

Energy Consumption and Economic Growth: Empirical Evidence from Selected ECOWAS Countries

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Abstract

This study examines the long-run impact of energy consumption on economic growth and the causal relationship between the duos in selected member states of the Economic Community of West African States (ECOWAS). Using annual panel data from 1990 to 2024, the study applies panel unit root and cointegration tests to determine the time-series properties of the variables. The Panel Dynamic Ordinary Least Squares (PDOLS) estimator was employed to evaluate the long-run effects of electricity consumption on economic growth, proxied by GDP per capita growth, while controlling for exchange rate, lending interest rate, and inflation. Pairwise Granger causality tests were further used to explore short-run dynamics. The empirical findings indicated that electricity consumption exerts a positive and statistically significant long-run effect on economic growth within the ECOWAS sub-region. However, no significant short-run causality was detected between energy consumption and growth. These results suggest that the economic benefits of improved electricity supply materialize gradually rather than immediately. Diagnostic and stability tests confirm the robustness of the estimated model. The study concludes that sustained investment in electricity infrastructure and regulatory reforms is critical for long-term growth in ECOWAS countries.

Keywords: Energy consumption, Economic growth, ECOWAS, Panel DOLS

Introduction

Energy has emerged as one of the most indispensable inputs in modern economic systems, underpinning production processes, technological advancement, and improvements in human welfare. In both developed and developing economies, virtually all productive activities from industrial manufacturing and agricultural processing to digital services, healthcare delivery, and education depend critically on reliable energy supply. As a result, energy consumption has increasingly been recognized not merely as an energy indicator, but as a meaningful proxy for economic activity, structural transformation, and development outcomes (Ferguson, Wilkinson & Hill, 2000; Morimoto & Hope, 2001; Esen & Bayrak, 2017). This growing recognition has placed energy consumption at the centre of academic and policy debates on sustainable economic growth.

Globally, energy demand has expanded rapidly over the past few decades, outpacing other forms of energy consumption. According to the International Energy Agency (IEA), global energy demand more than doubled between the early 1990s and mid-2010s, driven largely by population growth, urbanization, industrial expansion, and technological diffusion in developing regions (IEA, 2018). While advanced economies have largely succeeded in aligning energy supply with economic needs, many developing regions, particularly Sub-Saharan Africa, continue to face

persistent energy shortages, low access rates, and unreliable power systems. These structural deficiencies have raised critical questions about the extent to which energy consumption can effectively support sustained economic growth in such contexts.

Energy consumption refers to the amount of electrical energy utilized by households, firms, and public institutions within an economy, commonly measured on a per capita basis. Economic growth, in turn, is typically defined as the sustained increase in real output or income, proxied by real gross domestic product (GDP). The theoretical relationship between these concepts is well grounded in both neoclassical and endogenous growth theories. Energy enhances productivity by enabling mechanization, reducing production costs, supporting capital accumulation, and facilitating technological progress (Isaac, 2012; Solow, 1956). Conversely, inadequate or unreliable energy supply constrains productive capacity, disrupts industrial activity, discourages investment, and weakens competitiveness, thereby slowing economic growth (Akinlo, 2009; Odhiambo, 2009).

The burden of inadequate energy supply is particularly pronounced in West Africa. Despite abundant endowments of energy resources, including hydroelectric potential, natural gas, solar, and wind, many countries in the sub-region continue to experience limited energy access and chronic power outages (Gnansounou, 2008; Adenikinju, 2008). Within the Economic Community of West African States (ECOWAS), energy access rates remain uneven across member countries, with urban areas significantly better served than rural communities. In several ECOWAS countries, less than half of the population has access to energy, while firms routinely depend on costly self-generation through diesel and petrol generators (IEA, 2015; World Bank, 2020). These alternatives substantially increase operating costs, reduce firm productivity, and undermine economic efficiency.

The economic consequences of energy inadequacy in ECOWAS countries are far reaching. Empirical studies show that unreliable energy supply leads to output losses, reduced firm level productivity, lower employment creation, and weakened industrial performance, particularly among small and medium sized enterprises (SMEs), which are widely regarded as engines of economic growth (Morimoto & Hope, 2001; Kwakwa & Adu, 2015). At the macroeconomic level, energy shortages have been associated with slower GDP growth, limited structural transformation, and persistent income disparities across countries (Kouakou, 2011; Akinlo, 2009). Moreover, governments incur significant fiscal costs through subsidies, emergency power interventions, and fuel imports for backup generators, diverting scarce resources from critical social and infrastructure investments.

In response to these challenges, regional policymakers have increasingly pursued energy market integration as a strategic solution. The establishment of the West African Power Pool (WAPP) reflects a collective effort to integrate national energy systems into a unified regional market capable of delivering reliable and affordable power in the medium to long term (WAPP, 2015). By promoting cross-border energy trade, coordinating generation and transmission investments, and optimizing resource utilization, the WAPP aims to reduce energy supply constraints and promote more equitable access across ECOWAS member states. However, despite these initiatives, energy consumption patterns and access levels remain highly uneven, raising concerns about whether regional integration efforts have translated into meaningful growth outcomes.

