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Electricity Consumption and Industrial Outputs in Economic Community of West African States Countries: Evidence from a Panel Dynamic Ordinary Least Squares and Granger Causality

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ABSTRACT

This study examines the influence of electricity consumption on industrial outputs in ECOWAS countries from the year 2000 to 2023. The study uses Panel Dynamic Ordinary Least Square regression analysis to obtain long run estimates among the variables, it also uses a Granger-Causality test (to determine the causal relationship between electricity consumption and industrial output). Based on the estimated results, this study concludes the following; electricity consumption contributed a significant positive impact on industrial output in ECOWAS sub region. Similarly, labour force caused a positive and significant impact on industrial output. Whereas, a negative and significant impact of money supply was felt on industrial output in ECOWAS sub region. A uni-directional causality flowing from electricity consumption to industrial output occurred in ECOWAS sub region Due to the findings that emerged from this study, this study recommended that the policymakers in ECOWAS countries should embark on policies that would increase supply and accessibility of electricity to industrial sub sector in all ECOWAS countries in order to ensure a substantial growth in the industrial output of the sub regional economy. In the same vein, the policymakers in ECOWAS sub region could also drive industrial expansion by granting immediate tax relief for privately generated electricity for industrial consumption.

Keywords: Electricity Consumption, Industrial Output, Economic Community of West African States
JEL Classifications: Q2, Q4, L60, L94

1. INTRODUCTION

Electricity consumption in African countries is influenced by several factors, including population growth, urbanization, economic activities, and access to modern energy services (Afolayan and Aderemi 2019; Olusegun et al., 2020; Osabohien et al., 2021). Electricity plays an indispensable role in driving industrialization and economic development, particularly in regions like the Economic Community of West African States (ECOWAS). Comprising 15 member states, ECOWAS represents a dynamic economic bloc with varying levels of industrialization and energy infrastructure. However, persistent energy challenges have significantly constrained industrial growth, stifling the region's potential to achieve sustainable development and economic diversification (Onatunji, 2022). Understanding the interplay between electricity consumption and industrial output is crucial for policymakers aiming to bolster productivity, attract investment, and improve living standards across member nations.

Industrial output depends heavily on reliable electricity supply to power manufacturing processes, operate machinery, and ensure efficiency in production lines. A stable and affordable energy supply is a prerequisite for fostering competitiveness in domestic and export markets (Okorie et al., 2020). Conversely, irregular electricity supply often forces industries to rely on costly and environmentally harmful alternatives such as diesel generators, which increases operational costs and limits growth. In ECOWAS, energy access remains uneven, with countries like Ghana and Côte d'Ivoire demonstrating better electricity coverage compared to nations such as Liberia and Guinea-Bissau (IEA, 2020). This disparity in access exacerbates industrial inequalities across the region, highlighting the need for collaborative strategies to bridge the energy gap.

The ECOWAS region faces unique energy challenges that hinder industrial growth. Chief among these is inadequate infrastructure, characterized by outdated transmission networks, limited generation capacity, and high technical losses. Additionally, rapid urbanization and population growth have placed immense pressure on existing energy systems, leading to chronic supply shortages. According to the World Bank (2020), electricity access rates in the region average around 50%, with rural areas experiencing significantly lower coverage. This energy deficit has stymied industrialization, particularly in energy-intensive sectors such as mining, manufacturing, and agro-processing.

Another critical issue is the overreliance on fossil fuels for electricity generation, which raises environmental concerns and exposes economies to fluctuations in global oil prices. While renewable energy sources like solar, wind, and hydropower offer promising alternatives, their adoption has been slow due to high upfront costs, limited technical expertise, and policy inconsistencies. Nevertheless, countries such as Senegal and Cabo Verde have made significant strides in integrating renewables into their energy mix, demonstrating the feasibility of sustainable energy solutions in the region.

