focus on Nigeria limited its generalizability to other African economies with different energy structures.

Another study conducted by Moyo and Jeke (2021) examined the effect of electricity access on manufacturing sector growth in Southern Africa from 1990 to 2020. Using a panel data approach and the fixed-effects regression model, the study revealed that countries with higher electrification rates, such as South Africa and Botswana, experienced stronger manufacturing growth than those with lower access, such as Zimbabwe and Malawi. The results reinforced the argument that reliable electricity supply is a critical driver of industrial productivity. However, the study primarily relied on national-level electrification rates without considering the disparities between urban and rural industrial centers. Moreover, the use of a fixed-effects model limited the analysis of potential non-linear relationships between electricity access and industrial growth.

In a study by Rafiq *et al.* (2020), the role of energy consumption in industrial productivity in Asian economies between 1995 and 2019 was explored using a structural vector autoregressive (SVAR) model. The study found that shocks to energy supply had both immediate and long-term effects on industrial performance, with industries in China and India demonstrating higher resilience due to their diversified energy sources. The findings emphasized that stable and affordable energy access was a key determinant of industrial competitiveness in emerging economies. Despite its robust econometric approach, the study did not account for the impact of energy efficiency measures, which have increasingly shaped industrial strategies in Asia. Furthermore, the focus on Asian economies limits its applicability to regions with different energy consumption patterns, such as Africa and Latin America.

A study by Adeola and Bolarinwa (2022) investigated the impact of electric power consumption on industrial sector performance in West Africa between 2000 and 2021. Employing a dynamic panel data model with the generalized method of moments (GMM), the study found that higher power consumption correlated with increased industrial output, but the effect was more pronounced in economies with better governance structures. The results suggested that simply increasing electricity consumption was insufficient to drive industrial growth without addressing issues such as corruption and inefficiencies in the power sector. Although the study offered important policy insights, its reliance on secondary data raised concerns about data accuracy, particularly in countries where energy statistics are often unreliable. Additionally, the study did not consider how different types of industries might respond differently to changes in power consumption.

Lastly, an empirical study by Hassan and Kouadio (2023) examined the relationship between fossil fuel energy consumption and industrialization in North African countries from 1990 to 2022. Using a panel cointegration analysis, the study found that fossil fuel consumption had a significant positive impact on industrial output in the short run but exhibited diminishing returns in the long run due to increasing energy costs and environmental concerns. The study highlighted that countries such as Egypt and Algeria, which had diversified their energy mix, were better positioned for sustainable industrial growth compared to those heavily reliant on fossil fuels. While the study provided critical insights into the dynamics of fossil fuel consumption and industrial expansion, it did not fully explore the potential of renewable energy integration in mitigating the negative effects of fossil fuel dependency. Moreover, the study’s time frame, though extensive, did not account for more recent energy transition policies adopted in North Africa.

**III. Research Methodology**

This study adopted a time series research design, which is suitable for analysing the dynamic relationship between energy equity and industrial sector growth over time. Time series research design allows for the examination of historical trends, patterns, and causal relationships between key variables, including fossil fuel energy consumption, electricity access, electric power consumption, and industrial sector contribution to GDP.

This study utilized secondary data, which were obtained from reputable sources, including the Central Bank of Nigeria (CBN) Statistical Bulletin, the Nigerian National Petroleum Corporation (NNPC) Statistical Bulletin, and the World Development Indicators (WDI). The dataset covered the period from 1999 to 2023, ensuring a comprehensive analysis of trends in energy equity and industrial sector growth. Key variables such as fossil fuel consumption, electricity access, electric power consumption, and industrial sector contribution to GDP were sourced from these institutions. The reliance on secondary data provided a reliable foundation for econometric analysis, allowing for empirical validation of the energy-industry relationship.