A substantial body of empirical literature has examined the energy-economic growth nexus, yielding mixed and sometimes contradictory findings. While some studies support the growth

hypothesis, suggesting that energy consumption drives economic growth (Belaid & Abderrahmani, 2013; Ferguson, Wilkinson & Hill, 2000), others find evidence in favor of the conservation hypothesis, feedback hypothesis, or neutrality hypothesis (Ouedraogo, 2013; Odhiambo, 2009). These inconsistencies are often attributed to differences in methodology, country coverage, time horizons, and the inclusion or exclusion of key control variables such as capital and labor. In the African context, much of the existing evidence is based on single country studies or limited regional samples, thereby restricting the generalizability of the findings.

More importantly, relatively few studies have adopted a comprehensive ECOWAS-wide panel approach to examine the impact of energy consumption on economic growth within the context of regional integration. Existing regional studies remain sparse and often fail to adequately capture cross-country heterogeneity, dynamic adjustments, and short-run growth effects. This gap is particularly significant given the strategic importance of energy expansion and market integration in West Africa's development agenda.

Against this backdrop, this study investigates the impact of energy consumption on economic growth in ECOWAS countries. By employing a dynamic panel framework grounded in conventional growth theory, the study seeks to provide robust empirical evidence on the magnitude and direction of the energy-growth relationship in the region. In doing so, it contributes to the growing literature on energy-led growth in developing economies and offers relevant policy insights for designing energy strategies that support inclusive and sustainable economic growth in West Africa.

Review of Empirical Literature

This section extensively reviews the both methodological and empirical literature on energy consumption and economic growth.

Uzoechina, Ezekwike, Ekwoh, Eze, Imoagwu and Edeh (2024) using data obtained from the World Bank and the Central Bank of Nigeria Statistical Bulletin, investigated the impact of energy consumption and corruption on life expectancy in lower-middle-income West African countries from 1990 to 2021. The results of the cross-sectional auto regressive distributed lag technique showed that renewable energy had a positive and significant impact on life expectancy in lower-middle-income West African countries in both the short and long run. However, non-renewable energy was found to have a significant and negative impact on life expectancy in the long run and a negative but non-significant impact in the short run. Corruption had a debilitating effect on life expectancy in both the short and long run. The study recommended that policymakers should make a conscious and deliberate push toward transitioning to renewable energy through public-private partnerships to provide affordable and clean energy while tackling corruption.

Bekun, Etokakpan, Agboola, Uzunar and Wada (2023) explored the asymmetric relationship between coal energy consumption, economic growth, rising urban population and emission level in South Africa. The study span was conducted on an annual frequency basis from 1965-2018. This study applies the novel Non-linear Autoregressive distributed lag methodology (NARDL) for the highlighted variables. Empirical results validated the asymmetric relationship between the variables under review over the study period. The NARDL regression further showed positive shock by GDP increases CO₂ emission level while negative impact affected otherwise in the long run. On the other hand, coal consumption positive shock exhibited a detrimental impact on environmental quality in South Africa. The urban population showed non-significant effect on

emission levels over the sampled period. The knowledge of both positive and negative shock effects of GDP, coal energy consumption and urban growth was vital for policy construction in terms of both economic and environmental sustainability. Thus, policy prescription ranged from energy transition to alternative and cleaner energy sources like renewables and responsible energy consumption (SDG-12) should be pursued in South Africa. More far-reaching environmental policies are highlighted in the concluding section.

Ishioro (2023) examined the type of relationship existing between wealth accumulation (and /or human development), and natural gas energy consumption (NGC) in Nigeria using the Human Development Index (HDI1 and HDI2) as proxies for human development and wealth accumulation for the period of 1990 to 2020. The study collected annual time series data for the selected indicators for several years. ARDL Bounds Tests was used to analyze the data. The results indicated that in the long-run, natural gas energy consumption does not facilitate human development and wealth accumulation vice versa in Nigeria. The study suggests that natural gas energy is consumed or utilized in Nigeria for non-wealth accumulation and non-human development purposes. The study recommended that gas energy should be consumed and/or redirected to a more purposeful wealth and human development facilitating consumption.

Felix and Adeola (2023) examined the effect of energy consumption (decomposed into renewable and non-renewable energy) on life expectancy in Nigeria for the period of 1981 to 2022. Energy consumption was proxied by Alternative and Nuclear Energy (ANE), Per Capita Electricity Consumption (CPN) and Fossil Fuel Energy Consumption (FEN), while Life expectancy was proxied by life expectancy at birth. The study adopted the Autoregressive Distributed Lag (ARDL) in analyzing the data. The result indicated that there is long-run relationship existing among the variables. The long result showed that Per Capita Electricity Consumption (EPN) and Per Capita Income (PCD) have positive effect on life expectancy, while Fossil Fuel Energy, Trade Openness, and Alternative and Nuclear Energy (ANE) have negative effect on Life Expectancy in Nigeria. The short run result also showed that per capita electricity consumption has positive effect on life expectancy, while fossil fuel energy consumption and trade openness have negative effect on life expectancy in Nigeria. This study recommended that to improve life expectancy in Nigeria green energy consumption should be adopted.

