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ENERGY CONSUMPTION IN WEST AFRICA: THE ROLE OF TECHNOLOGICAL INNOVATION, TRADE OPENNESS AND ECONOMIC GROWTH

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ABSTRACT
The study examines the effect of technological innovation, trade openness, economic growth, on energy consumption. The main objective is to investigate the short-run and long-run impact of the independent variables on energy consumption for West African economies. The study aims to determine the causal relationship between the variables and identify the heterogeneity of energy consumption among the observed variables. The study employed a second-generation heterogeneous method of analysis using the long run panel cointegration estimators from 1984 to 2020 while utilizing the Dumitrescu-Hurlin panel causality. The results indicated the existence of long-term relationships between all study variables. The empirical evidence indicates that technological innovation and economic growth positively affect energy consumption, while trade openness remains inversely linked with energy consumption. The model two's empirical outcome reveals the interplay between technological innovation, economic growth, and trade openness yields a positive conclusion that holds throughout the short-term and long-term periods. Thus, empirical results lend credence to the scale effect's validity as a causal factor between innovation and trade openness.
Keywords: Economic growth, Trade Openness, Technological Innovation and Energy Consumption.

1. INTRODUCTION

Energy has become an indispensable catalyst for driving civilization, the global challenge of energy consumption has consistently been on an increasing trend. This, nevertheless, reflects on the significance of energy as a mechanism for growth. The global energy demand is estimated to increase by about 1.3 percent across the globe in the year 2022 and continues to surge with more than average to the year 2030. The increase reflects on the intransigent international dynamics across the globe. Accordingly, energy consumption was slightly below 600 trillion of British thermal units (Btu) in the last decade and by the year 2030, energy consumption will be 663 trillion Btu as well as 736 Btu by 2040 (IEA, 2023).

The African continent has been starved in millennia for energy, specifically on electricity. The region power sector is extensively lagging beyond power access and installed capacity or, in fact, overall consumption (Moustapha & Yu, 2021). Notably, in spite, the region's abundant energy resource potential, the existing installed capacity is about 31,678 MW, and so far, only 60 percent is fully operational (AEO, 2022). These have led most of the countries in a load shading process to overcome the pressing demand (Akintande et al., 2020). On this regard, there is a persistent increase in demand reinforced with a growing population and urbanization projected to be about 60,000 MW, which exceeds the current generation facility. This variation has led to about 53 percent on commercial and technical losses (Atta et al., 2022; Karaki, 2017) Figure 1.1, bellow, Shows the average consumption rate of energy within the West African region. The trend becomes negative over time, signaling a decline in supply. The negative growth rates of energy supply imply a reduction on energy consumption owing to shortages on the availability of primary energy source, despite an increase in population and industrial activity in most countries. The need to simulate a scenario in which the analyzed economies' energy intensity demand over time can be not be over emphasized.