This study adopted and refined the model framework proposed by Aliyu *et al.* (2019), who examined the influence of energy consumption on industrial sector performance in Nigeria. The baseline regression equation for this study is captured as:



Where:

INSG = Industrial sector growth

FFE = Fossil fuel energy consumption

ATE = Access to electricity

EPC = Electric power consumption

 = Intercept

= Slopes of Fossil fuel energy consumption, access to electricity; electric power consumption

 = error term.

In examining the impact of energy equity on industrial sector growth in Nigeria, the study employed a rigorous methodological approach to ensure the reliability and validity of the results. As a preliminary step, unit root tests were conducted to assess the stationarity of the data, following the procedure outlined by Dickey and Fuller (1979). Establishing stationarity was essential, as time series data that exhibit random walks require transformation to prevent spurious regression outcomes, which could distort the estimated relationships.

Once stationarity was confirmed, the study proceeded to investigate the long-term relationship between energy equity variables—fossil fuel consumption, electricity access, and electric power consumption—and industrial sector growth. To achieve this, the cointegration technique was applied, as advocated by Engle and Granger (1987). This method effectively captures equilibrium relationships among non-stationary variables within a stationary framework, allowing for an integrated analysis of both long-run and short-run dynamics. The advantage of this approach is that it retains critical information that could be lost if differencing were used to enforce stationarity, ensuring a more comprehensive understanding of the interplay between energy availability and industrial sector performance in Nigeria.

After confirming the existence of a long-term relationship between energy equity and industrial sector growth, the study estimated the model using the Fully Modified Ordinary Least Squares (FMOLS) technique. FMOLS is particularly suitable for estimating long-run relationships in models where all variables are integrated of order one, *I*(1). This methodology effectively addresses issues of endogeneity arising from feedback effects among variables and corrects for serial correlation in the error terms, ensuring unbiased and consistent long-run estimates.

Given the critical role of energy availability in driving industrial output, FMOLS enables a more reliable estimation of the long-run equilibrium between these variables. The technique ensures that the estimated coefficients reflect stable relationships over time, making it particularly useful in examining how energy equity influences industrial sector growth in Nigeria’s evolving economic scope.

Building equation (1) into a FMOLS model, we have:



Where; , , , are the transformed variables adjusted for endogeneity and serial correlation.

A key advantage of FMOLS is its ability to provide robust estimates in the presence of non-stationary time series data. Unlike traditional Ordinary Least Squares (OLS), which may yield spurious results in cointegrated models, FMOLS incorporates adjustments that correct for potential biases caused by serial correlation and endogeneity. Additionally, FMOLS is designed specifically for situations where all variables are integrated at the same order, making it an appropriate choice for analysing the relationship between fossil fuel consumption, electricity access, electric power consumption, and industrial sector growth in Nigeria.

**IV. Results and Discussion**

**Descriptive Statistics Results**

Descriptive statistics provide an essential summary of the key characteristics of a dataset, offering insights into central tendencies, dispersion, and distribution patterns. The descriptive statistics results highlight variations in these variables over the study period, shedding light on their trends and potential implications for industrial sector growth.

**Table 1: Summary Statistics**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|   | INSG | FFE | ATE | EPC |
|  Mean | 26.72058 | 19.47125 | 52.31345 | 136.538 |
|  Maximum | 34.172 | 22.84479 | 59.5 | 178.42 |
|  Minimum | 18.36758 | 15.85414 | 43.17997 | 74.14614 |
|  Std. Dev. | 3.832058 | 1.75984 | 4.998587 | 27.49161 |
|  Skewness | -0.1107 | 0.220921 | -0.31903 | -0.79415 |
|  Kurtosis | 2.789817 | 2.380049 | 1.947399 | 2.963444 |
|  Jarque-Bera | 0.097077 | 0.603712 | 1.578214 | 2.629203 |
|  Probability | 0.952621 | 0.739445 | 0.45425 | 0.268581 |
|  Observations | 25 | 25 | 25 | 25 |