Eneche, Douglas and Nwobia (2023) applied the ARDL approach to examine energy consumption and economic growth in Nigeria (1980–2021) The ARDL model evaluated short run and long-run interactions among the specified variables. The results revealed the presence of long-run relationship among the variables. The results showed that both residential energy consumption and industrial energy consumption exerted positive and significant effect on economic growth in Nigeria. The results also indicated that public sector energy consumption had a negative and insignificant effect on economic growth in Nigeria in the short run while in the long run, it had positive and insignificant effect on economic growth in Nigeria. Based on the findings, the study therefore recommended that government should ensure that the demand for electricity was met in the residential, public and industrial sectors of the economy by improving the nation's electricity generating capacity to meet the daily demand.

Ikpe and Oyediji (2023) examined the intricate interplay between electricity consumption and economic growth, specifically Gross Domestic Product (GDP), in Nigeria. Despite the acknowledged influence of electricity consumption on GDP, the research took a comprehensive approach by scrutinizing various economic factors that may contribute to Nigeria's remarkable

GDP performance within the African context. Utilizing a meticulous methodology, the investigation explored the relationships between GDP and variables such as unemployment, population, lending interest rates, importation costs, and inflation rates across a 50-case observational dataset. The findings highlighted the substantial impact of electric power consumption, population, and lending interest rates on Nigeria's GDP, while revealing the relatively minor effects of other predictors.

Joesph and Tosin-Amos (2023) investigated the asymmetric impact of renewable energy consumption on life expectancy in Nigeria using data from 1980 to 2021. The analysis utilized the non-linear Autoregressive Distributed Lag (NARDL) methodology to examine the relationship between these variables. The results revealed a combination of positive and negative effects of renewable energy consumption on life expectancy. While certain positive effects are statistically significant, others are not in the short run. However, in the long run, the positive effect prevailed over the negative effect, indicating an overall favourable influence of renewable energy consumption on life expectancy. Additionally, GDP per capita and urbanization are found to have positive impacts on life expectancy, whereas inflation rate shows an adverse effect. In light of these findings, it was recommended that the Nigerian government should focus on investing in renewable energy infrastructure while addressing any potential negative consequences associated with specific aspects of renewable energy production.

Zhang, Chen and Li (2022) examined the transmission channels and impacts of energy use on health outcomes in Asia by adopting a panel of selected Asian economies for the period of 1991 and 2019. The findings of the study showed that energy causes a rise in infant mortality rate and a reduction in life expectancy. Furthermore, the study found that a high degree of pollution emissions causes a rise in infant mortality and a decline in life expectancy.

Prince, Ogbodo, Callistus, and Samuel (2021) analyzed the causal relationship between energy consumption and economic growth in Nigeria using the multivariate framework from 2000Q1 2018Q4, the Autoregressive Distributed Lag (ARDL) bounds test approach, Error Correction Model (ECM), and the Clemente-Montanes-Reyes unit root for structural breaks in the series. Findings revealed a co-integrating relationship, a bidirectional relationship between petroleum, liquefied natural gas, and electricity consumption. A unit increase in energy consumption stimulated economic growth through product and service value addition. A unit decrease in electricity consumption increases petroleum consumption while decreasing economic growth as a result of distribution failure, estimated billing system and over-dependence on generating set as an alternative energy source. The non-causal relationship can be accredited to the energy demand-supply gap. The study recommended among other things review of the billing system, pricing framework, and policies toward supporting and ensuring efficient and responsive energy distribution and maintenance to spur value addition and economic growth.

Acheampong, Amponsah, and Boateng (2021) investigated the impact of access to energy on human development in 79 energy-poor countries from sub-Saharan Africa, South Asia and Caribbean-Latin America. Using data from 1990 to 2018 and Lewbel's two-stage least squares approach, the study found that clean energy and electricity have a positive impact on human development in the aggregated sample. Furthermore, the study found that clean energy and electricity improved human development in the Caribbean, Latin America and sub-Saharan Africa, but worsened human development in South Asia.

Akinwale (2021) explored the link between energy consumption, trade openness and economic growth in Nigeria between 1971 and 2015 using Vector error correction model (VECM). The result of Johansen co-integration test showed that the three series are co-integrated, hence long-run relationship was established among them. Causality analysis in VECM showed that there was a long run causality from economic growth and trade openness to energy consumption as well as from economic growth and energy consumption to trade openness. The results of the short run causality indicated the Granger causality from economic growth to trade openness only. These outcomes suggested that trade openness could be boosted by improving production in all sectors of the economy and not the other way round. Also, decisive improvement in economic activities would lead to increase in energy use in the country as the size of the current energy consumption was too weak to cause economic expansion in Nigeria. Furthermore, due to the huge energy gap between demand and supply, Nigerian government should utilise the low carbon energy options towards a sustainable economic growth trajectory.

Akintunde, Adagunodo, Akanbi and Ogunleye (2020) investigated the interactive effect of poverty and energy consumption on life expectancy in Nigeria from 1980 to 2017. The study adopted Autoregressive Distributive Lag (ARDL) approach to analyze the time series data. The study revealed that poverty had negative and significant impact on life expectancy in the short-run and in the long-run. Also, energy consumption had positive and significant impact on life expectancy in the long run. The coefficient of interactive effect of poverty and energy consumption is negative and significant on life expectancy in the short run and in the long-run. According to their findings, fossil fuel consumptions dominate energy consumption mix in Nigeria which showed that majority of Nigerian populace do not have access to renewable energy.

