Journal of Economics, Finance and Management Studies

ISSN (print): 2644-0490, ISSN (online): 2644-050

Volume 07 Issue 06 June 2024

Article DOI: 10.47191/jefms/v7-i6-29, Impact Factor: 8.044

Page No: 3350-3360

Do Energy Access and Climate Change Worsen Poverty in West Africa? Empirical Evidence using Panel Analysis

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ABSTRACT: This study examined how access to energy and climate change affect poverty level in some selected West African countries. To achieve the objectives of this study, the researchers collected data on energy access, electricity generated, electricity consumed, price of electricity, climate change (carbon emission) and poverty index from the six selected countries. The selected six (6) countries in west Africa for the study are: Benin, Ghana, Liberia, Nigeria, Senegal, and Sierra Leone based on energy consumption and population size. The period covered by the study is 1995-2022. Both statistical and econometric techniques were adopted for the analysis of the data. Based on the analysis of the data using the Arellano-Bond two-step GMM Dynamic Panel econometric technique, some key empirical findings were made are: Volume of electricity generated had positive and insignificant impact on poverty index. This shows that volume of electricity generated as measure of energy access was not a significant predictor of poverty reduction among the selected west African countries during the period reviewed. Electricity consumed had a positive but insignificant impact on poverty index. This implies that electricity consumed was not a significant predictor of poverty rate among selected west African countries during the period reviewed. Access to electricity had a negative but insignificant impact on and poverty index. This implies that access to electricity was not a significant predictor of poverty reduction among selected countries in west African sub region during the period reviewed. Also, carbon emission as a proxy for climate change impacted negatively but insignificantly on poverty level. This implies that climate change was not a significant predictor of poverty eradication among selected west African countries during the period reviewed. Based on these findings the study recommended effective policies that will address electricity pricing, electricity subsidy and electricity metering in the selected west African countries as possible measures of eradicating poverty in the sub region.

KEYWORDS: Poverty Index, Energy Access, electricity generated, electricity consumed, price of electricity and Climate change

I. INTRODUCTION

Over the years, energy access challenges have been one of the major problems in developing countries in the world. This problem has taken a more worrisome dimension across the countries in the West African sub region hindering socioeconomic development and exacerbating existing disparities among households and countries. One of the primary challenges in west African region is the low electrification rates, particularly in rural areas. Despite efforts to expand access, a significant portion of the population, especially in remote and underserved areas, still lacks reliable and affordable access to electricity. This hampers economic activities, limits educational opportunities, and affects overall quality of life. Also, limited energy infrastructure, including transmission and distribution networks, is a major impediment to improving energy access. Many rural and remote areas lack the necessary infrastructure for grid connectivity, making it challenging to extend electricity services to these locations. Insufficient infrastructure hampers the reliability and stability of energy supply. A substantial portion of the population in west African sub region relies on traditional biomass, such as wood and charcoal, for cooking. This dependence contributes to deforestation, indoor air pollution, and climate change.

Generally, climate change is already having serious impacts across Africa. Africa is particularly susceptible to climate change because it includes some of the world's poorest nations. Its population is also growing quickly, and natural resources are being lost through environmental degradation. Millions of Africans are already feeling the impacts of climate change. This has resulted in significant economic and human losses and hindering efforts to meet the Sustainable Development Goals (SDGs). Poverty and a low capacity to adapt to a changed climate are exacerbated by rises in the sea level and temperature. Increasingly variable seasons, rainfall, drought, and weather extremes are also problematic. The West African sub region has experienced general increases in warm spells since the industrial era (IEA, 2022). Variable rainfall has also become more significant over the last five decades. In many west African countries, mean annual rainfall has declined steadily since the end of the 1960s. Other regions, particularly southern and eastern Africa, have seen more intense and widespread droughts and a significant increase in heavy rainfall. One third of Africans now live-in drought-prone areas, mainly in the Sahel, around the Horn of Africa and in southern Africa. Climate change is putting a range of pressures on people living in these areas, not least because their crops are less productive and water in short supply. All these have significant negative effect on economic development of this region especially livelihood and poverty incidence.

Some studies have been carried out on energy access-economic development nexus as well as climate change-economic development nexus across Africa with the aim of providing lasting solution to the problems identified earlier (see Onuoha, 2009; Zhai, Lin, and Byambdorj 2009; Boxal, Chan, and McMillan, 2004; and Seo, Mendelsohn, Dinar, Hassan, and Kurukulasuriya, 2009) However, these empirical studies generated mixed findings and failed to reach a consensus on the joint effect of energy access and climate change on economic development especially poverty alleviation. Also, none of these studies focused west African sub region nor covered up to 2022, a post COVID-19 era. Drawing from the identified problems and gaps therefore, the point of departure in this study is to empirically analyze the effect of energy access and climate change on poverty incidence in west African sub region from 1995 to 2022. We shall continue the investigation by reviewing relevant literature, followed by methodology employed, results and discussion of findings.