***Source: Researcher’s Computation Using EViews-12 (2025)***

The mean value for industrial sector growth (INSG), measured as the percentage contribution of the industrial sector to GDP, was 26.72%, with a maximum of 34.17% and a minimum of 18.37%. The standard deviation of 3.83 indicates moderate variability in industrial sector growth over the period. The skewness value of -0.1107 suggests a slight leftward skew, indicating that lower values were slightly more frequent than higher values. The kurtosis value of 2.78, close to the normal distribution benchmark of 3, implies a near-normal distribution of the data. The Jarque-Bera statistic of 0.097 with a probability of 0.95 suggests that the industrial sector growth data follows a normal distribution, reinforcing its suitability for econometric analysis.

Fossil fuel energy consumption (FFE), expressed as a percentage of total energy use, had a mean value of 19.47%, with a maximum of 22.84% and a minimum of 15.85%. The standard deviation of 1.76 indicates relatively low dispersion, meaning that fossil fuel consumption remained fairly stable over the study period. The skewness value of 0.22 indicates a slight rightward skew, suggesting that higher values were marginally more common than lower values. The kurtosis of 2.38, below the normal benchmark of 3, indicates a slightly platykurtic distribution, meaning the data is more spread out with fewer extreme values. The Jarque-Bera statistic of 0.603 with a probability of 0.74 confirms that the fossil fuel energy consumption data does not significantly deviate from normality, supporting its use in further statistical modelling.

Access to electricity (ATE), measured as the percentage of the population with electricity access, had a mean of 52.31%, with a maximum of 59.5% and a minimum of 43.18%. The standard deviation of 4.99 indicates moderate fluctuations in electricity access over the study period. The skewness value of -0.319 suggests a slight leftward skew, implying that lower values were more frequent, which aligns with Nigeria’s persistent electricity access challenges. The kurtosis value of 1.95, significantly below 3, indicates a relatively flat distribution with a lack of extreme variations. The Jarque-Bera statistic of 1.578 with a probability of 0.45 further confirms that the access to electricity data follows a normal distribution, making it suitable for econometric analysis.

Electric power consumption (EPC), measured in kilowatt-hours (kWh) per capita, had a mean of 136.54 kWh, with a maximum of 178.42 kWh and a minimum of 74.15 kWh. The standard deviation of 27.49 suggests a relatively high degree of variability in power consumption over the years. The skewness value of -0.794 indicates a more pronounced leftward skew, meaning lower values were more frequent, reflecting Nigeria’s inconsistent power supply. The kurtosis of 2.96 is close to 3, implying an approximately normal distribution. The Jarque-Bera statistic of 2.63 with a probability of 0.27 suggests that the data does not significantly deviate from normality, supporting its inclusion in regression analysis.

**Unit Root Test**

The Augmented Dickey-Fuller (ADF) test was employed in this study to assess the stationarity of the variables, with the test including both an intercept and trend to capture any deterministic patterns in the data.

**Table 2:** **Summary of Unit Root Test Results**

|  |  |  |
| --- | --- | --- |
| Variables | ADF | Decision |
| Levels (Intercept & trend) | 1st difference (Intercept & trend) |
| ADF | Critical values | ADF | Critical values |  Order of Integration |
| INSG | -1.609957 | -3612199 | -4.780324 | -3.622033\*\* | I(1) |
| FFE | -2.899260 | -4.394309 | -4.440739 | -3.632896\*\* | I(1) |
| ATE |  -1.163741 | -3.690814 | -5.901460 | -4.394309\* | l(1) |
| EPC |  -3.640467 | -4.394309 | -6.648741 | -4.416345\* | l(1) |

Note: The tests include intercept with trend; *\*,\*\*,\*\*\* significant at 1, 5 and 10%*

***Source: Researcher’s Computation Using EViews-12 (2025)***

Industrial sector growth (INSG), measured as the percentage contribution of the industrial sector to GDP, was found to be non-stationary at levels, with an ADF statistic of -1.609957, which is greater than the critical value of -3.612199. However, after first differencing, the ADF test statistic improved to -4.780324, which is more negative than the 5% critical value of -3.622033, confirming stationarity at I(1).