Pasternak (2020) investigated the relationship between human well-being and consumption of energy and electricity in sixty (60) populous countries encompassing 90% of the world's population over the period 1997 - 2020 using correlation analysis. The findings showed that there was a significant positive relationship between electricity consumption and Human Development Index. It also revealed that HDI attained a maximum value when electricity consumption annually was about 4,000 kWh per capita, which was lesser as well as greater than the consumption levels of most developed and developing countries, respectively.

Sasmaz *et al* (2020) investigated the relationship between renewable energy and human development in 28 Organizations for Economic Cooperation and Development (OECD). Using data from 1990 to 2017 and employing the Westerlund and Edgerton panel cointegration test, and Dumitrescu and Hurlin causality test, renewable energy was found to affect human development positively. In the same study, bidirectional causality was found between renewable energy and human development.

Sarkodie and Adams (2020) investigated the nexus between electricity, human development income level, income inequality and political system environment in Sub-Saharan Africa, using data from 1990 to 2017. Using a non-parametric regression analysis, human development was found to have a positive impact on access to electricity consumption.

Yunashev *et al* (2020) investigated the impact of quality and volume of energy consumption on human development, using sample countries for the period of 1985 to 2018. Using three-stage least squares, and HDI as a proxy for human development, energy consumption and renewable energy

as proxies for energy consumption, the study found the share of clean energy consumption to have a positive impact on human development.

Mamudu and Ochei (2020) empirically examined the impact of electricity consumption on economic growth in Nigeria with the application of the Augmented Dickey-Fuller test statistics, Johansen Cointegration techniques and the Error Correction Mechanism on a multiple log linear regression framework. The empirical results from the short run error correction model showed that the entire explanatory economic and electricity variables in the estimation met their expected signs except Electricity Losses in transmission and distribution. The empirical results also revealed that electricity consumption, electricity generation and electricity price had direct and significant impact on real gross domestic product in Nigeria. This means that 1 per cent increase in ELEC, ELEG and ELEP, increases real gross domestic product in Nigeria by 60, 44 and 14 per cent respectively. Electricity Losses in transmission and distribution also had negative effect on the real gross domestic product in Nigeria. This implies that 1 per cent increase in electricity losses in transmission and distribution reduced real gross domestic product in Nigeria by 29 per cent approximately. The error correction mechanism (ECM) result which was -0.700952 was statistically significant and had the appropriate sign. It suggested, however, that there was a high adjustment process in the practice of the power sector since the speed of adjustment was 70.1 per cent approximately. Finally, the Diagnostic and stability tests confirmed the robustness of the model over time. The study therefore, recommended that the Nigerian Electricity Regulatory Commission (NERC) should strengthen policy on electricity generation of power to meet up with the increasing demand for electricity so as to sustain production and economic growth in Nigeria.

Kassim and Isik (2020) used a systematic method of literature review to analyse the energy trend, as well as the energy-growth nexus research, carried out in transition economies. The concluding result after the systematic review showed that (14%) of the study confirmed the growth hypothesis, (54%) feedback hypothesis, (9%) neutrality hypothesis, and (23%) conservation hypothesis.

Anochiwa, Enyoghasim, Oguwuike, Uma, *et al.* (2020) examined the relationship between economic growth and energy consumption in Nigeria by using ARDL bound test regression analysis. In the investigation process energy consumption, was disaggregated into electricity, coal and petroleum with growth rate of GDP data were used from 1980 to 2017. The findings showed that petroleum and electricity variables were positive and significant to growth while coal was positive but not significant. Overall outcome was that energy consumption had a positive relationship with economic growth. The study recommended that coal deposit must be put in use to increase energy production and consumption and stimulate other economic activities for growth.

Methodology

Research Design

This study adopts an ex post facto research design, appropriate for analysing historical data without manipulation (Obadan, 2012; Ashakah, 2019). The design allows examination of relationships among macroeconomic variables across countries over time.

Data Sources and Variables

Annual panel data covering 1990–2024 were sourced from the World Development Indicators (2024). The sample includes eight ECOWAS countries: Benin, Burkina Faso, Côte d'Ivoire, Ghana, Niger, Nigeria, Senegal, and Togo.

Variables:

- GDP per capita growth rate (GDPPC) – proxy for economic growth
- Electricity consumption (ELC) – proxy for energy consumption
- Exchange rate (EXHR)
- Lending interest rate (LIR)
- Inflation rate (INFL)

Model Specification

The econometric model is specified as:

$$GDPPGR_{it} = \alpha_0 + \alpha_1 ELC_{it} + \alpha_2 EXHR_{it} + \alpha_3 LIR_{it} + \alpha_4 INFL_{it} + \mu_{it} \quad (1)$$

Where:

GDPPGR: gross domestic product growth rate as a proxy for economic growth,

ELC: electricity consumption which stand as proxy for energy consumption

EXHR: official exchange rate

LIR: lending interest rate

INFL: inflation rates

μ : represents the error term

i: represent an individual country

α : represents the parameters of the variables

Estimation Techniques

The panel dynamic ordinary least squares (PDOLS) was employed in data analysis. The choice of panel dynamic ordinary least squares for estimating the specified model was based on its ability to address endogeneity in the model. Before estimating the model, the variables were tested for unit root using the Levin-Lin-Chu, LLC (2002), Im, Pesaran and Shin (IPS), ADF Fisher and Phillips-Perron unit root tests. This was to determine the level of variable integration. It was also considered appropriate to test for co-integration of the variables using the Kao co-integration test. Post estimation test- stability test focusing on the Brown-Durbin-Evans cumulative sum of recursive residual test, was carried out to confirm policy applicability of the estimated model. Eviews 12 was used for all computations and estimation. The application of co-integration and unit root tests to our panel data set was to assess the data's properties.

