Natural Resources for
Human Health

eISSN: 2583-1194

Original Research

Received 04 May 2026
Revised 09 June 2026
Accepted 22 June 2026

Natural Resources for Human Health 2026, Vol. 6 (12s): 602–615

KEYWORDS:
Clean energy, industrial development, ECOWAS, cointegration

Clean Energy Utilization and Sustainable Industrial Development in ECOWAS: Evidence from Panel Cointegration

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ABSTRACT: This paper aims to examine the impact of the use of clean energy on industrial development in the Economic Community of West African States. This was done with the aim of bridging the gap in the supply of energy in the West African region and accelerating the rate of industrialization in the region. Data employed in this study were sourced from World Bank's World Development Indicators (WDI) from 1990 to 2023. Using the Fully Modified Ordinary Least Squares method, in addition to the Dynamic Ordinary Least Squares method for robustness checks, this paper found out that clean energy positively and significantly influences industrial output. On the other hand, renewable energy was found to have no influence on industrial output. Foreign direct investment was found to have a negative and significant influence on industrial output. The results of the Granger causality test showed that there was a unidirectional causality from clean energy to industrial output. This paper concluded that the improvement of access to clean and modern energy in West Africa is essential in accelerating the rate of industrialization in the region.

INTRODUCTION

Energy, therefore, remains a key factor in driving economic growth, social welfare, and stability, especially in powering industrial production, transportation, homes, and public infrastructures. The absence of sustainable energy systems, therefore, means that productive activities slow down, economic transformation stagnates, and governments cannot provide essential services (Sikwela and Aderemi, 2025). Modern and sustainable energy access, therefore, has become a key aspect of global development agendas, especially in the context of Sustainable Development Goal 7, which focuses on affordable and clean energy access for sustainable economic development.

Under this backdrop, the Economic Community of West African States (ECOWAS) is caught in the energy-development conundrum. The region contributes only about 1.8 percent to the overall carbon emissions globally, but at the same time, it is highly vulnerable to the adverse effects of climate change, including flooding, droughts, and increased temperatures. The environmental shocks have the potential to undermine the foundation for industrial development (Odoi-Yorke et al., 2025; Okoh and Omachi, 2025). At the same time, the region is endowed with tremendous potential for renewable energy sources, including solar, wind, and hydro energy.

Nevertheless, the exploitation of these renewable resources is still limited. In fact, Africa generates only 3 percent of the world's clean energy despite its vast renewable energy endowment (Iweh et al., 2023). In West Africa, for instance, solar irradiance is between 4.70 and 6.42 kWh/m2/day, which is quite high, indicating vast prospects for developing solar energy. However, clean energy systems and infrastructure development are still underdeveloped in ECOWAS member states (Odoi-Yorke et al., 2025). The implication of this is seen in Nigeria, where a huge percentage of the population still relies on traditional biomass fuels such as firewood and charcoal. This, therefore, hinders economic development since it limits our technology and prevents us from advancing from low-productivity activities to industrial manufacturing (Sikwela and Aderemi, 2025). In addition, although Ghana has impressive levels of electricity access, which is about 88.8%, modern renewable energy contributes less than 1% to Ghana's energy mix, which puts Ghanaian industries at risk of price fluctuations in fossil fuels (Akpahou et al., 2025).

The energy deficit has also limited the growth rate of industrialization in the region. For instance, the value added in the industrial sector in West Africa from 2010 to 2018 was only 19.34 percent of the region's GDP, while that of the Southern African region was 29.43 percent (Eke et al., 2020). This is attributed to the availability of infrastructure, but also the level of production efficiency and technological know-how in the region. Industrial activities in the region, especially in the ECOWAS region, also tend to have high energy intensity. For instance, the industrial sector in Nigeria uses about 12.5 megajoules of energy to produce only one dollar of the country's GDP, compared to the world average of only 4.5 megajoules (Ogunsola and Zwane, 2025). This shows that the industrial sector in the region needs more energy to produce the same amount of output, hence increasing the cost of production and reducing the competitiveness of the region's products in the international market.