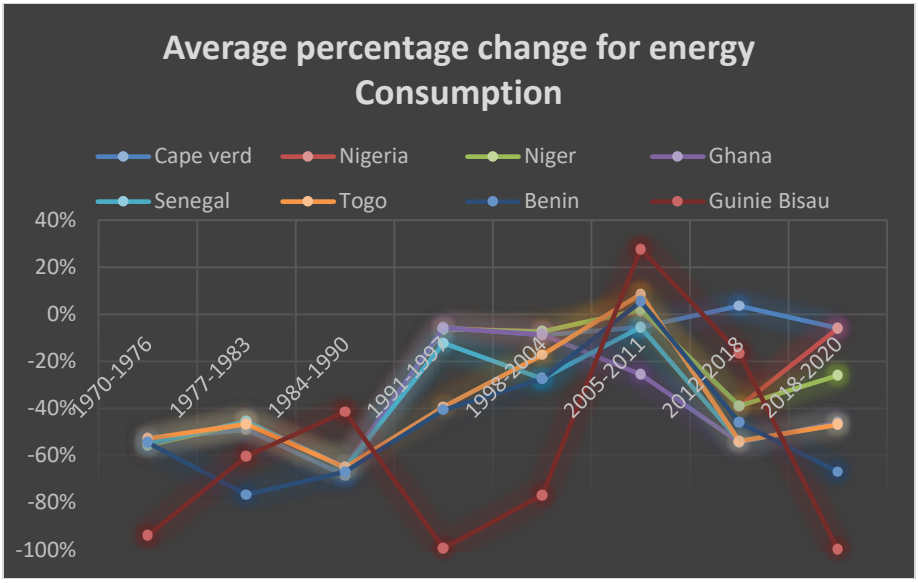

Figure 1.1: Average Percentage Change for Energy Consumption (1970-2020)
(World Bank, 2020)

On the above figure, the average consumption rate becomes negative over time, signaling a decline in supply. Negative growth rates of energy supply imply a reduction in energy consumption against the above background, we assume a separate approach to examine empirically the role of technological innovation, trade openness and economic growththat could possibly explain energy demand model. Accordingly, the paper is decentralized in to five segments. Starting with introduction, followed by literature review, accompanied with materials and method, tailed with result and discussion and finally summary and conclusion.

2. LITERATURE REVIEW

2.1 Technological Innovation and Energy Consumption

Meanwhile, some literatures have tried to analyze the synergy between technological innovation, energy environment nexus trying to understand both causal and long run relationship between the two variables using different estimation procedures. Findings however, unanimously support technology to be influencing energy efficiency. Furthermore, Li, Zhang, Ali, and Khan (2020) analyses eco innovation productivity using renewable energy consumption, energy intensity, income and human capital as major determinants of renewable energy consumption for the organization of economic co-operation and development countries (EOCD) between 1990 to 2017. The analysis utilizes the augmented mean group (AMG) and the augmented auto regressive distributive lag model (ARDL). Findings however, were complacent to energy productivity through human capital in the long run. While, Godil, et al. (2020) assert that technological innovation have gotten to a peak stage of suppressing energy consumption

2.2 Trade Openness and Energy Consumption

Nasreen, and Anwar (2014) examine the underlying association between trade openness economic growths on energy consumption across 15 Asian countries. The studies employed a panel cointegration test and establish the presence of a long run relationship among the variables. More specifically, there is a positive causal connection between economic growths to trade openness. Furthermore, a bidirectional causal relationship was observed from economic growth to energy consumption, energy consumption to trade openness. This convention conforms with (Narayan & Smyth, 2009). In-addition, Shahbaz, et al (2014)employed panel cointegration to analyze the causal linkage between trade openness and economic growth using homogeneous and heterogeneous causality across high income, middle income, and low-income countries and found long run cointegration between trade openness and energy consumption.

2.3 Economic Growth and Energy Consumption

Although, several studies hypothesize four plausible conjectures with regards to energy as a fundamental element for sustainable economic growth. It has become imperative to highlight the nexus between energy consumption and economic growth. Firstly, when a unidirectional relationship is said to exist between energy consumption and economic growth, then the economy is deemed to be energy dependent. Hence, the energy protection strategy might unfavorably affect economic growth. In other words, this is known to be the growth hypothesis. Secondly, when an inverse relationship is found reflecting on a causality running from economic growth to energy consumption indicating conservative or environmental

policy hypothesis, The third is a bidirectional relationship that confirms what is known as the feedback hypothesis, causing a two-way relationship, and lastly, the neutrality hypothesis, which indicates no evidence of a relationship between the two variables (Dagher & Yacoubian, 2012).