Presentation and Discussion of Estimation Results

Descriptive Statistics

This section presents the descriptive statistics for the variables used in the analysis. The aim is to provide an initial understanding of the distribution, central tendencies and variability of the dataset used to examine how energy consumption influences economic growth across selected ECOWAS countries.

Table 1: Descriptive Statistics

Source: Author's Computation 2026

Statistic	GDPPCGR	ELC	EXCHR	INFL	LIR
Mean	1.889161	145.7753	454.6032	4.812997	4.330300
Median	2.226546	122.4746	522.4256	1.923975	4.744167
Maximum	12.21039	552.5028	1478.965	41.50950	24.77083
Minimum	-7.404250	0.000000	0.000000	-3.233389	0.000000
Std. Dev.	2.857946	110.7890	228.9464	7.572166	5.578565
Skewness	-0.309603	1.155947	-0.534111	2.526765	1.561278
Kurtosis	4.800750	4.400156	4.439799	10.39000	4.974252
Jarque-Bera	30.21766	60.87747	26.78434	667.9187	113.7335
Probability	0.000000	0.000000	0.000002	0.000000	0.000000
Sum	377.8323	29155.05	90920.64	962.5994	866.0601
Sum Sq. Dev.	1625.403	2442566.	10430878	11410.20	6192.958
Observations	200	200	200	200	200

The average GDP per capita growth rate stands at 1.89 per cent, suggesting that the ECOWAS sub-region generally experienced modest economic expansion during the study period. However, the wide spread between the maximum value (12.21%) and the minimum value (−7.40%) highlights clear fluctuations in economic performance, which may stem from structural rigidities, fiscal instability and varying exposure to external shocks across member countries. The standard deviation of 2.86 further confirms this high degree of variability.

Electricity consumption records a mean of 145.78 kWh, with a median of 122.47 kWh, indicating that many ECOWAS countries operate at relatively low energy consumption levels. The difference between the maximum (552.50 kWh) and minimum (0.00 kWh) reflects substantial disparities in access to and utilisation of electricity within the sub-region. The positive skewness (1.16) suggests that countries with significantly higher consumption levels influence the distribution.

The exchange rate variable, with an average of 454.60, also shows wide variation, ranging from 0.00 to 1,478.97. This variation is consistent with the coexistence of fixed, managed and floating exchange rate regimes in the ECOWAS region. The negative skewness (-0.53) implies that exchange rate observations are slightly clustered around higher values.

Inflation has a mean value of 4.81 per cent, yet the standard deviation (7.57) demonstrates considerable disparities across countries. The maximum inflation rate of 41.51% underscores the existence of macroeconomic instability in some member states, while the negative minimum value (-3.23%) indicates periods of price contraction in others. The high kurtosis (10.39) and strong positive skewness (2.53) point to the presence of extreme inflationary episodes.

The lending/interest rate displays similar dispersion, with values ranging from 0.00 to 24.77 and an average of 4.33 per cent. The positive skewness (1.56) and kurtosis (4.97) suggest a distribution characterized by a few exceptionally high-interest rate episodes, possibly reflecting periods of tight monetary policy or financial market distortions.

Finally, the Jarque–Bera statistics for all variables are significant at the 1% level, confirming deviations from normality. This outcome is common in macroeconomic panel datasets and does not hinder the analysis, especially given the use of Dynamic Least Squares (DOLS), which is robust to issues such as non-normality and endogeneity. The descriptive statistics reveal marked heterogeneity across ECOWAS countries in economic growth, energy consumption, and macroeconomic indicators. This variation underscores the appropriateness of panel econometric techniques in analysing the relationship between energy consumption and economic growth.

Correlation Matrix

This section examines the pairwise correlation among the variables used in the study. The correlation matrix provides preliminary insights into the direction and strength of the linear relationships between economic growth (GDPPCGR) and the explanatory variables: electricity consumption (ELC), exchange rate (EXCHR), inflation (INFL), and interest rate (LIR). This assessment helps identify potential multicollinearity issues and offers an initial understanding of how the variables co-move before proceeding to the more robust panel econometric estimations.

Table 2: Correlation Matrix

	GDPPCGR	ELC	EXCHR	INFL	LIR
GDPPCGR	1	0.0959	-0.2332	-0.0176	0.0999
ELC	0.0959	1	-0.4954	0.3243	-0.1348
EXCHR	-0.2332	-0.4954	1	-0.5130	-0.2977
INFL	-0.0176	0.3243	-0.5130	1	0.0103
LIR	0.0999	-0.1348	-0.2977	0.0103	1

Source: Author's Computation 2026

The results show that GDP per capita growth (GDPPCGR) is positively but weakly correlated with electricity consumption (0.096) and the interest rate (0.10). Although the magnitudes are small, the positive sign suggests that improvements in electricity consumption and moderate increases in

lending rates may coincide with periods of stronger economic performance in the ECOWAS region. However, because the correlations are weak, these relationships should be interpreted cautiously, and more reliable panel estimations are necessary to determine the true causal effect.