In addition, persistent electricity shortages have forced many manufacturing firms to rely on self-generated electricity through fossil-fuel-powered generators. In Nigeria, frequent power outages have increased the dependence of industries on diesel and petrol generators, which not only raise operational costs but also contribute to environmental pollution and greenhouse gas emissions (Akinola, 2023). As a result, unreliable electricity supply has reduced the productivity of manufacturing firms, increased production costs, and weakened the competitiveness of locally produced goods (Ayomitunde and Samuel, 2022; Akinola, 2023).

Existing empirical studies have examined the relationship between renewable energy and industrial performance across different geographical contexts. Some studies have focused on individual countries such as Nigeria, while others have analyzed broader regional dynamics within West Africa. However, limited empirical evidence exists on the direct relationship between clean energy utilization and industrial development within the ECOWAS bloc as an integrated regional economy. Addressing this gap is important because regional energy dynamics, policy coordination, and economic integration can significantly influence industrial performance across member states.

Previous studies have explored the link between renewable energy and industrial performance in various geographical areas. Some studies have concentrated on single nations, such as Nigeria, while others have explored the broader regional linkages in the West African region. However, little empirical evidence exists on the link between clean energy utilisation and industrial performance in the ECOWAS region as an integrated regional economy. Such an issue is important to address because regional energy linkages have the potential to significantly impact the performance of industries in the member states.

In this regard, this study aims to answer the question of the long-run impact of clean energy utilization on the development of industries in the ECOWAS countries. To achieve this objective, the study utilizes the Fully Modified Ordinary Least Squares method to examine the long-run relationship between clean energy and the development of industries in the ECOWAS countries. In addition, the Dynamic Ordinary Least Squares method is utilized to validate the findings obtained in the study. Furthermore, the study utilizes the Granger causality method to examine the causality link between clean energy utilization and the development of industries in the ECOWAS countries. This study is an updated contribution to the literature on the impact of clean energy utilization in the ECOWAS countries.

METHODOLOGY

The theoretical foundation of this research is the Energy-Led Growth Theory which states that energy supply and its utilization are the major factors that contribute to economic development, efficiency improvement and industrialization (Ezeji, 2020). This theory asserts that energy is one of the basic inputs for the production process because industry operations are largely dependent on a reliable and cheap energy supply which powers machines and makes industrial operations effective. Hence, lack of energy will limit the growth of industries.

Model Specification

To accomplish the research objective, the study builds on the model proposed by Aderemi et al. (2022), which investigated the nexus between clean energy supply and industrial development in Nigeria. The model was refined and extended to suit the present analysis, which focuses on examining the relationship between clean energy and industrial development across ECOWAS member states. These adjustments ensure that the model reflects the regional scope and specific characteristics of the selected countries while maintaining its theoretical foundation.

The original model is specified as:

IDV = f (CES, GCEX, FDI, PGR) ……………………………………………………. *(1)*

Where:

IDV = Industrial development

CES = Clean energy supply

FDI = Foreign Direct Investment.

GCEX = Government capital expenditures

PGR = Population growth rate

To align with the focus on clean energy and industrial development in ECOWAS, this study modifies Aderemi et al. (2022) to attain model 2 below;

$MSO_{it} = f\ (CLE_{it}, REC_{it}, FDI_{it}, GCF_{it}, INF_{it})$ …………………………..2

Explicit Model Specification

The econometric form of the model is written thus:

Model for Manufacturing sector output:

$MSO_{it} = \beta_0 + \beta_1 CLE_{it} + \beta_2 REC_{it} + \beta_3 FDI_{it} + \beta_4 GCF_{it} + \beta_5 INF_{it} + \epsilon_{it}$……………3

Where:

MSO = Manufacturing sector output

CLE = Clean energy

REC = Renewable energy consumption

FDI = Foreign direct investment

GCF = Gross capital formation

INF = Inflation

β_0 = Intercepts of model 3.