Regional cooperation within ECOWAS provides an avenue for addressing these challenges and enhancing industrial outputs through improved energy systems. Initiatives such as the West African Power Pool (WAPP) aim to create a unified electricity market that promotes cross-border energy trade and optimizes resource utilization. By pooling resources and expertise, member states can achieve economies of scale, reduce electricity costs, and ensure more stable energy supplies. For example, Ghana's surplus electricity has been exported to neighboring countries like Togo and Benin, demonstrating the potential benefits of regional energy integration.

Policy interventions at both national and regional levels are critical for aligning electricity consumption with industrial growth. Governments must prioritize investments in energy infrastructure, including modernizing grids, expanding generation capacity, and reducing transmission losses. Additionally, fostering private sector participation in the energy sector can mobilize the financial and technical resources needed to bridge infrastructure gaps. Incentivizing renewable energy projects through tax breaks, subsidies, and streamlined regulations can also accelerate the transition to sustainable energy systems.

2. EMPIRICAL REVIEW

Onatunji (2022) explored the long-term and causal links between power consumption alongside industrial production in few ECOWAS nations from 1971 to 2017. His study made use of the ARDL bounds testing technique to evaluate the variables of the study. Long-term results showed that increasing power supply boosts industrial output only in these countries; Nigeria, Sierra Leone, Benin, Liberia, Senegal, Gambia, Guinea and Cote d'Ivoire Abokyi et al. (2018) explored the causal link between power consumption and industrial growth in Ghana in between 1971 and 2014. The research's estimating approach is the ARDL bound test, Toda-Yamoto test, and the findings of the ARDL bounds test revealed that the variables had a long-run connection. Error repair term was also large and negatively signed, providing more indication of a long-term connection.

Majia et al (2019) assessed the influence of energy from renewable sources on growth in economies of the West African nations using panel dynamic ordinary least squares (DOLS) from 1995 to 2014. The study made use of the Panel DOLS, and the results showed that renewable energy usage decreased economic development in these nations because inefficient renewable energy sources delayed economic growth by interfering negatively with productivity. Ouedraogo (2017) created a scenario-based model that could recognize and fulfill an array of electricity demand in Africa, derived from the African power system of development, employing Schwartz scenario-based methodology. The findings showed a 4% increase in demand by 2040, shortages of supply, and high pollution of greenhouse gases.

Espoir et al. (2023) used random-coefficient linear regression and kernel-based regularized least squares machine learning to analyze how energy affected African countries in four regional economic blocs, namely, ECOWAS, EAC, SADC and COMESA. The study found cointegration among variables. Both NREC and REC had prominent favorable impact on growth, while NREC has a greater influence. The marginal impacts of NREC and REC differs among African areas.

Agbede and Onuoha (2020) examined the impact of power usage on industrial production in Nigeria. The study employs ARDL and granger causality. The ARDL results showed that the usage of power impacted a positive but insignificant influence on industrial output. Whereas, credits to industries caused a direct and significant link with industrial production. Also, the causality test confirmed the presence of a unidirectional causal relationship between the variables.

N'Zué and Iqbal (2021) assessed how access to power affected economic performance. The research included 14 nations in the ECOWAS area and used data from 1990 through 2016. The Pool Mean Group estimator was employed alongside ARDL scenario to predict the short and long run interferences of access to power on growth. Over time, access to electricity boosted economic expansion, but not in the short term. There was a long-run causal link between access to electricity and economic performance. When the sample is disaggregated to account for currency, language, and geographical differences, access to electricity had no significant effect on economic development. Adeoye and Spataru (2019) conducted a research on building hourly power demand models for 14 West African nations between 2016 and 2030.The model used real 2016 monthly and yearly power demand statistics. The authors revealed that power consumption varies seasonally, with hourly demand being higher in dry seasons than in rainy seasons. According to the findings, West African power consumption is expected to be 5 times more in 2030 than it was in 2016. Sarwar et al. (2017) investigated empirical links between expansion in economy, power consumption, oil prices, capital creation and population. The study used Pedroni panel cointegration, completely modified OLS, and panel vector error correction tests to investigate the connection between variables in both short and long runs. Full panel results showed a bidirectional linkage between electricity usage, oil price, fixed capital creation, population, and GDP. Furthermore, the findings showed that in nations that rely on nonrenewable sources for energy generation was negatively related to economic development.