GDPPCGR exhibits a mild negative correlation with the exchange rate (-0.233), indicating that currency depreciation is loosely associated with slower economic growth in the sub-region. This aligns with theoretical expectations, as weaker exchange rates often disrupt import-dependent economies, raise production costs and dampen growth. The correlation between GDPPCGR and inflation (-0.018) is negligible, implying no meaningful linear relationship between the two variables at this preliminary stage.

Electricity consumption shows a moderately negative relationship with the exchange rate (-0.495), suggesting that countries experiencing currency depreciation tend to have lower electricity consumption. This may reflect macroeconomic instability, limited capacity for energy importation, or weak investment in electricity infrastructure. Conversely, electricity consumption is moderately positively correlated with inflation (0.324), which may indicate that periods of economic overheating or demand-driven inflation coincide with higher energy use.

The exchange rate is strongly and negatively correlated with inflation (-0.513), consistent with the view that exchange rate depreciation can fuel inflationary pressures in import-dependent economies, a common feature within ECOWAS. The interest rate shows weak correlations with all variables, suggesting that lending rates operate largely independent of the other macroeconomic indicators. The correlation matrix reveals no excessively high pairwise correlations (e.g., above 0.8), indicating that multicollinearity is not a major concern in the subsequent estimation. Nevertheless, the observed relationships provide useful preliminary hints on how the variables interact, which the panel DOLS and causality tests will explore more rigorously.

Panel Unit Root Tests

To determine the stochastic properties of the variables and establish their order of integration, a series of panel unit root tests were carried out using the Levin–Lin–Chu (LLC), Breitung, Im–Pesaran–Shin (IPS), and Fisher-type ADF and PP tests. These tests enable the identification of whether each variable is stationary at level or becomes stationary only after differencing. Establishing the correct integration order is important for selecting an appropriate estimation technique and ensuring valid long-run inferences.

Table 3: Panel Unit Root Test Results

Variable	LLC Test	IPS Test	ADF Fisher	PP Fisher	Order of Integration
GDPPCGR	-1.91796 (0.0276)	-3.99137 (0.0000)	43.4887 (0.0002)	129.081 (0.0000)	I(0)
ELC	3.78313 (0.9999)	-0.80937 (0.2092)	16.5588 (0.4147)	15.4454 (0.4923)	Non-stationary at level
D(ELC)	-6.33135 (0.0000)	,	64.9769 (0.0000)	149.199 (0.0000)	I(1)

EXCHR	Mixed results	Mostly insignificant	Partly significant	Partly significant	I(1)
INFL	-1.76474 (0.0388)	-3.00532 (0.0013)	46.0708 (0.0001)	53.3083 (0.0000)	I(0)
LIR	0.99632 (0.8405)	0.32405 (0.6270)	10.3045 (0.7396)	16.0340 (0.3113)	Non-stationary at level
D(LIR)	-6.36309 (0.0000)	-6.15969 (0.0000)	62.8777 (0.0000)	125.803 (0.0000)	I(1)

Source: Author's Computation 2026

The panel unit root results reveal a mix of stationary and non-stationary variables among the ECOWAS countries studied. GDP per capita growth (GDPPCGR) is stationary at level across all test categories. The LLC (-1.92 , $p = 0.0276$), Breitung (-4.40 , $p = 0.0000$), IPS (-3.99 , $p = 0.0000$), and both Fisher tests strongly reject the null hypothesis of a unit root, showing that growth rates fluctuate around a stable mean without exhibiting persistent long-run trends.

Electricity consumption (ELC), in contrast, is found to be non-stationary at level. The level LLC statistic (3.78 , $p = 0.9999$), IPS (-0.81 , $p = 0.2092$), and Fisher ADF/PP probabilities indicate failure to reject the null hypothesis. However, after first differencing, all tests become highly significant, with LLC (-6.33 , $p = 0.0000$), ADF Fisher (64.98 , $p = 0.0000$), and PP Fisher (149.20 , $p = 0.0000$) confirming that ELC becomes stationary only in its differenced form, implying that it is integrated of order one.

The exchange rate (EXCHR) produces mixed signals in its level form. In some specifications, particularly those including both individual effects and linear trends, the LLC test is significant (-3.14 , $p = 0.0008$). However, the IPS tests remain largely insignificant, and some Fisher tests fail to reject the unit root in their level specifications. Once differenced, exchange rate behaviour aligns strongly with $I(1)$ characteristics, making it appropriate to treat EXCHR as integrated of order one.

Inflation (INFL) behaves differently from the other macroeconomic variables. The series appears stationary at level across most test categories. LLC (-1.76 , $p = 0.0388$), IPS (-3.01 , $p = 0.0013$), and both Fisher ADF (46.07 , $p = 0.0001$) and PP (53.31 , $p = 0.0000$) statistics reject the null hypothesis at traditional significance levels, pointing towards an $I(0)$ process. This outcome suggests that inflation in the region fluctuates but does not follow a long-run random walk.

The interest rate (LIR) is found to be non-stationary at level, as indicated by LLC (0.9963 , $p = 0.8405$), IPS (0.32 , $p = 0.6270$), and Fisher tests ($p > 0.31$). After first differencing, the series becomes strongly stationary across all test criteria, with LLC (-6.36 , $p = 0.0000$) and IPS (-6.16 , $p = 0.0000$) returning very large negative values. Thus, LIR is integrated of order one.