3. MODEL, DATA AND METHODOLOGY

We apply the cost minimization approach to the energy demand function by using the Cobb-Douglas production function, which relates output to production parameters as adopted by (Hasanov & Mikayilov, 2020). The study implores the annualized pooled series data for the observed countries with the principal objective of examining the effect between technological innovation, trade openness, economic growth, on energy consumption in West African states between 1984 – 2022.

$$Q = AK^{\emptyset}L^{Y}E^{\partial}W^{\alpha}$$

Given the Cobb Douglass production function, it is reasonable to assume that a cost function exists as a dual function of the production function, and output largely depends on relative contribution of substitution effect. Consequently, the economy reflects on contestant return to scale and thus, demand and supply for goods and services determine price and income level

$$\beta_0^{'} = \frac{\left[-lnX+\alpha ln\left(\frac{p}{\phi}\right)\boldsymbol{\beta ln}\left(\frac{y}{\delta}\right)\boldsymbol{\alpha ln}\left(\frac{y}{\gamma}\right)\right]}{\emptyset+\beta+\alpha+\gamma}$$

$$\rho_0 = \frac{\emptyset}{[a+\propto+\delta+\theta]} = \gamma_0 \frac{\delta}{[a+\propto+\delta+\theta]} = \beta_0^{'} = \frac{\alpha}{[a+\propto+\delta+\theta]} = \lambda_0^{'} = \frac{\emptyset-\alpha-\delta}{[a+\propto+\delta+\theta]} = k_n^{'} = \frac{1}{[a+\propto+\delta+\theta]}$$

Where: $\emptyset, \alpha, \delta \; reprset \; positive \; values$. Hence, we formalized the model in to econometric form:

$$B_0 + BI_{xi} + B2_{X2} + B3_{x3} + B4_{X4} + Bn_{xn} + \mu$$

By taking the natural logarithm of the equation and incorporating the variables, we deduce it to

$$\mathrm{LnEC_{it}} = \alpha + \beta_1 \mathrm{LnTEC_{it}} + \beta_2 \mathrm{LnTOP_{it}} + \beta_3 \mathrm{LnGDP_{it}} + +\varepsilon_{it}$$

Thus,

EC= energy consumption proxy in oil equivalent per capita
LnTEC= technological innovation
LnTOP= trade openness
LnGDP=economic growth

Table 3.0 Variable Proxy and description

S/N	Variable	Measurement/ proxy	Data source	Countries
1.	Energy Consumption	kilograms tons of oil equivalent	World Development indicators (WDI)	W/Africa
2	Technological Innovation	total expenditure on research and development	World Development indicators (WDI)	W/Africa
3	Trade Openness	Trade openness computed using the values of exports and imports divided by GDP at constant prices	World Development indicators (WDI)	W/Africa
4	Economic Growth	GDP at constant prices	World Development Indicators (WDI)	W/Africa

3.1 **Table 3, 2 Cross-sectional Dependency Test Result**

Variable	CD Test	P value	Correlation	Abs Correlation
Lnec	3.14	0.002	0.085	0.389

Lntec	3.67	0.000	0.099	0.410
Lntop	-3.69	0.000	-0.100	0.489
Lngdp	-0.74	0.458	-0.020	0.339

Notes: Under the null hypothesis of cross-section independence, CD ~ N (0, 1)

Table 3.2 above demonstrate the mean and variance of the pair wise correlation between the cross section of a panel data, by the chudik pesaran coefficients ranging from -0.74 to 3.14 with corresponding p values. Although, some variables appear to be statistically in significant, hence, the table demonstrates the diversity of the panel, reflecting on the model coefficients becoming heterogeneous with a slope that varies autonomously. Additionally, it demonstrates that the series are independent of each other with no direct influence on a country's socioeconomic structural linkages.

3.2Testing Slope Homogeneity

We utilized the Pesaran and Yamagata heterogeneity test (2008) to capture slope homogeneity between the cross-sections of the series. This test is also an advanced specification to the normal traditional homogeneity measurements, The P&Y slope homogeneity test was therefore used in this analysis (Erdoğan et al., 2019; Le et al., 2020). This test expresses the empirical model as:

$$\bar{\delta} = \sum_{i=1}^{\tau} \left(\breve{\alpha}_i - \bar{\alpha}_{WFT}\right)' \frac{E_i' J_t B_i}{\breve{\delta}^2{}_i} \left(\breve{\alpha}_i - \bar{\alpha}_{WFT}\right) \quad (4)$$