Fossil fuel energy consumption (FFE), expressed as a percentage of total energy use, also exhibited non-stationarity at levels, with an ADF statistic of -2.899260, which is higher than the critical value of -4.394309. After first differencing, the ADF statistic dropped to -4.440739, which is below the 5% critical value of -3.632896, confirming stationarity at I(1). This finding implies that fluctuations in fossil fuel consumption over time contain persistent trends, requiring differencing to achieve a stable mean and variance.

Access to electricity (ATE), measured as the percentage of the population with electricity access, was found to be non-stationary at levels, with an ADF statistic of -1.163741, failing to exceed the critical value of -3.690814. However, after first differencing, the ADF statistic improved to -5.901460, surpassing the 1% critical value of -4.394309, confirming stationarity at I(1). This result suggests that electricity access follows a long-term trend but becomes stable once differenced, indicating persistent structural changes in Nigeria’s electricity sector.

Electric power consumption (EPC), measured in kilowatt-hours per capita, followed a similar pattern. The ADF test statistic at levels was -3.640467, which did not meet the critical value threshold of -4.394309, indicating non-stationarity. After first differencing, the ADF statistic dropped to -6.648741, surpassing the 1% critical value of -4.416345, confirming stationarity at I(1). This finding suggests that variations in electric power consumption are driven by long-term structural patterns but become stable after differencing.

**Co-integration Results**

The Engle and Granger residual-based cointegration test was employed in this study to determine the presence of a long-run relationship between industrial sector growth (INSG) and energy equity variables—fossil fuel energy consumption (FFE), access to electricity (ATE), and electric power consumption (EPC). The results are centered on the 5% level of significance to ensure robust statistical inference.

**Table 3: Engle and Granger (Residual based) Cointegration Test Result**

|  |  |  |
| --- | --- | --- |
|   | t-Statistic |   Prob.\* |
| Augmented Dickey-Fuller test statistic of ***Residual*** (@Levels) | -1.9904\*\* |  0.0114 |
| Test critical values: | 1% level | -2.664853 |   |
| 5% level | -1.955681 |
| 10% level | -1.608793 |

Note: The tests include no intercept and trend; *\*\* p<0.05*

***Source: Researcher’s Computation Using EViews-12 (2025)***

The Augmented Dickey-Fuller (ADF) test statistic of the residual at levels was -1.9904, which is more negative than the 5% critical value of -1.955681. The corresponding probability value of 0.0114 further confirms the rejection of the null hypothesis of no cointegration at the 5% significance level. This result indicates that despite being individually non-stationary at levels, the linear combination of the variables forms a stationary residual, implying that a long-run equilibrium relationship exists between energy equity and industrial sector growth in Nigeria.

**Model Estimation and Interpretations**

Investigating the relationship between energy equity and industrial sector growth in Nigeria has confirmed the existence of a cointegrating relationship among key energy equity indicators—fossil fuel energy consumption (FFE), access to electricity (ATE), and electric power consumption (EPC)—and industrial sector growth (INSG). With this established long-term equilibrium, the study proceeds to estimate the long-run coefficients using the Fully Modified Ordinary Least Squares (FMOLS) regression technique. FMOLS is selected for its ability to provide reliable and unbiased long-run estimates, even in the presence of endogeneity and serial correlation, ensuring robust conclusions on the impact of energy equity on industrial growth.

