



Yusuf BASIRU
Department of Economics,
Nigerian Defence Academy
yusufkurami@gmail.com

Mustapha MUKTAR
Department of Economics,
Bayero University Kano
murtaronline@gmail.com

Bernard Ojonugwa Anthony
Department of Economics and
Statistics,
Kampala International University

Zakaree S. SAHEED
Department of Economics,
Nigerian Defence Academy
zssaheed@nda.edu.ng

Ishola Wasiu Oyeniran
Department of Economics,
Nigerian Defence Academy
iwoyeniran@nda.edu.ng

***Corresponding Authors:**

Yusuf BASIRU
Department of Economics,
Nigerian Defence Academy
yusufkurami@gmail.com

IMPACT OF ENERGY CONSUMPTION ON ECONOMIC GROWTH IN LOWER MIDDLE INCOME ECONOMIES IN AFRICA

ABSTRACT

The persistent challenge of achieving sustainable economic growth in African middle-income economies underscores the critical role of energy consumption as a key input in production and development. This study investigates the dynamic relationship between energy consumption and economic growth in these economies over the period 2003 to 2023. Employing a panel ARDL estimation technique, the research examines both short-run and long-run relationship across a panel of fifteen selected middle-income African countries. The findings reveal a significant positive long-run relationship between energy consumption and economic growth, highlighting energy as a critical driver of economic growth. However, the short-run results suggest mixed impacts, with some economies experiencing negative effects due to inefficiencies in energy use. Based on these findings, the study recommends the adoption of energy-efficient technologies, investment in renewable energy infrastructure, and policies that promote sustainable energy consumption to enhance economic growth across the region. These measures are essential for ensuring both economic resilience and environmental sustainability.

Keywords: *Economic Growth, Energy Consumption, Lower Middle-income Economies; Africa*

JEL Code: *C23, O47, Q43, R11*

1. Introduction

Economic growth is a fundamental driver of national prosperity, with a direct impact on improving living standards, reducing poverty, and creating employment opportunities (Abubakar, 2023). One of the key indicators of economic performance is the increase in Gross National Income (GNI) per capita, which provides a more comprehensive measure of the economic well-being of a country's population than GDP (Osberg & Sharpe, 2015). GNI per capita accounts for both the domestic production of goods and services and the income received from abroad, offering a clearer picture of a nation's wealth on a per-person basis. A consistent increase in GNI per capita not only signifies a rise in the average income of citizens but also reflects the ability of a nation to create economic opportunities that benefit all sectors of society (Bilan et al., 2020). For developing countries, the pursuit of higher GNI per capita is particularly crucial as it signifies progress in closing the income disparity gap between themselves and more developed nations.

Achieving sustained growth in GNI allows developing countries to invest in vital infrastructure, improve human capital through better education and healthcare, and foster industrialization. This creates a cycle of economic growth that has the potential to elevate the quality of life for individuals and generate a more equitable distribution of resources across society. For these nations, the emphasis on enhancing GNI is a strategic approach to achieving long-term sustainable development and improving the overall well-being of their populations (Giovannini & Rondinella, 2018).

Economic growth is influenced by a wide range of factors, both internal and external to a country. Among the most significant determinants are human capital, physical capital, technological advancement, institutional quality, and energy consumption. Human capital refers to the skills, education, and health of the workforce, which directly impact productivity and innovation. Physical capital, such as infrastructure, machinery, and technology, enhances a nation's productive capacity. Technological advancements drive efficiencies, innovation, and new industries, enabling countries to remain competitive in the global market (Bostan et al., 2023). Strong institutions that enforce rule of law, protect property rights, and encourage investment are also critical for fostering an environment conducive to economic growth. Another vital determinant is energy consumption, which plays a pivotal role in supporting the overall growth process by facilitating industrial output, technological innovations, and the daily functioning of economies. Without adequate energy resources, other growth factors may be limited in their effectiveness, as energy is fundamental for powering industries, transport, and services (Umar & Zakari, 2020).

Energy consumption is a key driver of economic development, especially for low and middle-income countries striving to achieve sustainable growth. The availability and efficient use of energy enable industries to produce goods and services, which in turn boosts gross national income and promotes job creation (Twerefou et al., 2018). In low- and middle-income economies, where industrialization is a critical part of the growth agenda, energy consumption is particularly important. It supports the establishment and expansion of industries, the transportation of goods, and the provision of essential services such as healthcare, education, and sanitation (Androniceanu & Georgescu, 2023). As economies grow, energy consumption tends to increase, reflecting a higher demand for electricity, fuel, and other energy sources. The development of infrastructure such as energy grids and renewable energy sources also plays a crucial role in expanding access to energy, thereby stimulating further economic activity. In this context, the efficient use and management of energy resources can enhance productivity and lower production costs, contributing to the competitiveness of industries. Moreover, as global demand for energy rises, countries that can secure a reliable energy supply are better positioned to achieve sustained economic growth (Gyimah et al., 2022).