In addition, Δ and the $\bar{\nabla}_{adj}$ are specified as:

$$\bar{\nabla} = \sqrt{n}\left(\frac{n^{-1}\bar{\delta} - m}{\sqrt{2m}}\right) \quad (5)$$

$$\bar{\nabla}_{adj} = \sqrt{n}\left(\frac{n^{-1}\bar{\delta} - Y(\bar{\alpha}_{it})}{\sqrt{var(\bar{\alpha}_{it})}}\right) \quad (6)$$

Where $Y\left(\bar{\alpha}_{it}\right) = m$ and $var\left(\bar{\alpha}_{it}\right) = \frac{2m(n-m-1)}{n+1}$

3.3 Panel unit root test

In order to verify stationarity of variables, the study implores the second "generations' of panel root unit tests. Techniques of the first generation presume that the units in the panel data are unassociated sectionally while the second generation allows panel unit cross-relationship. Furthermore, in comparison to second-generation panel unit root checks, a null hypothesis of non-stationarity is assumed. Pesaran, Ullah and Yamagata (2007)

$$\Delta B_{i,t} = \pi_i + \omega_i B_{i,t-1} + \delta \bar{B}_{t-1} + \alpha_i \Delta \bar{B}_{i,t} + \varepsilon_{it} \quad (7)$$

Similarly, the CIPS statistic as:

$$\bar{B}_{t-1} = \frac{1}{n}\sum_{i=1}^{\tau} B_{i,t-1}\,;\ \Delta\bar{B}_{i,t} = \frac{1}{n}\sum_{i=1}^{\tau} B_{i,t-1}\,\Delta B_{i,n} \quad (8)$$

$$CIPS(n,N) = \frac{1}{\tau}\sum_{i=1}^{\tau}(n,N)\,n_i \quad (9)$$

(n,N) t_iIndicates the t statistic of ω_i

3.4 Panel Co-integration Test

This research used co-integration tests to determine the long-term relationship between the variable in both models. Due to its model applicability, the Westerlund co integration test is significant. In addition, the test deals with cross-sectional dependence. The Westerlund test uses four statistics of the experiments. The remaining two reflect statistics from the classes (Gt and Ga) (denoted by Pt and Pa). This test assesses the common factors responsible for CSD by taking the averages of every variable in the cross-sections. Due to its flexibility to various cross-section combinations and time periods, this test has increased capacity. In addition, the test enables the panel data to be structurally split. The co integration test panel presented in the following error correction equation was created by Westerlund (2007):

$$\Delta L_{i,t} = \partial_i^{'}\pi_t + \alpha_i\left(R_{i,t-1} - \gamma_i^{'}L_{i,t-1}\right) + \sum_{j=1}^{m}\delta_{ij}\Delta R_{i,t-j} + \sum_{j=0}^{m}\beta_{ij}\Delta L_{i,t-j} + \varepsilon_{i,t} \quad (10)$$

The Gτ and Gα statistics are used to check if co integration occurs in at least one cross-sectional unit, and they are computed as:

$$G_\tau = \frac{1}{\tau}\sum_{i=1}^{\tau}\frac{\breve{\alpha_\iota}}{Se(\breve{\alpha_\iota})} \quad (11)$$

$$G_\alpha = \frac{1}{\tau}\sum_{i=1}^{\tau}\frac{T\breve{\alpha_\iota}}{1-\sum_{j=1}^{m}\widehat{\alpha_{\iota j}}} \quad (12)$$

The statistics on P_τ and P_α are used to examine if the whole panel involves cointegration and the formulas are presented in Eqs. (13) and (14):

$$P_\tau = \frac{\breve{\alpha}}{Se(\breve{\alpha})} \quad (13)$$

$$\breve{\alpha} = \frac{P_\alpha}{T} \quad (14)$$

Gt and Ga define the statistics of the group. Pt and Pa are the statistics of the panel. The error correction parameter (α α) can be determined by setting the value of the equation (13)$P_\alpha = T\breve{\alpha}$(14). Consequently, the constraint for error correction is$\breve{\alpha} = \frac{P_\alpha}{T}$, which signifies the proportion of the error to be corrected annually, in case the short-term disproportion happens.