β_1 to β_5 : Coefficients

ϵ_{it} = Error terms for each model.

Sources of data

This study relies on secondary data, which was sourced from the World Bank's World Development Indicators (WDI). The data will cover a 34-year period, from 1990 to 2023.

Measurement and description of variables

The table below shows the list of variables used in this study with the measurement from the sources.

Table 1: Measurement and Sources of Data

Variable	Representation	Measurement	Data Source (Year)
Dependent Variable			
Industrial Development	MSO	Manufacturing, value added (% of GDP)	World Development Indicators (WDI, 2024)
Independent Variables			
Clean Energy	CLE	Access to clean fuels and technologies for cooking (% of population)	World Development Indicators (WDI, 2024)
Renewable Energy Consumption	REC	Renewable energy consumption (% of total final energy consumption)	World Development Indicators (WDI, 2024)
Control Variables			
Foreign Direct Investment	FDI	Foreign direct investment, net inflows (% of GDP)	World Development Indicators (WDI, 2024)
Gross Capital Formation	GCF	Gross capital formation (% of GDP)	World Development Indicators (WDI, 2024)
Inflation	INF	Inflation, consumer prices (annual %)	World Development Indicators (WDI, 2024)

Source: Authors' Compilation, 2026

Estimation Techniques

The descriptive statistic stage of the empirical analysis included studying the distributional features of the data while the correlation analysis stage involved investigating the strength and direction of the relationships between the variables. In view of the panel structure of the study, it was necessary to carry out cross-sectional dependence test to find out if the shocks in one country had an impact on other countries in the panel. The finding from this stage revealed that there was no cross-sectional dependence in the countries.

Stationarity of the variables was thereafter evaluated using the Augmented Dickey Fuller (ADF) panel unit root test. It was found that there were different orders of integration whereby some variables were stationary at level whereas others were stationary at first difference. Since it was found that the variables had cointegration, a panel cointegration test was conducted in order to find out whether there was any stable equilibrium between the variables. After it was shown that there was cointegration, the Fully Modified Ordinary Least Squares (FMOLS) method was used in order to capture the long run impact of clean energy consumption on industrial development in ECOWAS. Dynamic Ordinary Least Squares (DOLS) method was further used as a robust estimation method. The Granger causality test was thereafter performed in order to determine the direction of causality among the variables.

PRESENTATION AND DISCUSSION OF RESULTS

Descriptive Statistics

The descriptive statistics offer an initial idea about the nature of the variables that are being used to measure the relationship between clean energy and industrial development in the ECOWAS region.

Table 2: Descriptive Statistics

	CLE	REC	MSO	FDI	GCF	INF
Mean	14.14634	66.67024	9.770336	2.719600	21.10130	9.059776
Median	3.850000	73.60000	9.395517	1.620346	20.07910	4.852010
Maximum	83.00000	95.00000	21.58690	32.41435	53.92784	72.83550
Minimum	0.100000	19.70000	1.532975	-2.574548	-2.424358	-3.502586
Std. Dev.	20.68751	20.45820	4.889864	3.400642	9.338090	12.21153
Skewness	1.775821	-0.653925	0.395097	3.078683	0.867588	2.516924
Kurtosis	5.227067	2.351570	2.644667	20.57323	4.201778	10.08987
Jarque-Bera	273.8614	33.11830	11.16619	5403.232	66.26969	1077.383
Probability	0.000000	0.000000	0.003761	0.000000	0.000000	0.000000
Sum	5290.730	24868.00	3488.010	1017.130	7533.163	3098.443
Sum Sq. Dev.	159634.0	155696.2	8512.234	4313.508	31043.18	50850.42
Observations	374	373	357	374	357	342

Source: *Authors' computation (2026)*

From the results in Table 2 above, clean energy (CLE) has a mean of 14.15 with significant dispersion, as shown by the high standard deviation of 20.69 and the maximum value of 83.00. In addition, the positive skewness of 1.78, coupled with the kurtosis, indicates that the distribution of clean energy values is not symmetrical, suggesting that some countries had relatively higher values of clean energy compared to the overall values. Renewable energy consumption (REC), on the contrary, indicates that the region has a relatively high level of consumption, as shown by the relatively high mean of 66.67 and the median of 73.60. However, the fact that the distribution of the values of REC is negatively skewed indicates that some values are below the overall mean. Manufacturing sector output (MSO), the industrial development proxy, has a relatively high mean of 9.77, with moderate dispersion.