II. LITERATURE REVIEW

As attested by the Energy-Led Growth Hypothesis, the application of energy is one of the primary factors that propels economic expansion and improvement. The theory by Kraft and Kraft (1978), argues that the more energy is consumed, the higher the level of economic activity and progress. It implies that energy is a key component of production and that the demand for energy rises in tandem with economic progress. An indication or proxy for economic progress is consumption of energy, as attested by the Energy-Led Growth Hypothesis. Consumption of energy, they say, is a good indicator of a nation's degree of industrialization and general economic growth.

As attested by Yildrim and Aslan (2012), research into the link between consumption of energy and economic progress has been going on since the 1970s, with the seminal work of Kraft and Kraft (1978). In that study, the authors found a unidirectional causality between consumption of energy and growth in the United States' Gross National Product (GNP) from 1947 to 1974. Many researchers have now conducted further experiments to establish a causal link between energy use and GDP growth.

As attested by the Energy-Led Growth Hypothesis, economic progress and productivity are both boosted by an advanced and efficient energy infrastructure. Industries, transportation, and other vital sectors rely on a steady and plentiful energy supply. But changes in energy use led to shifts in growth which may affect job creation and poverty eradication. The conventional wisdom is that boosting consumption of energy will have a multiplicative result on the economy, increasing growth, employment and living standard by boosting industrial output and service provision. West African sub region lacks basic infrastructure that tends to promote energy utilisation in spite of vast energy resources. This has contributed to low level of investment, economic growth, employment and living standard in the sub region.

Empirically, Eseyin and Ogunjobi (2021) investigated the impact of sustainable electricity supply on poverty reduction in Nigeria. A time series data from 1981 to 2018 was analysed for this study. The result of the study showed that apart from the fact that poverty level in the past period is found to have a direct and statistically significant effect on the poverty rate in the current period, it was also revealed that lower unemployment rate does not really translate into reduction in the poverty level in Nigeria. Based on the outcome of this study, it could be seen clearly that while electricity generation play a significantly role reducing poverty in the country, electricity consumption does not guarantee poverty reduction. The study therefore recommended that electricity generation should be given more attention and while trying to address the menace of unemployment in the country, underemployment and labour exploitation must also be tackled headlong.

In a similar study, Akintunde, Adagunodo, Akanbi and Ogunleye (2020) investigated the interactive effect of poverty and energy consumption on life expectancy in Nigeria from 1980 to 2017. Secondary data were used for the study. Autoregressive Distributive Lag (ARDL) approach was used to anaylse 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 longrun. 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. This result affirmed that fossil fuel consumptions dominate energy consumption mix in Nigeria which showed that majority of Nigerian populace do not have access to renewable energy. This fact is buttressed by the coefficient of interactive effect of poverty and petroleum products consumption on life expectancy which is negative and significant in both short run and long-run. Therefore, in order to increase the life expectancy in Nigeria, government should reduce poverty and also ensure that people make use of clean energy that is healthy as a source of energy.

Arouna and Richard (2020) investigated the effect of household's access to electricity on poverty in Côte d'Ivoire and how it has varied over the last two decades. The study showed a positive and significant effect of access to electricity on household consumption per capita. Access to electricity increases household consumption per capita by 5.2 to 23.3 percent. The results also highlighted that the lower the regional rate of access to electricity, the higher the regional poverty rate. Based on the findings, the study recommended that policy should be designed to expand the access to electricity. Promoting renewable energy, improving the institutional framework, spreading the access to Solar Home System in off-grid areas and implementing incentive measures such as the reduction of customs and tax taxes on renewable energy equipment are measures that might help to combat energy and monetary poverty.

Oshota (2019) examined the role of information and communication technology (ICT), access to electricity and transport infrastructure in reducing poverty and promoting inclusive growth in Nigeria for the period 1980-2014 using the error correction modeling approach (ECM). The results indicated that access to electricity and transport infrastructure is negative and statistically significant in both the incidence and the depth of poverty reduction and therefore concluded that this led to inclusive growth. In particular, the study showed that access to ICT negatively influences the incidence of poverty, but the relationship is not robust when the measure of poverty is the poverty gap.

Shaobin and Haixia (2019) examined the relation between residential energy consumption and life expectancy at birth in mainland China. The result found Close association were found between household coal/ household electricity and life expectancy at birth at the provincial level in mainland China in 1990, 2000 and 2010. Household coal showed significant negative relations to life expectancy at birth while household electricity showed positive relations to life expectancy at birth. It was reported that household coal showed a negative relation to life expectancy in Chinese rural area than in urban areas. Furthermore, geographically weighted regression showed spatial non-stationary of the relations between residential energy consumption and life expectancy at birth in mainland China especially for the household coal and household electricity.