3.5 Cross Sectional Auto Regressive Distributive Lag (CSARDL)

Cross sectional auto regressive distribution lag (CSARDL) estimates are adopted for robustness and also to check mate the in consistencies of the first-generation methods of estimation bearing in mind the chances of occurrence of heterogeneity and cross-sectional dependency in the series. Thus, to restrain issues of spurious result, the study adopts the cross sectional auto regressive distributive lag estimates (CSARDL)

$$GDP = \propto 0 + \sum_{j=1}^{jp-1}\gamma itGDPit_j\, PC + \sum_{j=1}^{jp-1}\delta itXit_{-j} + \sum_{j=0}^{p}\sigma itZit_{-j} + \mu\tau \quad (15)$$

Where: Zt = $(\Delta ECit, Xit,)$reflecting a change in economic growth been the dependent variable and Xit representing a change in all the independent variable.

$$\Delta LNGDP_{it} = \alpha 1 + \sum_{j=1}^{p-1} \partial_{ij} \Delta LNEC_{it-j} + \sum_{1=0}^{q-1} \gamma_{ij} \Delta LNET_{ij-1} + \sum_{1=0}^{r-1} \alpha_{ij} \Delta LNC02_{ij-1} + \mu\tau (16)$$

3.6 Panel causality Test

The study took comfort to utilized the Dumitrescu and Hurlin panel co integration to observe the causal effect between the variable'stechnological innovation, trade openness and economic growth on the dependent variable energy consumption for both short and long run. Essential behind it isn't just for robustness but its fixed inherit coefficient to synchronize linear autoregressive system heterogeneous cross-sectionalprocedure. However, the same procedure is repeated across individual K^{th} regressors X_t onY_t.

$$\mathrm{LNEC_{i,t}} = \beta_i + \sum_{k=1}^{K} \partial_i^{(k)} \Delta \mathrm{LNTEC_{i,t-k}} + \sum_{k=1}^{K} \gamma_i^{(k)} \Delta \mathrm{LNTOP_{i,t-k}} + \sum_{k=1}^{K} \delta_i^{(k)} \Delta \mathrm{LNGDP_{i,t-k}} + \varepsilon_{i,t} \quad (19)$$

$$\Delta \mathrm{LNTEC_{i,t}} = \beta_i + \sum_{r=1}^{r} \partial_i^{(k)} \Delta \mathrm{LNEC_{i,t-k}} + \sum_{r=1}^{r} \gamma_i^{(r)} \Delta \mathrm{LNTOP_{i,t-r}} + \sum_{r=1}^{r} \delta_i^{(r)} \Delta \mathrm{LNGDP_{i,t-r}} + \varepsilon_{i,t} \quad (20)$$

$$\Delta \mathrm{LNTOP_{i,t}} = \beta_i + \sum_{r=1}^{r} \partial_i^{(r)} \Delta \mathrm{LTEC_{i,t-r}} + \sum_{r=1}^{r} \gamma_i^{(r)} \Delta \mathrm{LNEC_{i,t-r}} + \sum_{r=1}^{r} \delta_i^{(r)} \Delta \mathrm{LNGDP_{i,t-r}} + \varepsilon_{i,t} \quad (21)$$

$$\Delta \mathrm{LNGDP_{i,t}} = \beta_i + \sum_{r=1}^{r} \partial_i^{(r)} \Delta \mathrm{LNEC_{i,t-k}} + \sum_{r=1}^{r} \gamma_i^{(r)} \Delta \mathrm{LNTOP_{i,t-r}} + \sum_{r=1}^{r} \delta_i^{(r)} \Delta \mathrm{LNEC_{i,t-r}} + \varepsilon_{i,t} \quad (22)$$