Foreign direct investment (FDI) and gross capital formation (GCF) display notable variability, particularly FDI, which shows strong positive skewness and high kurtosis, implying the presence of extreme inflows in certain periods. Inflation (INF) exhibits considerable volatility, with a maximum of 72.84 and high kurtosis, reflecting macroeconomic instability in some countries. Overall, the statistics highlight substantial cross-country disparities in energy structure, investment flows, and industrial performance within ECOWAS, justifying the need for robust econometric techniques in subsequent analysis.

Correlation Statistics

Table 3: Correlation matrix result

Correlation							
Probability	**CLE**	**REC**	**MSO**	**FDI**	**GCF**	**INF**	
CLE	1.000000						

REC	-0.733853	1.000000					

	0.0000	-----					
MSO	0.118145	-0.034521	1.000000				
	0.0386	0.5468	-----				
FDI	0.136645	-0.295536	-0.396189	1.000000			
	0.0166	0.0000	0.0000	-----			
GCF	0.229245	-0.138384	0.092576	0.268526	1.000000		
	0.0001	0.0152	0.1055	0.0000	-----		
INF	-0.238691	0.324120	-0.094206	-0.035654	0.245076	1.000000	
	0.0000	0.0000	0.0994	0.5337	0.0000	-----	

Source: *Authors' computation (2026)*

From the correlation matrix, it can be seen that the level of association between the variables is presented. Clean Energy (CLE) indicates a weak positive association with manufacturing sector output (MSO) at a statistical level of less than 0.05. This indicates that there is a positive association between the two variables. However, it is very weak. CLE indicates a strong negative association with renewable energy consumption (REC). This indicates that CLE and REC might be reflecting different aspects of the structure of the ECOWAS energy sector. FDI indicates a moderate negative association with MSO. On the other hand, gross capital formation (GCF) indicates a positive association with FDI. Inflation (INF) indicates a negative association with CLE and a positive association with REC and GCF.

With regard to multicollinearity, the strongest correlation is seen between CLE and REC at -0.734. Though this is a relatively high correlation coefficient, it is still not above the 0.80 threshold that is generally considered a warning for multicollinearity. Most other correlation coefficients are relatively low. Thus, though there is some correlation, especially among the energy variables, there is nothing alarming at this stage.

Cross Section Dependence Test

On the other hand, the cross-section dependence test checks for correlation in the residuals across panel units. This implies the presence of common shocks and spillover effects among ECOWAS countries. The null hypothesis for this test states that there is no cross-section dependence in the residuals.

Table 4: Cross-section Dependence test result

Null hypothesis: No cross-section dependence (correlation) in weighted			
residuals			
Test	**Statistic**	**d.f.**	**Prob.**
Breusch-Pagan LM	70.38358	55	0.0791
Pesaran scaled LM	1.466766		0.1424
Pesaran CD	-0.382413		0.7022

Source: *Authors' computation (2026)*

The results of the Breusch-Pagan LM test show a statistic of 70.3836 with a p-value of 0.0791. This implies that the p-value is greater than the conventional 5% significance level. In addition, the results of the scaled Pesaran LM test show a p-value of 0.1424. On the other hand, the results of the scaled Pesaran CD test show a p-value of 0.7022. This indicates that there is no strong evidence of cross-sectional dependence among the weighted residuals. In other words, the impact of a shock in one of the ECOWAS countries does not spill over to other ECOWAS countries in the model. This indicates that the panel units in this case are independent, and this supports the use of first-generation panel estimators since they assume cross-sectional independence. The absence of cross-sectional dependence makes the results of the long-run estimation more reliable.