Okwanya and Abah (2018) investigated the impact of energy consumption on poverty reduction in a panel of 12 African countries over a period of 1981-2014. Using the Fully Modified Ordinary Least Square (FMOLS) method, the study showed that a long-run negative relationship exists between energy consumption and poverty level, which underscores the importance of energy in poverty reduction in the selected African countries. The result also indicated that other variables such as capital stock and political stability have significant effect on poverty implying that these factors play critical role in reducing poverty. Furthermore, the granger causality test showed that a short-run unidirectional causality runs from energy consumption to poverty. The findings clearly suggest that increasing energy consumption leads to a decline in poverty level. The study therefore recommended that the government in the selected countries should improve infrastructure and maintain political stability in order to maximize the effect of energy consumption on poverty reduction.

Girma, Girma and Dereje (2015) examined the impact of rural electrification on poverty reduction in Northern Ethiopia. The study was premised upon and objective to determine the impact of rural electrification programme on household’s income, health and education and on farming activities. Primary data were used while legit regression was also used to estimate the impact of electrification on poverty. The result shows that the impact of electricity on reduction of poverty is positive and significant while the impact of electricity access on household income is found to be positive but insignificant.

Muawya and Walter (2012) examined the link between availability of energy and improvement of living condition and poverty reduction in sub-Saharan Africa. The study argued that modern sources of energy are required for the improvement of living standards; may be by helping to create jobs and by boosting productivity. For energy exporters, particularly oil producers, they provide revenues that may bring about sustainable poverty reduction. And the supply of energy improves living conditions by providing better lighting of homes, cleaner fuels for cooking and heating. The study found that, essential aspects of human welfare (leading long and productive life, enjoy good health, have access to knowledge and education opportunities, have the potential to earn sufficient income to supply themselves with ample nutrition, shelter and other material and aesthetic needs) may improve only if modern energy becomes available for all; yet there are nearly 2 billion people still without electricity in developing countries. The study also found that, energy can have major favorable effects in remote rural areas and renewable energy technologies offer a key prospect in areas where the grid cannot reach. Reliance of the poor on their natural surroundings indicates that any step towards poverty alleviation should incorporate environmental and economic sustainability as a priority for sustainable livelihoods. This study is a contribution in a process towards the use of energy to be one of the instruments to reduce poverty in developing countries especially in Africa.

Thiam (2011) studied how renewable energy enhances the improvement of the standard of living in a Sahelian developing country of Senegal by employing a life-cycle-cost approach while incorporating an investigation of the environmental externalities. The study found that in distance rural communities where access to electricity is not available, photovoltaic (PV) renewable technologies provide veritable remedy for providing energy services although wind technology also complement. Based on his finding the paper recommended that: policies that will enhance the adoption of clean technologies in developing nations like Senegal could be considered as being the main components on the agenda of poverty reduction.

Diallo and Moussa (2020) examined the impact of household's access to electricity on poverty in CÃ´te d'Ivoire and how it has changed over the past twenty years. Their findings indicate a positive and significant effect of access to electricity on household consumption per capita. Access to electricity increases household consumption per capita by 5.2 to 23.3 percent. Furthermore, the study provided evidence that the lower the regional rate of access to electricity, the higher the regional poverty rate. The paper therefore recommended that policy should be designed to expand the access to electricity. Promoting renewable energy, improving the institutional framework, spreading the access to Solar Home System in off-grid areas and implementing incentive measures such as the reduction of import taxes on renewable energy equipment are measures that might help to combat energy deficiency and reduce poverty.

Study by Ayodele (2015) investigated the effects of urban environmental greening on climate change challenges in Nigeria situation and examined the problems that climate change caused to the realisation of sustainable city development in Nigeria. The posited the need to increase the campaign for urban environmental greening by the government, professionals and other stakeholders in order to cope with challenges of climate change in Nigeria.

In a study by Onuoha (2009) which focuses on the dangers that climate change poses worldwide, especially to poor nations that rely heavily on agriculture, which is very sensitive to changes in the weather. In order to green the drought-prone and desert-infested regions of Northern Nigeria, the research utilised the Green Wall Sahara Nigeria Programme, a sustainable development approach. As attested by the research, all parties involved in Nigeria's economic progress and sustainable development must work together to find innovative solutions to the problems caused by climate change.