Many researchers have empirically investigated the relationship between energy consumption and economic growth. Findings in Matar and Bekhet (2015); Wei-Wei (2017); Topolewski (2020); Resham et al. (2021); Ioana et al. (2022) and Androniceanu and Georgescu (2023) have revealed conflicting results. A common limitation of these studies is that they group countries with diverse economic profiles together, ignoring the unique challenges and economic dynamics faced by lower middle-income African nations. This approach overlooks the fact that lower middle-income African countries often experience distinct patterns of economic growth and energy consumption, shaped by factors such as limited infrastructure, energy access issues, and reliance on specific sectors like agriculture and mining.

The major motivation for this study therefore is the need to pool together African countries with similar economic growth and energy consumption patterns on the premise that such an approach is essential for developing targeted policies that can promote long-term, sustainable development and overcome existing energy-related barriers to economic progress. This study therefore contributes by examining the impact of energy consumption on economic growth in middle-income African countries. Following this introduction, the next section accounts for theoretical and empirical literature reviews. While section three of this study discusses methodology of analysis to be used, section four presents and discusses empirical findings. Finally, section five concludes the study.

2. Literature Review

This section provides a review of relevant literature, including conceptual, theoretical, and empirical perspectives.

2.1 Conceptual Review

This sub-section provides a conceptual overview of the key variables examined in this study: economic growth, energy consumption, labour force, gross capital formation, foreign direct investment, and official development assistance.

Economic growth refers to the increase in the production of goods and services within an economy over time. It is typically measured by the growth in Gross Domestic Product (GDP) or Gross National Income (GNI) and is often associated with rising income levels and improved standards of living. Economic growth signifies an expanding economy and serves as a vital indicator of national progress (Twerefou, Iddrisu, & Twum, 2018).

Energy consumption (EC), on the other hand, represents the total energy used across various sectors, such as industrial, residential, and transportation. It is a critical component of economic activity, as higher energy use often corresponds to increased production and industrialization. However, managing energy consumption and improving energy efficiency are essential for reducing emissions and promoting sustainable development (Sharaf, 2016).

The labour force (LF) comprises individuals of working age who are either employed or actively seeking employment. It is a crucial driver of economic activity, as a larger or more skilled workforce typically enhances productivity and contributes to economic expansion (Androniceanu & Georgescu, 2023). A robust labor force supports industrial and service sector growth, thereby influencing national output.

Gross capital formation refers to investments in physical assets such as machinery, infrastructure, buildings, and equipment. These investments are vital indicators of an economy's productive capacity and long-term growth potential. Higher levels of gross capital formation often signify industrial expansion and modernization but may also increase energy demand and emissions, particularly if the new investments are resource-intensive (Twerefou, Iddrisu, & Twum, 2018).

Foreign direct investment (FDI) involves investments made by individuals, companies, or governments from one country into business interests in another. It typically includes the transfer of capital, technology, and expertise, which can stimulate industrialization, create employment, and improve infrastructure. The impact of FDI on economic growth, however, depends on the host country's absorptive capacity and the sustainability of the investments (OECD, 2021).

Lastly, official development assistance (ODA) refers to financial aid provided by developed countries or international organizations to support the economic, social, and institutional development of recipient countries. It often takes the form of grants or concessional loans designed to address critical development challenges such as poverty, education, and healthcare. While ODA

plays a significant role in bridging resource gaps and funding infrastructure, its effectiveness hinges on good governance, alignment with local needs, and the efficient utilization of resources (World Bank, 2022).

2.2 Theoretical Framework

This study adopts the neoclassical growth model to investigate the impact of energy consumption on economic growth in lower middle-income African countries. The neoclassical growth model, rooted in economic thought from the late 19th and early 20th centuries, was pioneered by economists like Robert Solow. It focuses on the long-term factors that drive economic growth, building upon and addressing limitations of the classical economic theories that dominated the 18th and 19th centuries. Neoclassical economics emerged to better explain resource allocation and market dynamics, emphasizing the role of key growth determinants.

The theory posits that economic growth is primarily fuelled by increases in labour, capital, and technological advancements. It underscores the critical role of investments in human capital (labour), physical capital, and innovation in technology to achieve and sustain long-term economic growth. By incorporating these elements, the neoclassical growth model provides a robust framework for understanding how energy consumption, as a component of physical capital and technological use, influences economic development.