Stationarity Test

The dataset used in this particular study includes a time series dimension, which may have non-stationary behaviour. This indicates that the statistical properties of the time series may change over time. This may lead to biased and spurious results if conventional Ordinary Least Squares methods are applied. In order to overcome this issue, unit root tests are performed to find the stationarity of the variables. In this study, the Augmented Dickey-Fuller test is used to find the presence of unit roots in each of the variables. The results of the stationarity tests are presented in Table 5.

Table 5: ADF Panel Unit Root Test Result

VARIABLES	NUMBER OF DEFERENCING	T-Statistics (Probability)	ORDER OF INTEGRATION
CLE	Level	5.07675 (1.0000)	
	First Diff.	-4.56924 (0.0000)	I(1)
REC	Level	1.07858 (0.8596)	---
	First Diff.	-8.80404 (0.0000)	I(1)
MSO	Level	-0.22769 (0.4099)	
	First Diff.	-7.82672 (0.0000)	I(1)
FDI	Level	-2.76256 (0.0029)	I(0)
	First Diff.	-11.0995 (0.0000)	

GCF	Level	0.32217 (0.6263)	
	First Diff.	-10.3108 (0.0000)	I(1)
INF	Level	-5.01603 (0.0000)	I(0)
	First Diff.	-10.7309 (0.0000)	

Source: *Authors' computation (2026)*

The results from the Augmented Dickey- Fuller panel unit root tests showed that the variables had mixed orders of integration. From the results, clean energy (CLE), renewable energy consumption (REC), manufacturing sector output (MSO), and gross capital formation (GCF) can be classified as non-stationary at level, as the probability values are greater than 0.05. However, after the first difference, the variables had a p-value of 0.0000, implying that the variables are stationary at first difference. Therefore, the variables are integrated of order one, I(1).

Conversely, foreign direct investment (FDI) and inflation (INF) are found to be stationary at level, as shown by the significant test results, with the probability values being less than 0.05. Therefore, the variables are integrated of order zero, I(0). The findings showed the presence of mixed stationarity, as the dataset contains I(0) and I(1) variables. This implies that the use of long-run estimators, which can accommodate the presence of cointegrated variables with different orders of integration, will ensure consistent and reliable parameter estimation.

Endogeneity Test

Table 6: Endogeneity test results for the independent variables

Variable	Coefficient	Std. Error	t-Statistics	Probability
RESID_CLE	0.012619	0.019472	0.648037	0.5175
RESID_REC	-0.016707	0.020196	-0.827250	0.4088
RESID_FDI	-0.130949	0.053383	-2.453001	0.0148
RESID_GCF	0.051713	0.020500	2.522609	0.0123
RESID_INF	-0.052748	0.021650	-2.436429	0.0154

Source: *Authors' computation (2026)*

Table 6 below gives the endogeneity test results to investigate whether the variables of interest are endogenous by checking the significance level of the residuals. If the residuals' coefficient is insignificant, then the corresponding variable is not endogenous, while if significant, then there exists the endogeneity problem.

From the results shown in the table above, it can be observed that the coefficient of clean energy (RESID_CLE) is positive and insignificant, while the coefficient of renewable energy consumption (RESID_REC) is negative and insignificant. Therefore, both clean energy and renewable energy consumption are free from endogeneity concerns. On the other hand, foreign direct investment (RESID_FDI) has a negative and significant coefficient, and gross capital formation (RESID_GCF) and inflation (RESID_INF) also have a significant effect on the residuals. This confirms the existence of endogeneity with FDI, capital formation, and inflation.

As the endogeneity detected is primarily related to possible correlation between the regressors and the error term in the context of long run relationships, the paper uses FMOLS and DOLS estimators. These estimators are suitable since they correct for endogeneity and autocorrelation due to cointegration among variables, while offering consistent long run parameter estimates which is in line with the objective of this study.