Where: ϕI are fixed intercept term, for time. And $r$indicates the preceding year lag for all the individual series of the pulled data .Also, $\partial_i^{(r)}, \gamma_i^{(r)}, \delta_i^{(r)} and \theta_i^{(r)}$are the autoregressive values of the slope within individual Countries and: (H_0 :$\partial_i^{(r)}, \gamma_i^{(r)}, \delta_i^{(r)} and \theta_i^{(r)} = 0 \forall_{ij} = 1, .. N$). Is the null hypothesis

4. RESULTS AND DISCUSSION

We began our empirical discussion with the basic descriptive statistics and diagnostics checks to ensure the stability and reliability of the captured series. In such manner, we first adopt the Chudik Pesaran cross sectional dependency test followed by a slope homogeneity test which is later complimented by unit root test before embarking on estimation.

Table 4.1 Descriptive Statistics and Correlation Analysis Results

Variables	Mean	Standard deviation	Skewness	Kurtosis	Jarque-Bera
LEC_{it}	4.603	0.550	0.464	2.325	30.500* 0.000
$LNTEC_{it}$	0.230	0.121	0.851	3.945	87.813* 0.000
$LNTOP_{it}$	24.059	2.510	0.522	2.215	39.449* 0.000
$LNGDP_{it}$	6.355	0.694	0.490	2.933	22.379* 0.014

Notes: * and ** significant at 1 and 5percent levels.
Figures under denote *p*-values

The above Table 4.1a presents the descriptive statistics which gives a clear insight of the reliability of the observed data series. As above on Table 4.1a, highlights the sampled parameters starting with the dependent variable energy consumption ($LNEC_{it}$) and other independent variables such as technological innovation ($LNTEC_{it}$), trade openness ($LNTOP_{it}$), gross domestic product ($LNGDP_{it}$)

Variable	CD Test	P value	Correlation	Abs Correlation
LNEC	3.433*	0.001	0.085	0.59
LNTEC	-4.334*	0.000	0.099	0.78
LNTOP	36.345*	0.000	0.100	0.64
LNGDP	48.661*	0.000	0.020	0.339

Notes: Under the null hypothesis of cross-section independence, CD ~ N (0, 1)

According to Pesaran (2007) a test statistic based on the average of pair-wise Pearson's correlation coefficients from an autoregressive (AR) model's residual is proposed to converge to a typical normal distribution statistics data set when testing for cross-section independence. The probability values in parenthesis indicate that the null hypothesis of interdependence is strongly rejected at the 1 percent level of significance, indicating that cross-section dependence must be taken into account when computing panel data statistics in order to avoid misleading and spurious outcomes, the variables must be cross-sectionally independent and the panel data set must be statistically significant. However, The CD tests performed on these correlations suggest that variables are strongly independent of one another across the sampled studied countries, as seen in Table 4.1b

Table 4.2 Slope Homogeneity Result

Test Statistics	Value	p-value
$\overline{\nabla}$	16.582*	0.000
$\overline{\nabla}_{adj}$	17.910*	0.000

The table above demonstrates that there is no indication of homogeneity across observed series with varying slopes weighted by their accuracy. This suggests that the coefficients seen in the pooled data are diverse and statistically significant at both 1% and 5%. The slope homogeneity test was judged necessary to guarantee and validate the absence of evidence of homogeneity across the observed series. (Personal & Archive, 2014; Pesaran, Yamagata, Pesaran, Yamagata, & Fruhwirth-, 2010 Pesaran, Yamagata. 2008)