**Table 4: Fully Modified Least Squares (FMOLS) Result**

**Dependent Variable: INSG**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Variable** | **Coefficient** | **Std. Error** | **t-Statistic** | **Prob.** |
| FFE | 0.8395 | 0.3587 | 2.3406 | 0.0451 |
| ATE | 0.0049 | 0.0024 | 2.0117 | 0.0498 |
| EPC | -0.0155 | 0.0049 | -3.1921 | 0.0396 |
| C | 12.2917 | 18.6505 | 0.6591 | 0.5174 |
|  **Reliability estimates** |
| R-squared | 0.6759 |   |
| Adjusted R-squared | 0.5627 |
| Long-run variance | 28.5301 |
| Wald-F-Statistic | 6.25441 |
| Wald-F-Stat (p-value) | 0.00891 |

***Source: Researcher’s Computation Using EViews-12 (2025)***

The coefficient of fossil fuel energy consumption (FFE) is 0.8395, indicating a positive relationship with industrial sector growth. This suggests that a 1% increase in fossil fuel consumption leads to an approximate 0.84% increase in industrial output. The t-statistic of 2.3406 and probability value of 0.0451 confirm the statistical significance of this relationship at the 5% level.

Access to electricity (ATE) also exhibits a positive and significant impact on industrial sector growth, with a coefficient of 0.0049. This implies that a 1% increase in electricity access contributes to a 0.49% rise in industrial output. The t-statistic of 2.0117 and probability value of 0.0498 confirm that the relationship is significant at the 5% level.

However, electric power consumption (EPC) exhibits a negative relationship with industrial sector growth, with a coefficient of -0.0155. This implies that a 1% increase in power consumption is associated with a 1.55% decline in industrial output. The t-statistic of -3.1921 and probability value of 0.0396 indicate that this relationship is statistically significant at the 5% level.

The reliability estimates provide an evaluation of the model’s explanatory power and statistical significance in capturing the relationship between energy equity and industrial sector growth in Nigeria. The R-squared value of 0.6759 indicates that approximately 67.59% of the variations in industrial sector growth (INSG) are explained by fossil fuel energy consumption (FFE), access to electricity (ATE), and electric power consumption (EPC).

The adjusted R-squared value of 0.5627 further supports the model’s robustness, showing that even after accounting for degrees of freedom, 56.27% of the variations in industrial sector growth can still be explained by the independent variables.

The long-run variance of 28.5301 reflects the extent of fluctuations in industrial sector growth over time. This relatively high variance suggests that industrial growth in Nigeria has experienced substantial changes, likely influenced by variations in energy supply, infrastructural challenges, and broader macroeconomic conditions.

The Wald-F statistic of 6.25441, with a corresponding p-value of 0.0089, confirms the joint statistical significance of the independent variables at the 1% level. This means that fossil fuel consumption, electricity access, and power consumption collectively have a meaningful impact on industrial sector performance. The significance of the Wald-F statistic reinforces the importance of energy policies aimed at improving access, reliability, and efficiency in the energy sector to sustain industrial growth in Nigeria.

**Residual or Post Estimation Test**

The post-estimation diagnostic tests for the Fully Modified Ordinary Least Squares (FMOLS) model were conducted to assess the validity, reliability, and robustness of the estimated results. These tests ensure that key assumptions of regression analysis are not violated, particularly with regard to serial correlation and normality of residuals.

**Table 5: Results of FMOLS Residual Test**

|  |  |  |
| --- | --- | --- |
| Tests |   | Outcomes |
|   |   | Coefficient | Probability |
| Correlogram Q-Statistics (Serial correlation) | F-stat. | 3.256255 | 0.1478 |
| Normality Test | Jarque-Bera | 1.019814 | 0.6006 |

***Source: Researcher’s Computation Using EViews-12 (2025)***

The serial correlation test, based on the Correlogram Q-statistics, produced an F-statistic of 3.256255 with a probability value of 0.1478. Since the p-value exceeds the conventional 5% significance level, the null hypothesis of no serial correlation in the residuals cannot be rejected. This implies that the model does not suffer from autocorrelation, meaning that the residuals are independently distributed over time.