2.3. Empirical Review

Several empirical studies have explored the relationship between energy consumption and economic growth. For example, Matar and Bekhet (2015) analyzed the link between electricity consumption and economic growth in Jordan from 1976 to 2011. Using the ARDL model and Granger causality tests, their findings revealed a long-run equilibrium relationship between electricity consumption and real GDP per capita, exports, and foreign direct investment (FDI). In a similar study, Sharaf (2016) examined the causal relationship between energy consumption and economic growth in Egypt from 1980 to 2012, applying the Granger causality test. The results indicated that energy conservation policies did not negatively affect the long-term growth prospects of the Egyptian economy. Additionally, Wei-Wei (2017) employed cointegration, error correction models (ECM), and Granger causality tests to explore the energy consumption-economic growth nexus in China from 1992 to 2016. The study found that total energy consumption had a one-way causal effect on economic growth in China.

Twerefou et al. (2018) examined the relationship between energy consumption and economic growth in 17 West African countries from 1986 to 2017. Using panel cointegration techniques, their findings indicated no causal relationship between total energy, electricity, and petroleum consumption and economic growth. However, they found a unidirectional relationship running from economic growth to electricity consumption. Similarly, Ozturk and Suat (2018) investigated the impact of energy consumption on economic growth in Turkey using the ARDL approach. Their results revealed that economic growth positively influences coal consumption, while technological innovation has a negative effect on it in the long run. In a related study, Topolewski (2020) analysed the effect of energy consumption on economic growth during the 2008-2019 period using a dynamic panel model with the Arellano and Bond estimator. The study concluded that in the short run, an increase in production leads to a significant rise in energy consumption.

Resham et al. (2021) explored the relationship between energy consumption, exports, and economic growth in Nepal from 1980 to 2018 using the ARDL approach. Their findings revealed a positive and

statistically significant impact of exports on economic growth. Additionally, energy consumption and economic growth were positively linked, with unidirectional causality running from energy consumption to economic growth, from economic growth to exports, and from energy consumption to exports. Bassongui and Alakono (2021) examined the relationship between energy efficiency and economic growth in African countries using data from 1980 to 2020, employing the Function Approach. Their results indicated a significant relationship between energy consumption and economic growth across the continent. Furthermore, Ioana et al. (2022) assessed the impact of electricity access, energy use, and economic development in rural and urban China from 1995 to 2017. Using the ARDL approach, they found that energy use was positively associated with economic growth in China.

Gyimah et al. (2022) investigated the relationship between renewable energy consumption and economic growth in Ghana using both the Granger causality and mediation models, based on data from 1990 to 2015. The study found a feedback effect between economic growth and renewable energy consumption. However, renewable energy consumption did not have a significant indirect impact on economic growth. Despite this, the study concluded that renewable energy had a significant total impact on economic growth, with an increase in renewable energy consumption positively influencing economic growth.

In a more recent study, Androniceanu and Georgescu (2023) explored the dynamic relationships between economic growth, CO₂ emissions, energy consumption, and foreign direct investments (FDIs) across 25 EU Member States (excluding Malta and Croatia) over the period from 2000 to 2020. The empirical analysis utilized first- and second-generation panel unit root tests (CIPS) and panel ARDL models with three estimators: PMG, MG, and DFE. The Hausman test indicated that the PMG estimator was the most efficient. The findings from the PMG and DFE estimators suggested that only short-run causalities exist between CO₂ emissions, energy consumption, FDIs, and GDP growth. In contrast, the MG estimator revealed both short-run and long-run causalities among the variables.

A significant gap in the existing empirical literature is the lack of studies specifically focusing on the relationship between economic growth and energy consumption in lower middle-income African countries. While a substantial body of research has explored this relationship in a variety of global contexts, including both developed and developing economies, most studies tend to use GDP as a measure of economic growth rather than GNI per capita, which may not fully capture the economic well-being of a nation. As a result, the energy-economic growth dynamics in this context remain underexplored. To address this gap, this study focuses specifically on lower middle-income African countries, using GNI per capita as a more accurate measure of economic growth. The aim is to provide insights into how energy consumption influences economic growth in this region and offer policy recommendations that could better address the unique developmental needs of these countries.

3. Methodology

3.1 Sources of Data

This study utilizes annual panel data from 15 lower middle-income African economies over the period 2003 to 2023. The data availability was the major criterion for timeline selection, the extent to which they share growth and energy consumption pattern is a major justification for county selection. The dependent variable (economic growth) is represented by GNI per capita. The primary

independent variable is energy consumption, while labour force, foreign direct investment and official development assistance are considered as supporting explanatory variable.