Sani et al. (2017) interrogated the symmetric link between application of electricity, manufacturing output, and financial development in Nigeria from 1981 to 2015 while embracing the VECM framework. The results showed that the variables move together over a long time horizon, implying that any inadequacy of electricity performance would hamper industrial productivity.

Kwakwa (2018) investigated the drivers of power consumption in Benin using yearly data from 1971 to 2014, estimating with the ARDL The findings showed that population, education, urbanization, and industrialisation all had a positive impact on the country's power consumption, but income has a negative impact. A more in-depth examination using rolling regression reveals that the influence of the aforementioned factors alter over time in response to certain social, political, and economic developments. While assessing inter link between loss in electricity distribution, energy consumption, growth and carbon emissions in West Africa, Atiku et al. (2022) employed CS-ARDL). It was asserted from the study that electricity distribution losses and energy consumption had a noticeable inverse relationship, but intensity of electricity, consumption of electrical power and economic growth showed otherwise.

Chitedze et al. (2021) appraised the contribution of power consumption intensity to sectorial performance of industries from 1981 to 2015 using VECM. The study attested that the influence of power consumption intensity was minor on production in the industrial, agricultural, and service sectors.

Aiyetan et al. (2021) looked at the constantly changing impacts of power generation from both sources of non-renewable and renewable energy on outputs from industries and agriculture in Nigeria. The authors separated power output by source (renewable and nonrenewable) and used Structural Vector Autoregressive (SVAR). The findings suggested that electricity generation from both avenues had a minor influence on the expansion of Nigeria's industries and agriculture. Furthermore, this analysis confirmed the current assertion that economic development and energy are related, refuting the neoclassical premise of the neutrality hypothesis.

Asaleye et al. (2021) used Canonical Cointegrating to analyze the long-term influence of energy usage on manufacturing sector performance represented by output, employment, and capital from 1981 to 2019. The findings implied that power usage and lending to the industrial sector had a negative impact on production. In the employment equation, electricity usage and interest rates had a negative effect on employment. In the capital equation, electricity use was not statistically significant. Yawa (2023) estimated how accessibility of electricity affected the consumption of electricity in Ghana between 1990 and 2020 using the VECM, and the results concluded that access rate of electricity increased consumption by per capita significantly with the immediate effect and in the long-run, respectively. Aransiola et al. (2022) analyzed data using Fully Modified Ordinary Least Squares (FMOLS) and the Granger causality test to identify factors driving industrial development in Nigeria. The findings indicated that market size, agricultural production, trade openness, GDP growth rate, and exchange rate do not are not powerful enough to propel Nigeria's industrial growth.

3. MATERIALS AND METHODS

3.1. Research Design

This study adopted ex post factor design. This type of research design is crucial in a study where data are originally available without interference from researcher. Therefore, data about consumption of electricity and output from electricity in ECOWAS countries were got from secondary data, specifically, the World Bank (2023).

3.2. Theoretical Framework

The research employs the Harold domar model, which demonstrates how capital stock growth, labor force growth, and technological sophistication interlink in a nation, in the same way they affect a country's overall production of goods and services. To capture the relationships within the framework of the ECOWAS structure, industrial output growth, labour employed, electricity consumption, inflation, money supply, and innovation.

The model is specified in its general form as:

$$Y = f(A, K, L) \tag{1}$$

Where technology is predetermined by external factors.

Y = Aggregate real output

K = Stock of capital

L = Stock of labour

A = Technological sophistication.

In the above model, Y is utilized as a proxy for industrial output growth, which is stated as a function of electricity consumption, foreign direct investment, labour employed, inflation, and money supply.