Employing time-series methods, Lim and Yo (2009) looked into the potential short- and long-term causal links between Korea's economic upturn and the nation's application of natural gas. It makes application of quarterly data spanning 1991–2008. This paper presents unit root, co-integration, and Granger-causality tests that are owing to multivariate vector error-correction models. The upshots demonstrated a two-way causal link between Korea's economic upturn and its application of natural gas. This indicates that both economic upturn and a rise in natural gas usage have a direct consequence on each other. Zhai, Lin, and Byambdorj (2009) evaluated how China's agricultural output and commerce may be affected by climate change in the long run. The study found that climate change could have a moderate consequence on the global economy due to a declining share of agriculture in GDP. It reached this conclusion by utilising a global CGE model that accounts for the entire economy likewise simulation scenarios that predict how climate change will affect global agricultural productivity up until 2080. Seo, Mendelsohn et al (2009) utilised the Ricardian approach to study the outcome of climate change on agricultural output in Sri Lanka. Rice, coconut, rubber, and tea are the four most substantial crops in the nation, and the model analyses their net income per hectare. owing to the wider variety in precipitation throughout the nation, the research primarily examined the influence of precipitation on crop output. However, the study could only conduct a basic test of temperature effects owing to the narrow range of temperature variation. The research concludes that all crops studied would profit from an upturn in precipitation, with benefits ranging from 11% to 122% of the crops' present net income. Conversely, it was anticipated that the economy would suffer severely as an upshot of rising temperatures, with agricultural production expected to decrease by anywhere from 18% to 50%.

Barrios, Ouattara, and Strobl (2004) evaluated how developing nations in Sub-Saharan Africa (SSA) and non-SSA (NSSA) are adjusting to climate change in terms of overall agricultural output. Within the context of agricultural output, the research made application of a novel cross-national panel meteorological dataset. The research found that agricultural productivity in NSSA nations seems to be unaffected by climate change, in contrast to SSA nations where it has had a substantial consequence on agricultural output (as assessed by changes in nationwide rainfall and temperature). Furthermore, the estimates-based simulations reveal that the unfavourable climatic changes since the 1960s may explain a substantial chunk of the disparity in agricultural output between SSA and the other emerging nations.

Boxal, Chan, and McMillan (2004) utilised two variables—the hazard effect and the amenity effect—to examine how crude oil and natural gas infrastructures affected the value of residential properties in rural areas. Within four kilometres of residential homes, they found that flaring platforms and natural gas wells reduced the property's value. The survey also found that the sourer gas wells there were, the lower the property values were. These upshots demonstrate the dangers to human health that come together with hydrogen sulfide's detrimental consequence on property values. Natural gas contains hydrogen sulphide. The health risks associated with hydrogen sulphide have led the World Health Organisation (WHO) to ban its inhalation. Exposure to hydrogen sulphide has short-, medium-, and long-term unfavourable health consequences, as attested by the World Health Organisation

(2003). People may become infertile, poisoned, or even die from prolonged exposure to hydrogen sulphide. Long-term exposure to hydrogen sulphide may cause a variety of health problems, comprising but not limited to: eye illness, respiratory stress, neurological disorders, cardiovascular disease, metabolic syndrome, and a lack of appetite (WHO, 2019).

III. METHODOLOGY

The theoretical framework of this study is the Energy-Led Growth Hypothesis, chosen for its relevance and applicability to this research. The Energy-Led Growth Hypothesis suggests that the availability and application of energy are crucial factors in stimulating economic progress and development especially poverty reduction and improve living standard. Owing to this idea, increase in energy accessibility and utilisation results in elevated levels of economic activity, employment and improve living standard (poverty reduction). The model for this study will be derived from the empirical research conducted by Okwanya and Abah (2018). This model will be adjusted as attested by the purpose of this research with minor alterations. The revised model is shown in its functional, pooling, fixed effect, and random effect versions as follows:

PI= f (VEG, ELC, AEC, CES) (i)

Pooled Regression Model Specifications

$PI_{it} = \delta_0 + \delta_1 VEG_{it} + \delta_2 ELC_{it} + \delta_3 AEC_{it} + \delta_4 CES_{it} + U_{it}$ (ii)

Fixed Effect Model Specifications

$PI_{it} = \delta_0 + \delta_1 VEG_{it} + \delta_2 ELC_{it} + \delta_3 AEC_{it} + \delta_4 CES_{it} + \sum_i^9 = 1\alpha_i idum\varepsilon 1_{it}$ (iii)

Random Effect Model Specifications

$PI_{it} = \delta_0 + \delta_1 VEG_{it} + \delta_2 ELC_{it} + \delta_3 AEC_{it} + \delta_4 CES_{it} + \mu i + \varepsilon 1_{it}$ (iv)

Where: δ_0 = intercept; PI = Poverty Index; VEG = Volume of electricity generated; ELC = Electricity consumed; AEC = Access to Electricity; CES = Carbon emission; $\delta_1 - \delta_4$ = Parameter estimate; U_i / $\varepsilon 1_{it}$ = Stochastic or disturbance/error term.

iv. Results

The plotted line graphs in Figure 1 shows the trend in Poverty Index among the selected countries namely Benin, Ghana, Liberia, Nigeria, Senegal, and Sierra Leone. Figure 1 shows that the level of poverty is higher in Nigeria and Sierra Leone when compared with other countries; as it is also shown the Ghana and Benin recorded low level of poverty during this period.