3.2 Model Specification

This study adopts the model specification of Androniceanu and Georgescu (2023), where the relationship between energy consumption and economic growth is modelled within the framework of a standard neoclassical production function augmented with energy as a key input. The empirical model is expressed as follows:

$$\ln GNI_{it} = \beta_0 + \beta_1 \ln GNI_{it} + \beta_2 \ln EC_{it} + \beta_3 \ln LF_{it} + \beta_4 \ln GCF_{it} + \beta_5 \ln FDI_{it} + \beta_6 \ln ODA_{it} + \delta \mu_i + \lambda_t + \varepsilon_{i,t} \tag{1}$$

Where, GNI represents gross national income at current US\$, while EC denotes total energy consumption measured in quad Btu. LF refers to the total labour force, and GCF indicates gross capital formation at current US\$. Additionally, FDI captures foreign direct investment inflows, and ODA reflects official development assistance at current US\$. The model includes β_0 as the intercept term, β_1 to β_5 as the coefficients to be estimated, and ϵ as the error term. This specification is designed to examine the direct impact of energy consumption on economic growth while accounting for other key factors influencing growth. This logarithmic specification allows for elasticity analysis, enabling an examination of proportional changes in economic growth relative to changes in energy consumption and other explanatory variables.

$$\Delta \ln GNI_{i,t} = \text{ect}_i + \varphi_{0i,j} + \sum_{j=0}^m \varphi_{1i} \Delta \ln GNI_{i,t-j} + \sum_{j=0}^m \varphi_{2i} \Delta \ln EC_{i,t-j} + \sum_{j=0}^m \varphi_{3i} \Delta \ln LF_{i,t-j} + \sum_{j=0}^m \varphi_{4i} \Delta \ln GCF_{i,t-j} + \sum_{j=0}^m \varphi_{5i} \Delta \ln FDI_{i,t-j} + \sum_{j=0}^m \varphi_{6i} \Delta \ln ODA_{i,t-j} + \delta \mu_i + \lambda_t + \varepsilon_{i,t} \tag{2}$$

Table 1 presents the variable codes, descriptions, measurement, expected signs, and sources of data.

Table 1. Variable codes, descriptions, measurement, expected signs, and sources of the data

Variables	Description and Measurement	Signs	Sources
GNI	GNI per capita, Atlas method (current US\$)	N/A	WDI (2023)
EC	Total energy consumption (quad Btu)	+	EIA (2023)
LF	Labor force (total)	+	WDI (2023)
GCF	Gross Capital formation (constant 2015 US\$)	+	WDI (2023)
FDI	Foreign direct investment, net inflows (current US\$)	+	WDI (2023)
ODA	Official Development Assistance (current US\$)	+	WDI (2023)

Note: WDI is World Development Indicators database of World Bank and EIA is Energy Information Administration.

3.3 Estimation Procedure

This study utilizes the panel ARDL introduced by Pesaran et al. (1999) to analyse the relationship between energy consumption. The panel ARDL approach is particularly advantageous due to its suitability for dynamic heterogeneous panels, allowing for variations in economic conditions across countries. Furthermore, the Panel ARDL estimator effectively addresses potential endogeneity issues and performs well even with small sample sizes, making it highly appropriate for studies focusing on African economies. Additionally, the method accounts for cross-sectional dependence, reflecting the interconnectedness of countries in the region.

Prior to the panel ARDL estimation, preliminary analyses are conducted to ensure the robustness and validity of the results. These include panel unit root tests (such as the CADF and CIPS tests) to assess the stationarity of the variables. The study also performed the Westerlund cointegration test to determine whether a long-run relationship exists among the variables. Additionally, the Pesaran CD test was used to examine cross-sectional dependence within the panel, ensuring that the model appropriately captures the interconnectedness of the countries in the study. These preliminary tests are crucial for confirming the suitability of the regression model and for making accurate inferences about the energy consumption-economic growth nexus. The panel ARDL specification is given in equation 3

$$Y_{it} = \sum_{j=1}^{p-1} \gamma_y^j (y_i)_{t-j} + \sum_{j=0}^{q-1} \delta_y^j (X_i)_{t-j} + \varphi^i (y_i)_{t-1} + \mu_i + \varepsilon_{it} \quad (3)$$

Where $(X_i)_{t-j}$ the $(k \times 1)$ is vector of explanatory variables for group i and μ_i represents the fixed effect. In principle, the panel can be unbalanced, and p and q may vary across countries. This model can be reparametrized as a VECM system:

$$\Delta Y_{it} = \theta_i (Y_{i,t-1} - \beta_i X_{i,t-1}) + \sum_{j=1}^{p-1} \gamma_y^j \Delta Y_{i,t-j} + \sum_{j=0}^{q-1} \delta_y^j \Delta (X)_{i,t-j} + \mu_i + \varepsilon_{it} \quad (4)$$