3.3. Model Specification

In extending the theoretical framework to capture the model specification, for examining electricity consumption and industrial output nexus, this study adapts its model from the studies of Aderemi et al. (2022), Ajibola et al. (2021), Omitogun et al. (2023) and Olanipekun et al. (2022). The functional relationship is expressed as:

$$IDG_t = (K_t, EC_t, LF_t, IN_t, MS_t) \quad (2)$$

For the purpose of this study, equation (2) can be expressed in a panel form as:

$$IDG_{it} = \beta_0 + \beta_1 FDI_{it} + \beta_2 EC_{it} + \beta_3 LF_{it} + \beta_4 IN_{it} + \beta_5 MS_{it} + \Sigma t \quad (3)$$

Where:

IDG_t = Industrial output growth at time t proxy by manufacturing value added

K_t = Foreign direct investment inflows

EC_t = Electricity consumption at time t

LF_t = Labor force at time t

IN_t = Inflation at time

MSt = Money supply at time

U_t = Stochastic error term at time t

β_o = Intercept term

I = Country

The A priori expectation of the previously stated model in the equation (3) are as follows (Tables and 1 and 2):

3.4. Scope of the Study

Originally, there were 15 countries under the ECOWAS sub region, but currently there are 12 countries due to the suspension of Burkina Faso, Mali and Niger for overthrowing democracy. The 3 countries, were excluded from this study. The remaining 12 countries used in this research are in no any particular order; Benin, Cape Verde, Cote d'Ivoire, The Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Nigeria, Senegal, Sierra Leone and Togo. In the same vein, the study considered a period of 2000 to 2023 owing to data availability.

3.5. Estimation Techniques

The estimation techniques employed are descriptive statistics and econometrics. The descriptive statistics involved are mean, median, minimum, maximum, jarque-bera, skewness, kurtosis, whereby the econometrics techniques involved are unit root test and panel Dynamic Ordinary Least Squares.

4. RESULTS AND DISCUSSION

4.1. Introduction

This section presents the results and interpretation of major findings of this study. The model was estimated with E-views software using various econometric techniques. The analysis starts with the presentation of descriptive statistics, followed by the presentation of correlation matrix, the unit root tests using the panel Levin, Lin and Chu t*. The DOLS regression results were reported and the findings were tested against the hypothesis of the study.

Table 1: A priori expectation

Label	Notations	Expected value
MVA	-	
EC	β1	Positive(+)
FDI	β2	Positive(+)
LF	β3	Positive(+)
IN	β4	Negative(−)
MS	β5	Positive(+)

Source: Authors' computation (2024)

4.2. Descriptive Statistics

In Table 3, descriptive statistics of the estimated results have been presented as follows; the mean value of industrial output is 8.8476 and both the maximum and minimum values are reported to 21.5869-1.5326 respectively. The implication of this is that, industrial outputs contribute about 8.84% to the GDP of the ECOWAS sub region.

The maximum value of electricity consumption (EC) was 31.5699 billion kWh and a minimum value of −0.0019 billion kWh respectively. Whereas its mean value was 3.8321 billion kWh which is below the value of the variable`s standard deviation. It shows that the dispersion of electricity consumption data is very large. In the case broad money supply, the mean value was 31.6%. The implication of this is that, on an average basis, both money in circulation and money in banks contain 31.6% of GDP of ECOWAS countries.

Consequently, the average value of industrial outputs was 8.8%. This implies that during the periods of analysis, industrial outputs has only contributed about 8.8%. Similarly, labour force had a mean value of 61.6%, which signifies that 61.6% of the population of ECOWAS sub region has the capacity to engage in productive venture. FDI possessed maximum and minimum values of 103.3% and −2.7% respectively with an average value of 5.16%.

In Table 4, every pair of the correlation shown indicates that all the variables are below 0.5. As a result of this, the variables employed in this research does not dependent on one another, and do not subject the study to the problem of multicollinearity issues. This position is reinforced by the position of Goldberger (1991), which admitted that simple correlation between a pair of explanatory variables could motivate the problem of multicolliearity in models if the value of such correlation exceeds 0.9. None of the pairs of the correlation analyses is close to 0.9.