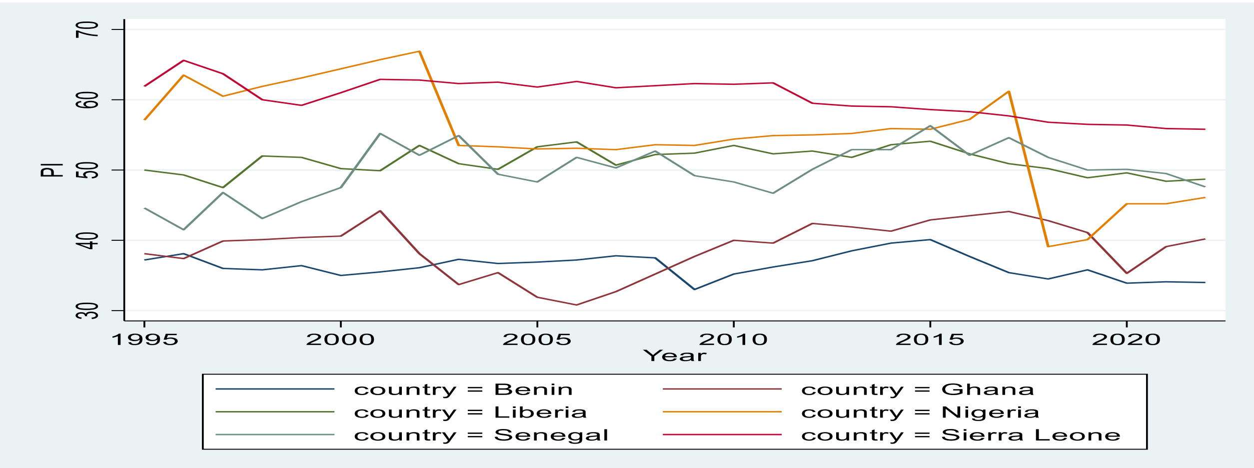

Figure 1: Line graph showing trend in Poverty Index (PI) among the Selected west African Countries

Source: Author's Plot, 2024.

The summary statistics were computed using the real values of the variables under study. The descriptive statistics assists in explaining the properties of the data both individually and collectively. Table 1 shows the summary of the dataset and the details of the observations (i.e., N =168, n = 6, and T = 28). This table presents source of all variables means, standard deviations (overall, between and within countries), and minimum and maximum values. The statistical description of the variables is crucial to observe the distribution and variability of the studied variables. This is done to circumvent the likely problems associated with time series and cross-section data. All the variables display considerable variation both between and within countries. For example, the between and within standard maximum statistic for access to electricity are 60.23 and 64.01 respectively. This suggests that the use of panel estimation techniques, which allows the identification of the various parameters of interest, is reasonable.

Table 1: Summary Statistics Result

Variable		Mean	Std.Dev.	Min	Max	Observations
PI	overall	48.64	9.33	30.80	66.90	N = 168
	between		9.29	36.38	60.38	n = 6
	within		3.85	32.69	60.49	T = 28
VEG	overall	33.75	41.06	0.03	100	N = 168
	between		44.76	0.82	97.35	n = 6
	within		2.48	22.11	44.31	T = 28
ELC	overall	130.24	102.57	18.97	409.45	N = 168
	between		105.57	40.92	316.78	n = 6
	within		34.30	24.08	222.90	T = 28
CES	overall	3841.01	4645.81	33.15	19902.56	N = 168
	between		4154.59	46.44	10352.44	n = 6
	within		2667.13	-3327.03	13391.13	T = 28
ACE	overall	35.75	22.17	1.11	88.49	N = 168
	between		20.99	9.26	60.23	n = 6
	within		11.06	7.97	64.01	T = 28

Source: **Author's Computation, 2024**

Estimation of the relationship between the variables would be difficult to achieve if there is an established colinear relationship between or among the variables. For example, if a single variable could be expressed in a linear relationship with the other variables. The pre-estimation data analysis was carried out on the data to validate their suitability or otherwise in being applied for the estimation of the relationships required. The results show that no perfect linear relationship exists among the variables in this panel. Table 2 shows the correlation coefficients between all key variables which help to design the model and to confirm to the choice of instruments. The result showed no threat of multicollinearity among variables as depicted in the correlation matrix. The highest correlation coefficient was 81.50% between volume of electricity consumed (ELC) and access to electricity (ACE). This was followed by the correlation coefficient between ELC and carbon emissions (CES) (i.e., 79.90%) and between CES and ACE (i.e., 72.60%).