Where the β_i are the long-run parameters and θ_i are the equilibrium (or error)-correction parameters. The pooled mean group restriction is that the elements of β are common across countries:

$$\Delta Y_{it} = \theta_i (Y_{i,t-1} - \beta_i X_{i,t-1}) + \sum_{j=1}^{p-1} \gamma_y^j \Delta Y_{i,t-j} + \sum_{j=0}^{q-1} \delta_y^j \Delta (X)_{i,t-j} + \mu_i + \varepsilon_{it} \quad (5)$$

Where, y is economic growth (GDP), X is a set of independent variables including the energy consumption, γ and δ represent the short-run coefficients of dependent and independent variables respectively, β are the long-run coefficients, θ is the coefficient of speed of adjustment to the long run status, while the subscripts i and t represent the country and time, respectively. The term in the square brackets contains the long-run estimates.

4. Results and Discussion

4.1. Results of Summary Statistics

The summary statistics in Table 2 reveal significant disparities in key economic indicators across lower middle-income African countries. GNI per capita averages \$1578.16, ranging from \$130 to \$4810, with moderate positive skewness reflecting income inequalities. Energy consumption has a low mean of 0.187 but is highly skewed, indicating that a few countries consume much more energy than others. The labour force averages 9.3 million, with substantial variation from 48,352 to 75.7 million, reflecting wide differences in workforce sizes. Gross capital formation has a mean of 996 but shows extreme variability and skewness due to outliers. Foreign direct investment averages 651, with a positively skewed distribution influenced by countries receiving significantly higher inflows. Similarly, official development assistance averages 869 but exhibits large disparities and extreme

values. Overall, the data highlight high variability and skewness, reflecting the economic heterogeneity among the countries analysed.

Table 2. Summary statistics of variables

Variables/Sat.	GNI	EC	LF	GCF	FDI	ODA
Mean	1578.159	0.187	9275415.029	996.000	651.000	869.000
Median	1420.000	0.100	4743786.000	362.000	281.000	599.000
Maximum	4810.000	1.950	75721345.000	583.000	1003.000	114.000
Minimum	130.000	0.000	48352.000	663.000	-739.000	-521.000
Std. Dev.	791.391	0.342	14528894.872	515.000	178.000	108.000
Skewness	1.387	3.534	2.870	7.569	0.800	4.139
Kurtosis	5.479	15.480	11.011	69.821	12.529	33.068
Jarque-Bera	181.700	2699.990	1274.762	61611.675	1225.390	12765.054
Probability	0.000	0.000	0.000	0.000	0.000	0.000
Observations	315	315	315	315	315	315

Source: Researcher’s Computation (2024)

The Jarque-Bera statistics for all variables strongly reject the null hypothesis of normality, as indicated by their high values and associated probabilities close to zero. This suggests that the distributions of the variables are significantly skewed or have heavy tails, deviating from a normal distribution. Each variable in the dataset comprises 315 observations, drawn from 15 countries over the study period. The large sample size enhances the reliability of the summary statistics but also underscores the importance of addressing non-normality in further econometric analyses, such as transforming the variables or using estimation techniques robust to non-normal distributions.

4.2. Results of Corelation and Variance Inflation Factor

As part of preliminary analyses, pairwise correlation and variance inflation factor (VIF) are employed to detect the presence of multicollinearity among the independent variables under investigation and the results are presented in Tables 3. The results show a strong positive correlation (0.725) between energy consumption and economic growth, which is significant at the 1% level. This suggests that economic growth in Africa is closely associated with higher levels of energy consumption. Similarly, labour force, gross fixed capital formation, foreign direct investment, and official development assistance also exhibit positive correlations with economic growth, indicating their potential roles as growth-enhancing factors in the region.

Table 3: Results of Pairwise Correlation and Variance Inflation Factor (VIF)

Probability	GNI	EC	LF	GCF	FDI	ODA
GNI	1.000					

EC	0.725	1.000				
	(0.000)	-----				
LF	0.613	0.056	1.000			
	(0.040)	(0.000)	-----			
GCF	0.502	0.227	0.394	1.000		
	(0.001)	(0.000)	(0.000)	-----		
FDI	0.511	0.420	0.444	0.394	1.000	
	(0.000)	(0.000)	(0.000)	(0.000)	-----	

ODA	0.014 (0.829)	0.522 (0.000)	0.214 (0.000)	0.331 (0.000)	0.467 (0.000)	1.000
VIF statistic		2.51	2.50	3.52	3.26	3.92

Note: P-values in parentheses () and ln: natural logarithm.