The Levin, Lin and Chu test results shows that MS, FDI and EC are I (1) variables which implies that they are non-stationary in their level and therefore require differencing to acquire stationarity (Table 5). MVA, LF and IN on the other hand are I (0) variables implying that they are stationary in their levels and do not require differencing to achieve stationarity.

The DOLS outputs in Table 6 provide an interesting result, it shows that electricity consumption has a positive relationship with industrial output. The findings revealed that a unit change in electricity consumption increased industrial output by 32.56% and is statistically significant. This study found that electricity supply is a crucial factor influencing the growth of industrial production. The finding in this study is supported by these studies; Onatunji (2022), Abokyi et al (2018), Agbede and Onuoha (2020), but

Table 2: Measurement of the Variable

Abbreviation	Variable	Proxy to be used	Sources of data
IND	Industrial output	Manufacturing value added (% of GDP)	World development indicators
FDI	Foreign direct investment	FDI inflow % of GDP	World development indicators
EC	Electricity consumption	Electricity net consumption (Billion kWh)	Energy information administration
LF	Labour force	Labour force as % of population growth (annual %)	World development indicators
IN	Inflation rate	Consumer price index (annual %)	World development indicators
MS	Money supply	Broad money (% of GDP)	World development indicators

Source: Authors' computation (2024)

Table 3: Descriptive statistics

Statistics	MVA (%)	EC (kWh)	FDI (%)	IN (%)	LF (%)	MS (%)
Mean	8.8476	3.8321	5.1657	7.1109	61.6894	31.6198
Median	9.0227	0.6695	2.5193	5.3203	59.7910	25.3605
Maximum	21.5869	31.5699	103.3374	41.5095	77.2890	125.2995
Minimum	1.5326	−0.0019	−2.7201	−3.5026	45.4900	0.0353
Std. Dev.	4.5028	6.9189	10.8112	7.0908	7.5205	20.5889
Skewness	0.2755	2.4583	6.3020	1.6159	0.4579	2.1174
Kurtosis	2.7231	8.4443	48.6474	6.9362	2.7274	7.7868
Jarque-Bera	4.5627	645.7604	26910.57	311.2632	10.9581	490.1740
Probability	0.1021	0.0000	0.0000	0.0000	0.0041	0.0000
Sum	2548.108	1103.644	1487.718	2047.952	17766.55	9106.500
Sum Sq. Dev.	5819.039	13738.91	33545.19	14430.37	16231.95	121659.7
Observations	288	288	288	288	288	288

Source: Authors' computation (2024). EC: Electricity consumption

Table 4: Correlation matrix for the variables

Variable	MVA	EC	FDI	IN	LF	MS
MVA	1	0.194955	−0.359346	−0.258166	−0.377274	−0.066730
EC	0.194955	1	−0.138890	0.305750	0.011559	−0.149844
FDI	−0.359346	−0.138890	1	0.095654	0.305356	−0.022782
IN	−0.258166	0.305750	0.095654	1	0.273927	−0.294474
LF	−0.377274	0.011559	0.305356	0.273927	1	−0.284412
MS	−0.066730	−0.149844	−0.022782	−0.294474	-0.284412	1

Source: Authors' computation (2024)

Table 5: Panel unit root test

Variable	Levin, Lin, Chu	1st different	Order of integration
	Level		
MVA	−6.295 (0.0046*)	NA	I (0)
MS	NA	−14.472 (0.000*)	I (1)
LF	−3.764 (0.0034*)	NA	I (0)
IN	−10.554 (0.000*)	NA	I (0)
FDI	NA	−13.182 (0.000*)	I (1)
EC	NA	−13.178 (0.000*)	I (1)

Hint: (*) (**) indicate significance at 5% and 10% levels, respectively

Table 6: Panel regression analysis results of the relationship between electricity consumption and industrial output in ECOWAS sub-region