Finally, population growth rate (PGR), although not a core variable in the main model, exhibits clear non-stationarity at level, with stationary behaviour only after differencing. Its behaviour is consistent with a typical $I(1)$ demographic series. The panel unit root tests confirm a mixture of $I(0)$ and $I(1)$ variables in the dataset. This pattern supports the application of Dynamic Ordinary Least Squares (DOLS), a technique well-suited for regressions involving both stationary and non-stationary regressors, allowing for long-run cointegration relationships while addressing endogeneity concerns.

Kao Residual Cointegration Test

The Kao (1999) residual-based cointegration test was employed to examine whether a long-run equilibrium relationship exists among economic growth (GDPPCGR), electricity consumption (ELC), the exchange rate (EXCHR), inflation (INFL), and the interest rate (LIR) in the ECOWAS region. Unlike the Pedroni test, which allows for heterogeneity in the cointegrating vector, the Kao test assumes homogeneity across the cross-sectional units but remains suitable for balanced panel datasets such as the one used in this study.

Table 4: Kao Residual Cointegration Test Result

Test Statistic	Value	Probability
ADF t-Statistic	−1.828897	0.0337

Additional Outputs	Value
Residual Variance	11.32153
HAC Variance	4.844766

Source: Author's Computation 2026

The Kao ADF statistic of -1.8289 with a corresponding p-value of 0.0337 indicates rejection of the null hypothesis of *no cointegration* at the 5% level. This means that the residuals from the long-run relationship among GDP per capita growth, electricity consumption, exchange rate, inflation and interest rate are stationary. In practical terms, even though the individual variables may contain unit roots, their linear combination moves together over time and converges to a stable long-run path.

The result aligns with economic intuition: over the long run, macroeconomic fundamentals in ECOWAS countries tend to adjust toward equilibrium, with energy consumption and monetary variables jointly influencing economic growth dynamics. The presence of cointegration also justifies the use of Dynamic Ordinary Least Squares (DOLS), which is specifically designed to capture long-run elasticities in the presence of cointegrated relationships and correct for endogeneity by including leads and lags of the differenced regressors. The Kao test provides strong evidence in favour of a valid long-run equilibrium relationship among the variables, reinforcing the argument that energy consumption has a persistent long-run link with economic growth in the ECOWAS sub-region.

Panel Dynamic Least Squares (DOLS) Estimation Results

The Dynamic Ordinary Least Squares (DOLS) technique was employed to estimate the long-run relationship between economic growth (GDPPCGR) and the explanatory variables: electricity consumption (ELC), exchange rate (EXCHR), inflation (INFL), interest rate (LIR), and population growth rate (PGR). The method is particularly suitable given the mix of $I(0)$ and $I(1)$ variables and the confirmed presence of cointegration from the Kao residual test. The inclusion of leads and lags of the differenced regressors helps to correct for endogeneity and serial correlation, ensuring consistent long-run estimates.

Table 5: Panel DOLS Long-Run Estimation Results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ELC	0.023811	0.011630	2.047434	0.0478
EXCHR	0.003307	0.006098	0.542358	0.5908
INFL	-0.153935	0.150323	-1.024027	0.3125
LIR	0.452530	0.252202	1.794312	0.0809

Source: Author's Computation 2026

From Table 6 above, electricity consumption carries a positive and statistically significant coefficient of 0.0238 ($p = 0.0478$). This suggests that, in the long run, a one-unit increase in electricity consumption is associated with a 2.38% increase in GDP per capita growth, holding other variables constant. The finding is in line with the findings of Ashakah, 2025 and Mgbomene *et al.* 2025. The significance of ELC reinforces the idea that sustained improvements in energy availability and utilisation are crucial for supporting productive activities and overall economic expansion within ECOWAS. This finding is consistent with the expectation that electricity is a key intermediate input in both industrial and service-sector productivity.

The exchange rate shows a small positive coefficient (0.0033) but is statistically insignificant ($p = 0.5908$). This demonstrates that movements in exchange rates do not exert a meaningful long-run influence on economic growth in the selected ECOWAS countries. The region's heavy reliance on primary exports and imported manufactured goods may dampen the positive growth effects typically associated with exchange rate competitiveness. Additionally, structural distortions, currency instability, and frequent policy shifts in some member states could explain this muted long-run impact.

Inflation has a negative coefficient (-0.1539) as expected, but it is not statistically significant ($p = 0.3125$). While the negative sign suggests that rising prices tend to undermine growth, the lack of significance indicates that inflationary pressures may not consistently translate into measurable long-run declines in per capita income growth. This could reflect the presence of inflation-tolerant economies in ECOWAS or the weakness of monetary transmission mechanisms in low-income environments where price shifts do not uniformly affect output.

The interest rate has a positive coefficient (0.4525) and is marginally significant at the 10% level ($p = 0.0809$). This implies that increases in lending rates are associated with higher long-run growth, although the relationship is not strong enough to be considered decisive. A possible interpretation is that higher interest rates reflect tightening financial conditions, which may coincide with periods of improving macroeconomic stability or stronger financial-sector performance. Alternatively, the result may indicate that credit allocation in some ECOWAS economies is skewed toward productive sectors even when the cost of borrowing is relatively high.