Source: Researcher’s computations (2024)

Moving on to the correlation among the independent variables themselves, we can see that some of the independent variables have weak correlations. For instance, labour force (LNLF) has a weak positive correlation with energy consumption (0.346). Likewise, gross fixed capital formation (GFCF) has a weak positive correlation with energy consumption (0.263), suggesting minimal overlap in their predictive contributions to economic growth.

The Variance Inflation Factor (VIF) values, which provide a diagnostic measure of multicollinearity, were also examined. A VIF value exceeding 5 is typically considered a threshold signalling potential multicollinearity concerns. However, in this analysis, the VIF values for all independent variables were well below this threshold. This indicates that while there is some degree of correlation among the explanatory variables, it is not severe enough to raise major concerns for the reliability and validity of the regression analysis results.

4.3. Results of Cross-Section Dependence Test

The cross-sectional dependence (CD) test assesses whether the variables exhibit interdependence or correlation across the different panel groups, in this case, the lower middle-income African countries. Cross-sectional dependence can arise from shared regional characteristics or common external shocks affecting all countries. Identifying such dependence is crucial, as ignoring it could lead to biased results in panel data analysis. The results of the Pesaran (2007) CD test are presented in Table 4.

Table 4: Result of Cross-sectional Dependence Test

Variables	CD-test Statistics	P-values
GNI	33.843	0.000
EC	24.834	0.000
LF	45.662	0.000
GCF	20.065	0.000
FDI	6.072	0.000
ODA	9.732	0.000

Notes: The null hypothesis is cross-section independence and P-values close to zero indicate data are correlated across panel groups.

Source: Researcher’s computations (2024)

The CD test statistics for each variable, as seen in the table, are significantly high, with p-values equal to 0.000. These low p-values (0.000) strongly reject the null hypothesis of cross-sectional independence. In other words, the results indicate that there is significant cross-sectional dependence for all the variables under consideration. This suggests that the variables are correlated across the different panel groups (lower middle-income African countries), meaning that events or changes in one country are likely to affect others, due to economic and geographical linkages. For instance, in the case of GNI, the CD-test statistic of 33.843 with a p-value of 0.000 indicates that economic growth in one country is highly interconnected with economic growth in other lower middle-income African nations.

4.4 Results of Slope Homogeneity Tests

The results presented in Table 5 show the outcomes of slope homogeneity tests for the study’s model. The two different test statistics-Pesaran & Yamagata (2008) and Blomquist & Westerlund (2013) are used to assess the slope homogeneity.

Table 5 Results of Slope Homogeneity Tests

Tests:	Pesaran & Yamagata (2008)				Blomquist & Westerlund (2013)			
	Delta(Δ)	P-Value	Adj.(Δ)	P-Value	Delta(Δ)	P-Value	Adj.(Δ)	P-Value
Model 1	8.280	0.000	10.606	0.000	6.535	0.000	8.371	0.000

Note: Null hypothesis: Slope coefficients are homogenous

Source: Researcher’s Computation (2024)

These Tests implies that the coefficients (slopes) of the regression equations are the same across different groups, meaning that the effect of the independent variables on the dependent variable does not vary across different entities or time periods. These results strongly reject the null hypothesis, indicating that the slope coefficients are homogenous. The presence of cross-section dependence and slope heterogeneity highlights the need to employ unit root and cointegration tests that account for these factors. Similarly, it necessitates the use of the cross-sectional ARDL approach to estimate the coefficients in the model accurately.

4.3 Results of Panel Unit Root and Cointegration Tests

Results from the panel unit root tests, based on the Pesaran’s CADF and CIPS which are robust in the presence of cross-sectional dependence are reported in Table 5.

Table 5. Results of Panel Unit Root and Cointegration Tests

Variables	CADF		CIPS		Stationarity Status
	Level	1 st Difference	Level	1 st Difference	
lnGNI	-1.612	-2.549 **	-1.1039	-4.056***	I(1)
lnEC	-1.370	-2.667***	-1.143	-3.257***	I(1)
lnLF	-1.486	-2.813***	-1.236	-2.431**	I(1)
lnGCF	-2.407**	-3.440***	-2.469**	-3.536***	I(0)
lnFDI	-1.863	-2.857***	-2.332**	-3.117***	I(1)
lnODA	-2.711**	-2.907***	-2.491**	-4.456***	I(0)

Westerlund (2007) Cointegration Test

Variance ratio: t-statistic = -1.9278 p-value = 0.0269

Notes: *** denote significance at 1% level. Lag length is selected based on SIC.