Method: Panel dynamic ordinary least square Dependent variable: manufacturing value added (MVA)				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
EC	0.325652	0.068262	4.770591	0.0000
FDI	−0.012737	0.009221	1.381263	0.1728
IN	0.045386	0.039392	1.152166	0.2542
LF	0.074102	0.033358	2.221387	0.0305
MS	−0.047413	0.021455	2.209895	0.0313
R-squared	0.968285	Mean dependent var		8.777014
Adjusted R-squared	0.855263	S.D. dependent var		4.431463
S.E. of regression	1.685920	Sum squared resid		156.3279
Long-run variance	0.803921			

Source: Authors' computation (2024)

contradicts assertion of Asaleye et al (2021). In the same vein, Labour force shows a positive relationship with industrial output, implying that a percentage change in labour force will increase manufacturing value added by 74.1%. It is statistically significant at 5% level. Money supply has an inverse relationship with industrial output but is statistically significant at 5%. This shows the significant importance of money supply in driving industrial output in ECOWAS sub region.

However, the coefficient of FDI shows a negative but insignificant relationship with industrial output. The result means that, a percentage change in FDI will bring about a reduction in industrial performance by 0.018. This signifies that FDI impacted manufacturing value added performance negatively. This result connotes that influence of FDI on industrial output in ECOWAS is deficient. This reason for this outcome might be related to the

Table 7: Pairwise granger causality test results between electricity consumption and industrial output in ECOWAS sub-region

Null hypothesis	W-Stat.	Zbar-Stat.	Prob.
EC does not homogeneously cause MVA	9.83626	10.1163	0.0000
MVA does not homogeneously cause EC	1.90791	−0.47946	0.6316

lack of sufficient inflows of FDI in the direction of manufacturing sector in ECOWAS sub region. This results is in tandem with the submission of Keji (2023).

In addition, the coefficient of inflation rate shows a positive relationship with industrial output. This results means that a percentage change or increase in inflation rate will increase manufacturing value added by 45.39% though it is not statistically significant at both 5% and 10%.

The value of the R-Square (R^2) for the model is pegged at 0.9682% or 96.82% which implies that electricity consumption, FDI, inflation, labour force and money supply explained about 96% systematic variation in industrial output in ECOWAS over the observed years while the remaining 4% variation is explained by other variables outside the model.

From the test results in Table 7, the first test between electricity consumption and manufacturing value added, it indicates that the study which is significant at 5% level, indicates that electricity consumption does Granger-cause manufacturing value added is accepted. While the second test between manufacturing value added and electricity consumption, which is insignificant at 5% level indicating that the null hypothesis that the manufacturing value added does not Granger-cause electricity consumption is accepted. From the results, there is a uni-directional causality running from electricity consumption to industrial output in ECOWAS sub region. This implies that electricity consumption is an important input for industrial output in ECOWAS sub region. It is important to stress that for industrial expansion to take place in this economic bloc, generation of sufficient electricity cannot be undermined.

5. CONCLUSION AND RECOMMENDATIONS

This study examines the effect of electricity consumption on industrial output in ECOWAS countries from the year 2000 to 2023, using various econometric methods and time series data. This study considered six different variables which includes: FDI, inflation rate, labour force and money supply. The study uses Panel Dynamic Ordinary Least Square (DOLS) regression analysis to obtain long run estimates among the variables, it also used the Granger-Causality test (to determine the causal relationship with electricity consumption and industrial output) and Levin, Lin and Chu t-test for stationarity testing.

Based on the estimated results, this study concludes the following; electricity consumption contributed a significant positive impact on industrial output in ECOWAS sub region. Similarly, labour force caused a positive and significant impact on industrial output. Whereas, a negative and significant impact of money supply was felt on industrial output in ECOWAS sub region. A uni-directional causality running from electricity consumption to industrial output occurred in ECOWAS sub region.

Due to the findings that emerged from this study, this study recommended that the policymakers in ECOWAS countries should embark on policies that would increase supply and accessibility of electricity to industrial sub sector in all ECOWAS countries in order to ensure a substantial growth in the industrial output of the sub regional economy. In the same vein, the policymakers in ECOWAS sub region could also drive industrial expansion by granting immediate tax relief for privately generated electricity for industrial consumption.

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