REGRESSION RESULT

The table below shows the regression results of this study for the Fully Modified Ordinary Least Square (FMOLS) model and the Dynamic Ordinary Least Square (DOLS) model for estimating the objectives of the study.

Table 7: Regression Result (Cointegration Regression)

	Methodology	
	(FMOLS)	**(DOLS)**
Independent Variables	**Dependent Variable (MSO)**	**Dependent Variable (MSO)**
CLE	0.102986 (0.0414)	0.336977 (0.0307)
REC	0.005441 (0.8559)	-0.003247 (0.9522)
FDI	-0.240973 (0.0053)	-0.568872 (0.0407)
GCF	0.039624 (0.2527)	0.119503 (0.1003)
INF	-0.007875 (0.7282)	-0.003277 (0.9464)
R-Squared	0.772084	0.876338
Adj. R-Squared	0.759918	0.693318
S.E. of regression	2.314313	2.342344
Long-run variance	12.92342	5.194908
Mean dependent var	10.40675	11.19048
S.D. dependent var	4.723266	4.229668
Sum squared resid	1505.049	548.6574

Source: *Authors' computation (2026)*

Table 7 below presents the estimates from the long-run cointegration where the manufacturing sector output (MSO) has been used as the dependent variable in the FMOLS and DOLS models. The coefficients in the table indicate the changes in MSO in the long-run resulting from a unit change in each explanatory variable, ceteris paribus.

According to the estimates from the FMOLS model, it can be seen that the coefficient of clean energy (CLE) is positive and statistically significant at 0.102986 (p = 0.0414). This means that a unit increase in CLE is associated with a 0.103-unit increase in MSO in the long run. The coefficient of renewable energy consumption (REC) is positive and insignificant at 0.005441 (p = 0.8559), showing no statistically significant long-run association between REC and MSO. The foreign direct investment (FDI) has negative and significant coefficient at −0.240973 (p = 0.0053), and it shows that a unit increase in FDI is associated with a 0.241-unit reduction in MSO in the long run.

The estimates using DOLS also present quite similar results. While CLE coefficient stays positive and significant (0.336977; p = 0.0307), FDI coefficient continues to stay negative and significant (−0.568872; p = 0.0407). Coefficients for both REC and INF do not show any statistical significance while GCF coefficient is positive but marginally significant at the 10% level (0.119503; p = 0.1003). The similarity of signs for CLE and FDI coefficients in FMOLS and DOLS confirms their significant relationship with MSO in the long run.

Causality Test

Table 8: Granger Causality Test Result

Pairwise Granger Causality Tests			
Null Hypothesis:	**Obs**	**F-Statistic**	**Prob.**
CLE does not Granger Cause MSO	335	3.46633	0.0324
MSO does not Granger Cause CLE		1.31815	0.2690
REC does not Granger Cause MSO	334	0.71109	0.4919
MSO does not Granger Cause REC		0.15646	0.8552
REC does not Granger Cause CLE	351	0.30219	0.7394
CLE does not Granger Cause REC		0.40674	0.6661

Source: *Authors' computation (2026)*

From the results of Granger causality tests, it can be seen that there is a causal relationship between CLE and MSO. The null hypothesis of the Granger causality test, which states that CLE does not Granger cause MSO, was rejected at a 5 per cent significance level (p = 0.0324). However, the null hypothesis of the Granger causality test, which states that MSO does not Granger cause CLE, was not rejected at a 5 per cent significance level (p = 0.2690). Therefore, it can be concluded that there is a causal relationship between CLE and MSO, and this causal relationship works in one direction, from CLE to MSO. On the other hand, there is no causal relationship between MSO and CLE.

From the results of Granger causality tests for REC and MSO, it can be seen that neither of the causal relationships between REC and MSO works in either direction, since the p-values for both tests are greater than 0.05. Moreover, there is no causal relationship between REC and CLE in either direction.