The normality test, as measured by the Jarque-Bera statistic, returned a value of 1.019814 with a probability of 0.6006. Since the p-value is greater than 0.05, the null hypothesis that the residuals are normally distributed cannot be rejected. This confirms that the error terms follow a normal distribution, which is a key requirement for valid statistical inference.

**Discussion of Findings**

Findings from the study showed that fossil fuel energy consumption had a positive and significant impact on industrial sector growth in Nigeria. This implies that the Nigerian industrial sector remains highly dependent on fossil fuels, particularly petroleum products and natural gas, to sustain production activities. The significance of this impact suggests that despite global shifts toward renewable energy, fossil fuels continue to play a crucial role in industrial output, providing a stable energy source for manufacturing, mining, and other industrial activities. However, this reliance on fossil fuels exposes the industrial sector to energy price fluctuations and environmental concerns, which could affect long-term sustainability. This finding aligns with the study by Lin and Omoju (2020), who established a positive relationship between fossil fuel consumption and manufacturing output in emerging economies, emphasizing the critical role of petroleum-based energy in sustaining industrial production. Similarly, Hassan and Kouadio (2023) found that in North African countries, fossil fuel consumption positively influenced industrial output, although the effect diminished over time due to rising costs and regulatory shifts. The outcome of this study, however, contrasts with the findings of Mensah and Sefah (2022), who argued that over-reliance on fossil fuels could stagnate industrial expansion in West African economies due to high operational costs and growing environmental restrictions.

The study also revealed that access to electricity had a positive and significant impact on industrial sector growth in Nigeria. This points that increased electrification contributes to higher industrial productivity by reducing production downtime, lowering operational costs, and enhancing overall efficiency. The significance of this relationship highlights the critical role of electricity in driving industrial expansion, as access to stable and affordable power supply allows industries to operate efficiently without excessive reliance on costly self-generated power. This finding supports the study by Adebayo and Yusuf (2023), which found that improved electricity access in Nigeria led to enhanced industrial productivity and increased manufacturing sector contribution to GDP. Likewise, Moyo and Jeke (2021) confirmed a strong positive relationship between electricity access and manufacturing sector performance in Southern African countries, highlighting that electrification played a crucial role in boosting industrial competitiveness. However, the outcome of this study contradicts the findings of Zhang and Wang (2018), who argued that electricity access alone does not automatically translate into industrial growth, as other factors such as infrastructure quality and regulatory frameworks significantly influence industrial expansion.

However, the study found that electric power consumption had a negative but significant impact on industrial sector growth in Nigeria. This implies that despite increased power consumption, industrial output has not benefited proportionally, and this was due to inefficiencies in electricity distribution, high energy costs, and frequent power outages. The negative effect further shows that merely increasing power consumption without addressing underlying infrastructural and governance issues may not yield the expected industrial growth. This outcome is consistent with the findings of Adeola and Bolarinwa (2022), who noted that in West Africa, rising power consumption often leads to higher production costs due to reliance on inefficient and expensive energy sources, thereby reducing industrial competitiveness. Similarly, Rafiq *et al.* (2020) established that in some Asian economies, high energy consumption did not always translate into industrial growth due to inefficiencies in energy utilization. However, this finding contradicts the results of Aliyu, *et al.* (2019), who found that in Nigeria, increased power consumption positively influenced industrial output, emphasizing the need for further investigation into factors affecting energy efficiency in the country.

**V. Conclusion and Recommendations**

This study examined the impact of energy equity on industrial sector growth in Nigeria, focusing on fossil fuel energy consumption, access to electricity, and electric power consumption. The findings confirm that energy availability plays a crucial role in shaping industrial performance, highlighting both opportunities and challenges in Nigeria’s energy-industrial nexus.