Test of Hypotheses

This section presents the formal testing of the hypotheses formulated in line with the objectives of the study. The hypotheses were evaluated using the results obtained from the Panel Dynamic Least Squares (DOLS) long-run estimation and the Pairwise Granger Causality Test (See appendix 1).

Each hypothesis is assessed by comparing the empirical evidence with the stated null proposition, and conclusions are drawn accordingly.

Hypothesis 1: Electricity consumption has no significant impact on economic growth in the ECOWAS sub-region.

The DOLS results show that electricity consumption has a positive and statistically significant effect on economic growth (p-value = 0.0478, less than 5%). Therefore, the null hypothesis is rejected. This confirms that electricity consumption promotes long-run economic growth in ECOWAS countries.

Hypothesis 2: Electricity consumption does not Granger-cause economic growth in the ECOWAS sub-region.

The Granger causality test shows high p-values (0.6794 and 0.6190), meaning there is no short-run causality between electricity consumption and economic growth. Therefore, the null hypothesis is accepted. Electricity affects growth only in the long run, not immediately.

In summary, electricity consumption significantly impacts growth in the long run, but there is no short-run causal relationship.

Econometric Test of Reliability

Several diagnostic tests were conducted to ensure the model is reliable. Although the residuals were not perfectly normal, this does not affect the consistency of the DOLS estimates. The heteroskedasticity test showed no variance problems, and the serial correlation test confirmed no autocorrelation. The stability test indicated that the model remained stable throughout the study period. Overall, the diagnostic results confirm that the model is reliable and the long-run findings are valid.

Implications of Findings

The results suggest that ECOWAS governments should prioritize long-term investment in electricity infrastructure. Reliable electricity supports businesses, improves productivity, and strengthens economic growth. Since the benefits appear gradually, policymakers should adopt long-term energy strategies rather than expecting immediate results.

The findings also show that stable exchange rates and inflation control are important for supporting energy sector development. Energy reforms must work together with sound macroeconomic policies to achieve sustainable growth.

Conclusion

The study concludes that electricity consumption plays a vital role in promoting long-run economic growth in ECOWAS countries. Although the impact is not immediate, improved electricity supply gradually enhances productivity and economic performance. Therefore, sustained investment in electricity infrastructure and long-term energy planning are necessary for achieving sustainable economic growth in the region.

Recommendations

Based on the findings of the study, the following are recommended:

- i. Given the long-run positive and significant statistical relationship between electricity consumption and economic growth, ECOWAS countries' governments should increase capital investment in the electric energy sector to enhance electricity generation, transmission and distribution infrastructure in the region.
- ii. Given the constraints posed by financing in public sector, governments in ECOWAS should encourage private sector participation in the energy sector through clear, stable and transparent regulations and provide targeted incentives in form of tax holidays, import duty waiver to investors in alternative energy sources.
- iii. In view of the lopsided distribution of energy resources across ECOWAS region, efforts should be made to strengthen regional cooperation through power sharing arrangements, coupled with concerted effort to strengthen the operational efficiency of West African Power Pool.
- iv. Considering the finding that energy-growth effects are long-term rather than short-run, governments should focus on long-term energy planning aligned with industrial development. Efforts should be shifted from short run intervention to holistic and consistent long term energy policy.
- v. Although the results reveal that inflation and exchange rate were insignificant, their instability can undermine energy sector investments. Thus, governments in the region should enshrine policies that maintain macroeconomic stability to support energy investment.

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Appendix 1

Pairwise Granger Causality Test Results

Null Hypothesis	F-Statistic	Prob.	Conclusion
ELC does not Granger Cause GDPPCGR	0.17132	0.6794	No causality
GDPPCGR does not Granger Cause ELC	0.24810	0.6190	No causality
EXCHR does not Granger Cause GDPPCGR	5.85168	0.0165	EXCHR → GDPPCGR
GDPPCGR does not Granger Cause EXCHR	0.06563	0.7981	No causality
INFL does not Granger Cause GDPPCGR	0.82560	0.3647	No causality
GDPPCGR does not Granger Cause INFL	0.01531	0.9017	No causality
LIR does not Granger Cause GDPPCGR	0.73384	0.3927	No causality
GDPPCGR does not Granger Cause LIR	1.98172	0.1609	No causality
EXCHR does not Granger Cause ELC	4.81330	0.0295	EXCHR → ELC
ELC does not Granger Cause EXCHR	0.60600	0.4373	No causality
INFL does not Granger Cause ELC	2.61636	0.1074	No causality
ELC does not Granger Cause INFL	10.7155	0.0013	ELC → INFL
LIR does not Granger Cause ELC	0.27972	0.5975	No causality
ELC does not Granger Cause LIR	0.51087	0.4756	No causality
INFL does not Granger Cause EXCHR	14.4898	0.0002	INFL → EXCHR
EXCHR does not Granger Cause INFL	11.0009	0.0011	EXCHR → INFL
LIR does not Granger Cause EXCHR	10.9475	0.0011	LIR → EXCHR
EXCHR does not Granger Cause LIR	2.37103	0.1253	No causality
LIR does not Granger Cause INFL	1.02797	0.3119	No causality
INFL does not Granger Cause LIR	2.00704	0.1582	No causality