DISCUSSION OF FINDINGS

The use of manufacturing value added as a percentage of GDP (MSO) as a proxy for industrial development is based on its ability to reflect the structural contribution of manufacturing activities to economic transformation in ECOWAS countries. The results of the empirical study indicate a positive and statistically significant relationship between access to clean energy (CLE) and manufacturing sector output. This implies that access to clean energy is instrumental in supporting industrial development in ECOWAS countries. This result is supported by the findings of Luan et al. (2025), who indicated that improvements in access to clean energy lead to improved industrial productivity and economic transformation. Access to clean fuels and modern energy services helps reduce the reliance on inefficient traditional biomass fuels, improves health outcomes, and boosts labour productivity. On the other hand, improved and efficient energy supply helps reduce production losses; lower operating costs, and improve the overall ability of manufacturing industries to operate with efficiency. Thus, access to clean energy is not only a welfare-enhancing intervention but also a strategic industrial development tool with the potential to support economic transformation in ECOWAS countries.

On the other hand, the use of renewable energy consumption (REC), defined as a percentage of total final energy consumption, is not found to have a statistically significant long-run relationship with the output of the manufacturing sector. This finding may imply that the current composition of the use of renewable energy consumption in the ECOWAS region is not yet aligned with the needs of the industrial sector. In fact, the use of renewable energy consumption in most of the countries in the ECOWAS region is dominated by traditional sources such as biomass, not technologically advanced sources such as solar, wind, or hydropower that are suitable for the support of the industrial sector. This finding may highlight the need to move beyond traditional sources of renewable energy towards technologically advanced sources of renewable energy.

The results also reveal a negative relationship between foreign direct investment (FDI) and manufacturing sector output. This shows that the FDI flows into the ECOWAS countries may not be invested in manufacturing activities. This is because, traditionally, FDI flows into the ECOWAS region are invested in the extraction of oil, mining, telecommunication services, and financial services, rather than manufacturing activities. This hampers the ability of FDI to contribute to the development of manufacturing industries in these countries. Iseolorunkanmi et al. (2023) and Amos (2025), who proved that the ability of FDI to contribute to the development of these countries is usually hindered by the level of resource-seeking FDI rather than manufacturing-seeking FDI, have also proved this.

On the other hand, the coefficient estimate of Gross Capital Formation is positively related to the output of the manufacturing sector, although it is not significant. This suggests that even though domestic investment contributes to the development of the economy in terms of capital accumulation and infrastructure development, it is not entirely efficient in promoting the development of the manufacturing sector. This is in consonance with the findings of Udo et al. (2024) and Ogunjobi et al. (2025), which noted that the accumulation of domestic capital is not sufficient to drive the development of the manufacturing sector in the face of inadequate infrastructure and technological limitations. Although Aluogbuo et al. (2023) noted a significant relationship between capital formation and industrial growth, the consensus is that the economy is not transformed unless the economy is positively impacted by the effective mobilization of productive investment into the development of the manufacturing sector.

Finally, inflation (INF) reveals a low negative relationship with manufacturing sector output, though the relationship is found to be statistically insignificant. This implies that although inflationary factors may pose some production costs and macroeconomic instability, their long-run impact on manufacturing sector output may be low in the ECOWAS region. Nonetheless, macroeconomic stability is essential for encouraging investors and supporting the development of manufacturing industries in the region. Similarly, research works conducted by Aliyu (2024) and Aroghene and Agbamu (2024) revealed that inflation does not strongly impact the manufacturing sector in the long run, though macroeconomic instability may negatively influence investment decisions and manufacturing sector development over time.

CONCLUSION

This research explored the long-run relationship between the use of clean energy and the development of industries in the ECOWAS region. A panel econometric approach was employed to analyse the relationship. Diagnostic tests, such as descriptive analysis, correlation analysis, cross-section dependence tests, and panel unit root tests, established the appropriateness of the long-run approach. The presence of different orders of integration justified the use of the Fully Modified Ordinary Least Squares approach, while the use of the Dynamic Ordinary Least Squares method was for robustness. Granger causality was also applied to the analysis.