Table 2: Pairwise Correlation Analysis Result

Variables	(1)	(2)	(3)	(4)	(5)
(1) PI	1.000				
(2) VEG	-0.419**	1.000			
	(0.000)				
(3) ELC	-0.414**	-0.046	1.000		
	(0.000)	(0.553)			
(4) CES	-0.479	0.196*	0.799**	1.000	
	(0.000)	(0.011)	(0.000)		
(5) ACE	-0.309**	0.147	0.815**	0.726**	1.000
	(0.000)	(0.057)	(0.000)	(0.000)	

Source: Author's Computation, 2024

Note: * and ** signifies statistical significance of correlation coefficient at 5 and 10 percent respectively.

The cross-sectional dependence (CSD) test is another necessary preliminary test. In panel data analysis, the usual assumption is that disturbances in panel models are cross-sectionally independent, especially when a large cross-section (*N*) is involved.

Meanwhile, in reality, the cross-sectional dependence in panel analysis appears to be the rule of the game; thus, it cannot be underestimated (Adams & Klobodu, 2017; Beckmann & Czudaj, 2017; Pesaran, 2004, 2015). Therefore, assuming cross-section independence may pose serious problems that may result in estimator inefficiency and invalid test estimates. The result of the Pesaran (2015, 2021) cross-sectional dependence (CD) test in Table 3 showed the existence of cross-sectional dependence as the test strongly rejected the null hypothesis of cross-sectional independence at a 1% significance level in majority of the selected variables with failure to reject the null hypothesis of cross-sectional independence in the case of the volume of electricity generated (VEG). This finding highlighted the importance of accounting for cross-unit lagged interdependence across countries of the study.

Table 3. Pesaran (2015, 2021) Panel Cross-Sectional Dependence (CSD) Test Results

Variable	CD Test Statistic	P-value	Decision
PI	2.58*	0.010	Strong CSD
VEG	0.51	0.613	Weak CSD
ELC	7.43**	0.000	Strong CSD
CES	9.02**	0.000	Strong CSD
ACE	18.41**	0.000	Strong CSD

Note: (**) and (*) indicates significant at 1% and 5% respectively.

Source: Authors' computation, 2024.

Since Pesaran's CSD test revealed strong cross-sectional dependence across units for majority (i.e., four), indicating that the panel was heterogeneous; and weak cross-sectional dependence across units for only one variable; the study, therefore, examined further the stationarity of the variables with panel unit root tests, assuming heterogeneous slopes for the four variables. While the Im, Pesaran & Shin test (IPS) and Levin–Lin–Chu (LLC) heterogeneous panel unit roots tests were employed for the four variables that exhibited strong CSD across all units, the Pesaran CIPS and ADF-Fisher were employed for the two variables (namely unemployment rate and volume of electricity generated) that shows weak cross-sectional dependence across units. The results in Table 4 showed that while volume of electricity generate was stationary at level under the first-generation panel unit roots tests results panel. The result in Table 4 also shows that the second-generation heterogenous panel unit root test shows that that while volume of electricity generated was stationary at levels, the other ones only became stationary after first difference under Pesaran CIPS and ADF-Fisher tests results.

Table 4. Panel data unit root tests results

Unit Root Tests	**Panel A: First generation panel unit root tests results**				
	PI	VEG	ELC	CES	ACE
Im-Pesaran-Shin (IPS)					
Level	-	-2.45** (0.00)	-	-	-
First Difference	-	-	-	-	-
Status	-	I (0)	-	-	-
Levin-Lin-Chu (LLC)					
Level	-	-7.30** (0.00)	-	-	-
First Difference	-	-	-	-	-
Status	-	I (0)	-	-	-
Unit Root Tests	**Panel B: Second generation panel unit root tests results**				
	PI	VEG	ELC	CES	ACE

Pesaran CIPS					
Level	2.17	-	1.55	2.72**	3.18**
	(2.33)		(2.33)	(2.57)	(2.57)
First Difference	5.64**	-	5.19**	-	-
	(2.57)		(2.57)		
Status	I (1)	-	I (1)	I (0)	I (0)
Fisher-type					
Level	6.89**	-	2.63**	0.50	0.22
	(0.00)		(0.00)	(0.31)	(0.41)
First Difference	-	-	-	20.75**	22.89**
				(0.00)	(0.00)
Status	I (0)	-	I (0)	I (1)	I (1)

Note 1: (**) and (*) indicates significant at 1% and 5% level respectively. Note 2: While p-values are in bracket (...) under the IPS, LLC and the Fisher-type unit root tests statistics, the critical values are in bracket (...) under the Pesaran CIPS unit root test statistics.
Source: Author's Computation, 2024.