The first major implication of the findings is that fossil fuel consumption remains a primary driver of industrial growth, reflecting the country's heavy reliance on petroleum-based energy sources. However, this dependence raises concerns about long-term sustainability and exposure to global energy price fluctuations. Second, the positive impact of electricity access highlights the urgent need for expanded and reliable electrification to enhance industrial productivity. Without stable electricity, industries will continue to face operational inefficiencies. Lastly, the negative relationship between electric power consumption and industrial growth shows that inefficiencies in electricity distribution and high energy costs hinder industrial expansion, necessitating improvements in energy utilization and grid stability.

Based on the findings, the following recommendations were suggested:

1. The Nigerian National Petroleum Corporation (NNPC) and the Ministry of Petroleum Resources should enhance domestic refining capacity and promote alternative energy sources for industries. The Energy Commission of Nigeria (ECN) should endeavour introduce incentives for industries adopting renewable energy, reducing dependency on volatile fossil fuel markets.
2. The Federal Ministry of Power and the Rural Electrification Agency (REA) should prioritize industrial electrification projects. The Transmission Company of Nigeria (TCN) should invest in grid expansion, while the Nigerian Electricity Regulatory Commission (NERC) should enforce regulations ensuring stable electricity supply to industrial zones, minimizing disruptions to production.

The negative relationship between electric power consumption and industrial growth highlights inefficiencies in electricity distribution and high production costs, requiring urgent intervention. The Nigerian Bulk Electricity Trading Company (NBET) and power distribution companies (DisCos) should improve electricity distribution efficiency. The Manufacturers Association of Nigeria (MAN) should advocate reduced electricity tariffs, while the Bureau of Public Enterprises (BPE) must evaluate privatized power assets to ensure industries receive reliable and cost-effective electricity.

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Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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Details of the AI usage are given below:

1.

2.

3.

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**Appendices**

**Table 6: Data Presentation**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Year** | **Fossil fuel energy consumption (FFE, % of total)** | **Access to electricity (ATE, % of population)** | **Electric power consumption (EPC, kWh per capita)** | **Industrial sector growth (INSG, percentage of industrial sector contribution to GDP)** |
| 1999 | 18.45 | 43.18 | 74.15 | 29.67 |
| 2000 | 19.89 | 43.91 | 75.12 | 34.17 |
| 2001 | 19.76 | 44.63 | 103.86 | 28.57 |
| 2002 | 21.59 | 52.20 | 100.99 | 23.28 |
| 2003 | 21.28 | 46.08 | 122.33 | 26.27 |
| 2004 | 21.66 | 46.82 | 127.83 | 28.68 |
| 2005 | 19.70 | 47.58 | 110.37 | 28.49 |
| 2006 | 17.58 | 50.13 | 137.08 | 26.02 |
| 2007 | 18.43 | 50.30 | 125.48 | 24.60 |
| 2008 | 15.85 | 49.97 | 118.89 | 24.97 |
| 2009 | 18.08 | 48.00 | 134.35 | 21.46 |
| 2010 | 19.08 | 55.90 | 147.78 | 25.32 |
| 2011 | 18.77 | 53.02 | 154.17 | 28.35 |
| 2012 | 18.59 | 55.60 | 140.31 | 27.31 |
| 2013 | 18.88 | 54.15 | 142.13 | 26.04 |
| 2014 | 18.83 | 52.50 | 147.18 | 24.95 |
| 2015 | 19.20 | 59.30 | 147.12 | 20.38 |
| 2016 | 17.36 | 54.40 | 157.08 | 18.37 |
| 2017 | 22.84 | 56.50 | 159.58 | 22.55 |
| 2018 | 22.05 | 55.40 | 160.04 | 26.01 |
| 2019 | 17.84 | 55.40 | 161.81 | 27.65 |
| 2020 | 17.75 | 59.50 | 155.41 | 28.58 |
| 2021 | 20.44 | 56.79 | 161.29 | 31.87 |
| 2022 | 20.52 | 57.23 | 170.68 | 31.24 |
| 2023 | 22.36 | 59.33 | 178.42 | 33.22 |

***Sources: CBN, 2023; WDI, 2025***