The results from the above model clearly indicate that the empirical evidence supports that clean energy has a positive and significant effect on the long-run output of the manufacturing sector in ECOWAS. This supports the argument that better access to clean energy is a key factor in enhancing industrial output in ECOWAS. However, the results from the model show that renewable energy consumption does not have a significant effect on the output in the long run. This suggests that the composition of energy sources is more important than the overall consumption of renewable energy. Foreign direct investment has a negative and significant relationship with manufacturing output.

Recommendations

The ECOWAS governments must give priority to investments in renewable energy in large industrial hubs and Special Economic Zones. The investments must be on solar power, wind power, hydropower, battery storage, dedicated industrial feeders and enhanced transmission systems. Financing must come from government in form of concessionary loans, guarantees, transparent power purchase agreements and tax concessions on the basis of achievement in terms of reduced cost of energy, minimized production down time, increased manufacturing production and job creation.

There needs to be a provision for governments to facilitate private energy providers to provide energy to industrial clusters through clear and long-term power purchase agreements under concessional financing, risk guarantees, and exchange rate protection. Investment in renewable energy must also focus on feeder lines for industries, smart meters, substations, and transmission lines to facilitate efficient power supply. On the regional front, ECOWAS must support the development of the West African Power Pool by harmonizing grid standards, transmission between borders, and electricity trading arrangements. In addition, the incentive and subsidized financing scheme must have results linked to it, such as better electricity reliability, reduced downtime for production, cheaper energy costs, higher manufacturing capacity, and employment generation.

The adverse long-term effects of FDI make it necessary to enhance the quality and industry orientation of the investments. The incentive structure should favor those manufacturing activities that have high local value addition capabilities, technology transfers, product diversification in exports, and employment generation. Tax benefits and provision of facilities should come with conditions like local content requirements, training of workers, and research collaboration. Countries in ECOWAS must also ensure that they maintain transparency in their regulations, keep track of the development effects of FDI, and avoid FDI that is still stuck in extractive sectors.

Reforms within the institutions must also help in achieving these goals through investment decision-making processes that are open, stability in industrial regulations, predictability in tax collection, and effective enforcement of contracts. ECOWAS needs to devise a regional investment strategy, which will ensure that there is no destructive competition amongst member countries and governments do not offer incentives for investing in low-quality projects. There also needs to be a regional monitoring system for reviewing the sectoral composition and development contributions of FDI on an annual basis.

Contribution to Knowledge

This study contributes to knowledge in a number of significant ways. First, it fills the empirical void in the literature by focusing exclusively on the ECOWAS region as a unified economic bloc, thereby addressing the geographical focus of the literature. Secondly, it incorporates preliminary diagnostic tests, including cross-section dependence and panel unit roots, to ensure methodological robustness before conducting long-run estimations. Thirdly, the use of Fully Modified Ordinary Least Squares and Dynamic Ordinary Least Squares estimators in the ECOWAS region expands the methodological literature used in similar studies in the past. Fourthly, by using the Granger causality test, the study is able to ascertain the direction of causation between clean energy and industrial development, thereby providing deeper insights into the dynamic relationship between clean energy and structural transformation in the ECOWAS region. Lastly, the use of fresh data up to 2024 ensures that the study provides relevant knowledge in promoting clean energy-driven industrialization in the ECOWAS region.

Author contributions

Bassey, Rowland A., Nnoli, Ikenna T., Ajayi, Emmanuel O. and Ajibola, Akinyemi A.: Conceptualization, Investigation.

Olowo, Oluwole S., Olayiwola, Oluwasegun S., Ojo, David F., and Abiola, Adedeji J.: Methodology, Formal Analysis.

Imeokparia, Lawrence A., Oyinlola Abiodun and Omokore, David E.: Supervision, Writing—Review & Editing.

Conflict of Interest

The authors declare that there is no conflict of interest.

Ethics Statement

Ethical approval was not required for this study.

Data Availability Statement

Data supporting the findings of this study are available from the corresponding author upon reasonable request.

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