Two panel data cointegration tests were conducted to determine the presence of absence of a long run relationship between the variables in each of the models of interest in this study. They are the Kao and Pedroni cointegration tests. While the results of the Kao cointegration test is presented in panel A of Table 5 below, the results of the Pedroni cointegration test is presented in panel B.

Table 5. Panel data cointegration Test Results

Panel A: Kao Pedroni cointegration test results						
Dep. Var	Modified Dickey-Fuller t	Dickey-Fuller t	Augmented Dickey Fuller t	Unadjusted Modified Dickey-Fuller t	Unadjusted Dickey-Fuller t	Comments
PI	-05693 (0.2846)	-1.2101 (0.1131)	-0.5444 (0.2931)	-5.1130** (0.000)	-3.4530** (0.0003)	No cointegration
Panel B: Pedroni cointegration test results						
Dep. Var	Modified Phillips-Perron t		Phillips-Perron t	Augmented Dickey Fuller t		Comments
PI	0.5739 (0.2830)		-2.8554** (0.0021)	-3.3534** (0.0004)		No cointegration

Note: (**) and (*) indicates significant at 1% and 5% level respectively.
Source: Author's Computation, 2024

The panel cointegration test result is presented in tables 5 shows that we cannot fail to reject the null hypothesis of no cointegration between the variables in each of models and under the both tests conducted. The results show that at no point did all the statistics under each test for respective model prove to be statistically significant. Though some of the statistics proved significant under both test and in each of the models (e.g., Unadjusted Modified Dickey-Fuller t statistic under the Kao test for the poverty index model and the Modified Phillips-Perron t under the Pedroni test for the unemployment rate model), it was not sufficient to decide that a cointegrating relationship exist between the variables in each the models. Hence, the econometric technique adopted for estimating the models ignores the estimation of an error correction term.

Table 6 shows the results of the Arellano-Bond one-step GMM dynamic panel estimation of poverty (using poverty index as the dependent variable). First, the result shows that the coefficient of one-period lag of the natural log of poverty index (PI) appeared with a negative sign (i.e., -0.0522). This implies that one-period lag of poverty index had a negative impact on the level PI. The standard error (i.e., 1.3318), z-score (i.e., -0.04), and the p-value (i.e., 0.969) shows that the coefficient of one-period lag of PI is not statistically significant at any level of significant error. Second, the estimator of electricity generated appeared with a positive sign (i.e., 0.1480). This implies a positive relationship between volume of electricity generated and poverty. The standard error (i.e., 0.2182), z-score (i.e., 0.68), and the p-value (i.e., 0.498) shows that the coefficient of volume of electricity generated is not statistically significant at any level of significant error. Third, the estimator of electricity consumed appeared with a negative (i.e., 0.0084). This implies the volume of electricity consumed impacted negatively on poverty among the selected African countries during the period under review. Also, standard error (i.e., 0.0200), z-score (i.e., 0.42), and the p-value (i.e., 0.672) shows that the coefficient of volume of electricity generated is not statistically significant at any level of significant error. Fourth, the estimator of carbon emission appeared with a negative (i.e., -0.0002). This implies the level of carbon emitted impacted negatively on poverty among the selected African countries during the period under review. But the standard error (i.e., 0.0102), z-score (i.e., -0.01), and p-value (i.e., 0.988) shows that the coefficient of level of carbon emitted is not statistically significant at any level of significant error. Lastly, the estimator of access to electricity appeared with a negative (i.e., -0.1267). This implies that the percentage of population with access to electricity impacted negatively on poverty among the selected African countries during the period under review. But, the standard error (i.e., 1.6895), z-score (i.e., -0.08), and p-value (i.e., 0.940) shows that the coefficient of level of carbon emitted is not statistically significant at any level of significant error.

Table 6: Arellano-Bond one-step GMM Dynamic Panel Data (DPD) Poverty Model (Dependent Variable = Poverty Index)

Explanatory Variables	**Coeff.**	**St. Error**	**Z**	**P>|z|**
PI L1	-0.0522	1.3318	-0.04	0.969
VEG	0.1480	0.2182	0.68	0.498
ELC	0.0084	0.0200	0.42	0.672
CES	-0.0002	0.0102	-0.01	0.988
ACE	-0.1267	1.6895	-0.08	0.940

Note 1: (***), (**) and (*) indicates significant at 1%, 5% and 10% level respectively. Note 2: The internal instruments employed are VEG, ELC

Source: Author's Computation, 2024.