Table 4.3 Unit Root Test

Variables	At level **CIPS**	At first difference	Conclusion
$LNEC_{it}$	-2.634	-3.793*	I(1,0)
$LNTEC_{it}$	-0.283	-4.097 *	I(1)
$LNTOP_{it}$	-2.426	-5.094*	I(1)
$LNGDP_{it}$	-2.084	-5.219*	I(1)
	CADIF		
$LNEC_{it}$	-2.110 (0.579)	-2.977* (0.003)	I(1,0)
$LNTEC_{it}$	-0.863 (1.000)	-3.905* (0.000)	I(1)
$LNTOP_{it}$	-2.654 (0.083)	-3.658* (0.000)	I(1)
$LNGDP_{it}$	-1.163 (0.566)	-4.509* (0.000)	I(1)
CIPS Critical Values			
10%	-2.66		
5%	-2.76		
1%	-2.93		

Table 4.3: Owing to the stochastic nature of the large panel samples, we opt to use the second-generation unit root test to protect the results of the analysis from being

skewed or false. The CIFS and CADIF not only detect stationarity in the series, but they also detect all components of auto correlation, trend, and fluctuation in the observed structure as well. Most variables become stationary at first difference, although certain series demonstrate mixed stationarity, the likes of lngdp and lnec. Nevertheless, most variables become stationary at the first difference. However, it is worthy to note the powerful nature of the heterogeneous panel result embedded well-built conjecture of cross sectional dependency assumed by single common factor (Li et al., 2020). Nonetheless, it is reasonable to draw a conclusion and reject the null hypothesis of nonstationarity and test for co-integration.

Table 4.4 Panel co-integration

Statistics	Value	Z value	P value	Robust p value
Gt	-0.802	5.473	1.000	0.000
Ga	-0.829	4.854	1.000	0.000
Pt	2.526	8.546	1.000	0.010
Pa	2.159	4.574	1.000	0.000

Table 4.4 interprets the findings of the westernlund (2007) co integration generated by the equations of the statistical coefficient of Gt,Ga,Pt,Pa with their corresponding probability values. Consequently, the null hypothesis of no co integration was rejected implying the existence of long-term relationship among the observed variables. Nevertheless, the error correction mechanism $\check{\alpha} = \frac{P_\alpha}{T}$ indicates the rate of conversion to equilibrium per unit increase or decrease in economic distortion. Thus, for every distortion in equilibrium in the short run shall be adjusted commensurately by the values of error correction model. However, the westernlund adaptable and enables nearly full heterogeneity in both long- and short-run specification flanked with bootstrap option (Persyn, 2008).

Table **4.5**: Cross Sectional ARDL Estimate

Variables	Coefficients	Standard Error	Z-Statistics	P-value
Long run Results				
$lnTEC_{it}$	0.809*	0.061	13.26	0.000
$lnTOP_{it}$	-0.495*	0.104	4.759	0.000
$lnGDP_{it}$	0.601*	0.093	6.46	0.000
Short run Results				
ECM(-1)	-0.271*	0.084	3.20	0.001
$\Delta lnTEC_{it}$	0.274*	0.076	3.61	0.000
$\Delta lnTOP_{it}$	-0.317*	0.054	5.87	0.000
$\Delta lnGDP_{it}$	0.108*	0.021	5.14	0.000
Number of Groups	15			
R-square	0.52			

Table 4.5 presents the chudik and pesaran (2016) cross sectional augmented auto regressive model (CS-ARDL) highlighting the regressed model of energy consumption across the regressors in both short-run and long-run accompanied by the Ect value with corresponding significant p values. The findings from Table 4.5 above reveal the results of CS-ARDL estimation for the pool data which comprises a sample of the observed West African countries. The estimate however, revealed the estimated coefficients $lnTEC_{it}$ and $lnGDP_{it}$ to be positive and statistically significant at a 1 percent level of significance in the observed series at time t. While, the variable $lnTOP_{it}$ prevailed negative but statistically significant at 1 percent level of significance in the short run. Furthermore, the table presents the speed of adjustment denoted by ECM (−1)

as −0.27, showing that the rate of adjustment toward equilibrium is 27 percent for the CS-ARDL model.