Source: Researcher’s Computation (2024)

This study considers the estimation with constant and trend so as to exploit potential hidden features. Both tests, depicts that the null hypothesis of non-stationarity of the variables at levels for all panels of country groups cannot be rejected except for lnGCF and lnODA which was found to be stationary at level. The three other variables have unit root at levels, whilst in their first difference they have no unit root.

The Westerlund (2007) panel cointegration test reveals that, all the variables are cointegrated since the hypothesis of no cointegration is rejected at 5% level of significance level. We can therefore draw a conclusion that, the variables being analysed possess a long-run relationship.

4.4 Regression Estimation Results

After confirming the cointegration of the variables, the next step involves estimating the long-run and short-run coefficients using panel ARDL framework. The estimation results are presented in Table 6.

Table 6. Results of Long-run and Short-run Estimated Coefficients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Long Run Equation				
lnEC	0.248	0.073	3.38	0.001
lnLF	0.347	0.03	11.57	0.000
lnGCF	0.204	0.049	4.20	0.000
lnFDI	0.173	0.025	6.89	0.000
lnODA	0.115	0.117	0.99	0.326
Short Run Equation				
ECT _{t-1}	-0.606	0.094	-6.47	0.000
D(lnEC)	-0.193	0.039	-4.97	0.000
D(lnLF)	-0.034	0.035	-0.99	0.326
D(lnGCF)	0.057	0.020	2.87	0.004
D(lnFDI)	0.030	0.103	0.29	0.770
D(lnODA)	0.136	0.041	3.32	0.001
Constant	5.160	0.702	7.35	0.000

Source: Researcher's Computation (2024)

The results in Table 6 indicate that the coefficient of energy consumption is 0.248. This positive coefficient suggests that, in the long run, a 1% increase in energy consumption is associated with a 0.248% increase in GNI. The t-statistic of 3.38 and the p-value of 0.001 confirm the statistical significance of this relationship. This finding underscores the vital role of energy consumption in fostering economic growth, potentially reflecting its contribution to industrial activity and productivity enhancement.

The coefficient for the labour force is estimated at 0.347, implying that a 1% increase in the labour force corresponds to a 0.347% increase in GNI. This positive and statistically significant relationship (t-statistic = 11.57, p-value = 0.000) highlights the crucial role of a growing labour force in driving economic expansion in the long run. Similarly, the coefficient of gross capital formation is 0.204, indicating a statistically significant relationship with GDP. A 1% increase in gross fixed capital formation is associated with a 0.204% increase in GDP, as evidenced by the t-statistic of 4.20 and p-value of 0.000. This finding aligns with economic theory, underscoring the importance of capital investment in enhancing productivity and fostering economic growth.

In contrast, the coefficient of foreign direct investment is 0.173, which is also statistically significant (t-statistic = 6.89, p-value = 0.000), suggesting that FDI contributes positively to economic growth in the long run. However, the coefficient for official development assistance is 0.115, which is not statistically significant (t-statistic = 0.99, p-value = 0.326), indicating a weaker or inconclusive long-run impact on economic growth.

The error correction term (ECT_{t-1}) has a coefficient of -0.606, which is negative and highly significant (t-statistic = -6.47, p-value = 0.000). This indicates that the system corrects itself at a speed of 60.6% per annum when deviations from the long-run equilibrium occur. The negative sign of the ECT highlights a convergence mechanism that ensures adjustment toward the long-run equilibrium over time.

In the short run, the coefficient of energy consumption is -0.193, suggesting that a 1% increase in energy consumption is associated with a 0.193% decrease in GDP. This relationship is statistically significant (t-statistic = -4.97, p-value = 0.000). For the labour force, the coefficient is -0.034, but this relationship is not statistically significant (t-statistic = -0.99, p-value = 0.326).

The short-run coefficient for gross fixed capital formation is 0.057, which is statistically significant (t-statistic = 2.87, p-value = 0.004), suggesting that increases in capital formation positively affect economic growth in the short term. Similarly, the coefficient for official development assistance is 0.136, and it is statistically significant (t-statistic = 3.32, p-value = 0.001). However, the coefficient for foreign direct investment is 0.030, which is not statistically significant (t-statistic = 0.29, p-value = 0.770). Finally, the constant term is positive (5.160) and highly significant (t-statistic = 7.35, p-value = 0.000), reflecting the baseline level of economic growth in the model.

These findings provide a comprehensive understanding of the short- and long-run dynamics of the relationships between energy consumption, labour force, capital formation, FDI, ODA, and economic growth. While long-run relationships highlight the importance of energy, labour, and capital investment, short-run dynamics reveal mixed effects.