The two post-estimation tests conducted on each of the model are Arellano-Bond (AR) tests and Sargan-Hansen test for joint validity of the instruments. The aim of the Arellano-Bond (AR) tests is to check whether the idiosyncratic error term is serially correlated. While the AR (1) test is conducted for the first-differenced errors, AR (2) test is conducted for a higher order (i.e., second-order) serial correlation in first differences. Since a crucial assumption for the validity of dynamic panel model is that the instruments are exogenous, the Sargan-Hansen test for joint validity of the instruments is standard after estimating the Arellano-Bond dynamic model. The null hypothesis is that the instrument(s) as a group are exogenous; if the null hypothesis is rejected, the instrumental variable(s) is/are correlated to some set of residuals, and therefore they are not valid.

The results of the post-estimation test conducted on the poverty model are presented in Table 7. First, the result of the autocorrelation test (Arellano & Bond, 1991) shows that study reject the null hypothesis of no first-order (i.e., p-value = 0.9433>0.05) and second-order autocorrelation (i.e., p-value = 0.4709>0.05) in the error term, it rejects the null hypothesis of no first order and second-order serial correlation in one-stage GMM dynamic of the main model at the 5% level. Moreover, as also shown in table 4.9, the p-value result of the Sargan-Hansen test implies not rejecting the null hypothesis of joint validity in the dynamic panel model in at least one of the steps weighting matrix (i.e., under the 1-step weighting matrix as p-value = 0.6764 > 0.05). Hence, the instrument variable is valid and can be used to estimate the unemployment rate model using the Arellano-Bond two-step GMM dynamic estimation approach.

Table 7: Results of post-estimation test on Poverty Model

Arellano-Bond test for autocorrelation of the first-differenced residuals		Sargan- Hansen test of overriding restrictions	
Order 1 z [Pr > z]	Order 2 z [Pr > z]	1-step moment function, 1-step weighting matrix chi2 [Pr > chi2]	1-step moment function, 2-step weighting matrix chi2 [Pr > chi2]
-0.0711 [0.9433]	-0.7211 [0.4709]	0.1742 [0.6764]	6.0000 [0.0143]

Note 1: (***), (**) and (*) indicates significant at 1%, 5% and 10% level respectively.

Source: Author's Computation, 2024.

V. DISCUSSION OF FINDINGS

Salient findings have emerged from the data analysis to examine the effect of energy access and climate change on poverty level in West African sub region. Therefore, analysing the results following the literature review is a valuable endeavour. First, the study investigated the effect of energy access on poverty level. Moreover, out of the three variables that were selected for measuring energy access, none of the energy access variables impacted significantly on poverty index. Secondly, though access to electricity impacted negatively, the study found that none of the energy access variables had any significant impact on poverty among the selected west African countries. The findings of the study did not conform to that of Okwanya and Abah (2018) who found that increasing energy consumption leads to a decline in poverty level. Also, the findings of this on the relationship between energy access and poverty did not conform to the finding from the study of Thiam (2011) and Diallo and Moussa (2020) who showed how energy facilitates the improvement of the standard of living and household consumption per capita in Senegal and Côte d'Ivoire respectively.

Lastly, the study investigated the effect of climate change on poverty level among countries in west African sub region. Though the climate change variable (i.e., carbon emission) had a negative and impact on poverty level, an insignificant effect was revealed by this study. The findings of this study did not conform to the findings of the study by Kahn et al. (2021) and Babatunde and Ayodele (2015) who found that climate change to have a significant negative effect on per-capita real output, economic growth and poverty level

VI. CONCLUDING REMARKS AND RECOMMENDATIONS

This study examined how access to energy and climate change affect poverty level in some selected West African countries. To achieve the objectives of this study, the researcher reviewed relevant theoretical and empirical literature on energy access, climate change, and economic performance with emphasis on the extent to which poverty level has responded to changes in the energy access and climate change in the west African sub region. The study selected six (6) countries in west Africa namely: Benin, Ghana, Liberia, Nigeria, Senegal, and Sierra Leone based on energy consumption and population size. The period covered by the study is 1995-2022. Both statistical and econometric techniques were adopted for the analysis of the data.

Based on the analysis of the data using the Arellano-Bond two-step GMM Dynamic Panel econometric technique, some key empirical findings were made are: Volume of electricity generated had positive and insignificant impact on poverty index. This shows that volume of electricity generated as measure of energy access was not a significant predictor of poverty reduction among the selected west African countries during the period reviewed. Electricity consumed had a positive but insignificant impact on poverty index. This implies that electricity consumed was not a significant predictor of poverty rate among selected west African countries during the period reviewed. Access to electricity had a negative but insignificant impact on and poverty index. This implies that access to electricity was not a significant predictor of poverty reduction among selected countries in west African sub region during the period reviewed. Also, carbon emission as a proxy for climate change impacted negatively but insignificantly on poverty level. This implies that climate change was not a significant predictor of poverty eradication among selected west African countries during the period reviewed.

Based on these findings the study recommended effective policies that will address electricity pricing, electricity subsidy and electricity metering in the selected west African countries as possible measures of eradicating poverty in the sub region.

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