The coefficient for technological innovation stood at 0.274 precent which reflect at a 1 percent increase in the level of technology within the observed region will cause a 0.274 percent increases in the amount of energy consumption and the result confirms the prior expectation. Meaning that 1 percent increase on energy consumption among the selected West African Countries is associated with 0.274 percent spontaneous increase in the level of technological progression in the short run. While 0.809 percent implies a considerate stimulative effect in the long run. Nevertheless, it is imperative to note that the values of the aforementioned coefficient tend to be weak in the short run, which could be plausibly linked to the low level of technological innovation in the observed sampled countries. However, the figures are in line with the basic theoretical assumption. The empirical outcome reaffirms the fact that the energy sector is experiencing substantial uncertainty for both upstream the oil and power service sector. Players within the industry are confronted with several technological and innovative difficulties in producing current and future energy demand to its full potential.

Table 4.6 Dumitrescu Hurllin causality

	LNTEC−/→LNEC	*LNTEC←/−LNEC*
Panel test statistics		
W^{Hnc}	19.060*	22.758*
Z_{NT}^{Hnc}	49.459	62.299
$\tilde{Z}_{N}^{HNC}$	44.072	55.711
	LNTOP−/→LNEC	*LNTOP←/−LNEC*
Panel test statistics		
W^{Hnc}	3.393	8.624*
Z_{NT}^{Hnc}	6.554	20.879
$\tilde{Z}_{N}^{HNC}$	5.703	18.514
	LNGDP−/→LNEC	*LNGDP←/−LNEC*
Panel test statistics		
W^{Hnc}	4.223**	19.409*
Z_{NT}^{Hnc}	8.828	50.415
$\tilde{Z}_{N}^{HNC}$	7.737	44.927

Given the traditional notion of past values of two or more stationary variables to significantly predict the current value of individual variable i at period t in a panel data model, the study enrolled the Dumitrescu Hurling causality (2012) in other to understand the causal effect between the variables, we test for the significance impacts of previous x values on the current values of y to determining the presence of causation (Lopez & Weber, 2017). Consequently, the empirical outcome on table 4.6 discloses the existence of bidirectional causal relationship between technological innovation (*LNTEC)*, on energy consumption (*LNEC*). In other words, a two-way direction of causality exists from energy consumption to technological innovation which means that energy consumption causes technological innovation likewise, technological innovation does cause energy consumption. The empirical relationship confirms the findings of Adua et.al. (2020) who examined the complexities of energy behavior in the United States of America. The research confirmed a theoretical base of technological innovation causes energy consumption even though technological advancement varies in accordance to technological brands and types.

However, the coefficient for (*LNTOP)* indicates a unidirectional causality running from energy consumption (*LNEC*) to trade openness (*LNTOP*) revealing the causal relationship from energy consumption to trade openness. This means that energy consumption causes trade openness, validating the trade scale led hypothesis which infer on the possibility of trade to expand economic activities through export and imports (Adu-Gyamfi et al. 2020; Wan et al., 2015). In other words, a surge in energy demand as a result of an increase in domestic output is frequently referred to as the scale effect which impact comes as a result of trade liberalization. In addition, the effect of trade openness on energy consumption is determined by the country's economic position and the strength of the link between economic growth and trade openness (Shahbaz et al., 2013; Cole, 2006). Furthermore, there was evidence of bidirectional relationship from (*LNEC*) energy consumption to (*LNGDP)* economic growth at 1 percent level of significance while economic growth to energy consumption stood at 5 percent significant level. This implies the growth led hyphothesis, because the growth rate of the West African economies induces energy use through industial productivity which ultimately promoting an incrase in the level of energy consumption.

5. CONCLUSION

The analysis and discusses the empirical outcome of the results examining the correlation relationship between the observed variables. Furthermore, the models are further empirically examined using the CS-ARDL panel technique of estimation. The results reveal that technological innovation and economic growth poses a positive relationship with the dependant variable energy consumption. Furthermore, policy makers should consider enacting policies to increase the current and future infrastructure for electricity generation, transmission, and distribution as the existing energy infrastructure of the region suffers heavily with ageing imperial power plants which are obsolete.

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