5. Conclusion and Recommendations

This study investigates the relationship between energy consumption and economic growth in fifteen lower middle-income African economies using panel data spanning from 2003 to 2023. Employing the panel ARDL framework, the findings indicate a significant positive long-run relationship between energy consumption and economic growth, underscoring the pivotal role of energy in driving sustainable economic development. However, in the short run, energy consumption has a negative impact on growth, likely reflecting structural inefficiencies and challenges in energy utilization across these economies. Consequently, the study concludes that energy consumption is crucial for fostering long-term economic growth, while addressing short-term inefficiencies is vital to unlocking its full potential.

Based on these findings, the study recommends that policymakers of 15 lower middle-income African economies should focus on increasing investments in energy infrastructure to enhance access to reliable and affordable energy. Promoting energy-efficient technologies and diversifying into renewable energy sources are also vital for improving sustainability and reducing reliance on fossil fuels. Moreover, improving energy distribution systems to minimize inefficiencies and ensure equitable access should be a key priority. Regional collaboration in energy resource development and integration can further enhance cross-border energy trade and strengthen economic resilience across the region. These strategies are essential for harnessing energy consumption to drive inclusive and sustainable economic growth in African lower middle-income economies.

References

- Abubakar, E. (2023). Impact of Foreign Direct Investment on Poverty Reduction and Economic Development. *Journal of Poverty, Investment and Development*, 8(2), 80-89.
- Androniceanu, A., & Georgescu, I. (2023). The impact of CO2 emissions and energy consumption on economic growth: a panel data analysis. *Energies*, 16(3), 1342.
- Bilan, Y., Mishchuk, H., Samoliuk, N., & Yurchyk, H. (2020). Impact of income distribution on social and economic well-being of the state. *Sustainability*, 12(1), 429.
- Bostan, I., Toma, C., Aevoae, G., Robu, I. B., Mardiros, D. N., & Topliceanu, Ş. C. (2023). Effects of internal and external factors on economic growth in emerging economies: Evidence from CEE countries. *Eastern European Economics*, 61(1), 66-85.

- Chinedu, U. A., Daniel, O. C., & Ezekwe, U. C. (2019). Impact of energy consumption on economic growth in Nigeria: an approach of time series econometric model. *International Journal of Academic Research in Economics and Management and Sciences*, 8(2), 65-77.
- Dantama, Y. U., Abdullahi, Y. Z., & Inuwa, N. (2012). Energy consumption-economic growth nexus in Nigeria: An empirical assessment based on ARDL bound test approach. *European Scientific Journal*, 8(12).
- Giovannini, E., & Rondinella, T. (2018). Going beyond GDP: theoretical approaches. In *Handbook of Research on Economic and Social Well-Being* (pp. 1-51). Edward Elgar Publishing.
- Gyimah, J., Yao, X., Tachega, M. A., Hayford, I. S., & Opoku-Mensah, E. (2022). Renewable energy consumption and economic growth: New evidence from Ghana. *Energy*, 248, 123559.
- Matar, A., & Bekhet, H. A. (2015). Causal interaction among electricity consumption, financial development, exports and economic growth in Jordan: Dynamic simultaneous equation models. *International Journal of Energy Economics and Policy*, 5(4), 955-967.
- Osberg, L., & Sharpe, A. (2015). How should we measure the “economic” aspects of well-being?. *Review of Income and Wealth*, 51(2), 311-336.
- Pesaran, M. H., Shin, Y., & Smith, R. P. (1999). Pooled mean group estimation of dynamic heterogeneous panels. *Journal of the American statistical Association*, 94(446), 621-634.
- Romer, David. 2006. *Advanced Macroeconomics*. New York: McGraw-Hill, Third edition.
- Sharaf, M. F. (2016). Energy consumption and economic growth in Egypt: A disaggregated causality analysis with structural breaks. *Topics in Middle Eastern and African Economies*, 18(2), 61-86.
- Solow, R. M. (1955). The production function and the theory of capital. *The Review of Economic Studies*, 23(2), 101-108.
- Topolewski, Ł. (2021). Relationship between energy consumption and economic growth in European countries: Evidence from dynamic panel data analysis. *Energies*, 14(12), 3565.
- Twerefou, D. K., Iddrisu, K. S., & Twum, E. A. (2018). Energy consumption and economic growth: Evidence from the West African Sub region. *West African Journal of Applied Ecology*, 26, 217-233.
- Umar, A., & Zakari, J. Does Urbanization Increase Energy Consumption in Nigeria? An ARDL Bounds Testing Approach.
- Wei, W., & He, L. Y. (2017). China building energy consumption: definitions and measures from an operational perspective. *Energies*, 10(5), 582.