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Modelling Aggregate Energy Consumption for Growth in Nigeria

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ABSTRACT

The principal aims of this study is to modelled the connection of Aggregate energy consumption for growth in Nigeria. Annual time series data is used, ranging from 1985 to 2020. The study employed ARDL, Toda and Yamamoto approach in examining connection between the variables. The ARDL results with additional stability test shows that short and long run connection exists among the examined variables. The Toda and Yamamoto test reveals unidirectional causalities running among the variables. Furthermore, change in GDP stimulate further consumption of energy in Nigeria.

Keywords: Aggregate Energy, Growth, ARDL
JEL Classifications: O11, Z32, Q43

1. INTRODUCTION

Energy consumption is a vital mechanism for the existence of humanity, often government devote concerted effort to the aggregate energy consumption of their economies because it serves as benchmark for power behind social and economic advancement (Levinson, 2015; Leiwakabessy and Ayapo, 2022; Stamatiou, 2022; Croes et al., 2018; Tang et al., 2016). Aggregate energy demand over years continuously increasing, so intense that renew interest on what effect and relationship aggregate energy consumption can have on growth is ongoing worldwide given the current climate change mitigation. Efficient and reliable energy framework is essential which can forecast aggregate energy consumption that can stimulate growth for any economy.

Earlier empirical models of aggregate energy consumption base on inter-fuel switch as a mechanism of minimizing costs (Acaravci and Ozturk, 2010; Adekunle et al., 2018; Karanfil and Li, 2015). Though these empirical models are valuable when examining the consumption of a specific energy basis, however, discrepancies bound to occur due to the volatility between aggregate energy demand and macroeconomic variables which impact energy sources.

Numerous past studies have examined empirically the relationship between aggregate energy consumption and macroeconomic variables (Adom, 2011; Leiwakabessy and Payapo, 2022; Shin and Yoo, 2021). Most of earlier studies mostly used a single model approach. In spite of notable criticism such as ad hoc specification and lack of optimization behavior, this single equation system has become extensively employed because it requires less effort and data, the outputs are easy to interpret and forecast, and there is reliability between aggregate energy consumption and macroeconomic variables.

The prime aim of these previous studies has been to attain reliable estimates of the price and income resistances needed for forecasting and policy analysis" as Jones (1994) emphasizes. However, it appears that there is a reasonably acceptable estimations in the literature, particularly for the aggregate energy. Adeyemi and Hunt (2007) review some previous studies and show that the estimates of aggregate energy elasticity vary from −0.5 to 0.1 for OECD countries.

In explaining why the estimations of energy price variation are so volatile, countless previous studies have evaluated technical change effect. It is conceivable that final consumers worldwide react to price volatility differently, contingent on the cost of alternative and accessible energy-saving technology. Beenstock and Wilcocks (1981) capture a simple mathematical time trend in their energy demand model to estimate the technical dynamics. Griffin and Schulman (2005) employed independent time dummies to capture for technical dynamics in their models. Hunt et al. (2003) advances alternative method of capturing technical dynamics, they suggested dynamic stochastic trend should be included in aggregate energy consumption equation to capture technical change and other core economic and social variables. Empirically, it is difficult to establish best appropriate method to model technical dynamics when modeling aggregate energy consumption for a specific economy.

This current study suggests a different approach to measure technical dynamics in modeling aggregate energy consumption for Nigeria. Evidently, empirical outcomes can be enhanced by including total factor productivity (TFP) as a proxy variable of technical dynamics into the model. Total factor productivity is that part of output that cannot be captured by the accumulation of inputs such as labor and capital. As TFP is measured as residuals by subtracting the contributions of labor and capital from GDP, it can include anything else but labor and capital. TFP is employed as a popular method of measuring economic productivity of a country. TFP is a suitable proxy for both socio-economic variables and technical change.

In addition to its practical applicability and simplicity, introducing TFP in the empirical equation aids to elucidate a slow-down of energy consumption changes. Energy consumption changes as income rises, nonetheless at a reducing rate as income moves to higher points, due to the advancement of energy-saving technology or the economy is moving to a less energy-intensive industrial structure.

One distinct feature of this study is that numerous tests and techniques are employed in order to validate the stability of the empirical findings and results. The nonstationary of most time series variables relating to macroeconomic indices is a major concerned when analyzing the cointegration and error correction method is employed. It is an established fact that most cointegration tests have problems of size distortion or low power in a small sample. Hence, it is quite common to have contradictions in the test results for cointegration.

Earliest studies found a cointegrating connection among energy demand, income and energy price in Korea (Amaluddin, 2020; Bae 2016; Oh and Lee, 2003; Cowan et al., 2014; Ekananda, 2019). Though, these cointegrating relationship are constructed on one testing method only, Johansen (1991) and the stability and robustness of the cointegration has not been examined.

This study makes a distinct turn by adopting more robust techniques and incorporating Total Factor Productivity (TFP) in the model which is very scanty in Nigerian context when analyzing aggregate energy consumption in Nigeria Several phenomena or research gaps described are interesting for further research, especially regarding the pattern of relationships between the three variables. The objective of this study is to examine and analyze the dynamic relationship between energy consumption, poverty, and EG in the short and long run for panel data of 12 provinces of Eastern Indonesia from 2009 to 2019.

2. LITERATURE REVIEW

Policy makers often strive to achieve sustainable growth levels which is a fundamental instrument for economic growth and development. Aggregate energy consumption as it relates to growth has been previously examined in the economics and finance literature. Some of the previous studies found convergencies in the relation between aggregate energy consumption and economic growth (Mulder and Groot, 2012; Marrero and Ramos-Real, 2013; Jakob et al., 2012; Baldwin et al., 2013). Most of these studies found that convergence is shown by the fall in the standard deviation of energy concentration transversely industries within the producing segment of the economy.

Some of the earlier studies maintain that there is divergencies rather than convergences between aggregate energy consumption and growth. The outcome of those studies points out that advance countries basically the industrialized economy maintain industrial energy intensities that are both falling and lower than developing countries (Galeotti et al., 2020; Kepplinger et al., 2013; Brunel and Levinson, 2016; Shapiro and Walker, 2018; Ministerio de, 2019). The source of the differences between convergences and divergences may arise from different technique employed, the country region, time period and focus.

Other group of past studies examined causality between energy consumption and growth, and most of these studies found out that divergences occurred between energy usage and growth. Essentially, it means that there is various degree of relationship between AE and EG in both the short run and the long run (Cowan et al., 2014; Iyke, 2015; Wolde-Rufael, 2014; Shaari et al., 2013; Kasperowicz, 2014). Energy-led growth hypothesis (ELGH) is the theoretical framework in which most of these past studies based their work on. The ELGH states that energy consumption stimulates growth of economic activities thereby lead to economic growth of a country. Having reviewed series of empirical it is established that energy-growth revealed mixed findings which led to increasing research on this particular area, hence, no agreed consensus is reach on the ELGH.

Using multi-variate analysis, Amaluddin (2020) work on Indonesian provinces (33 precisely), evaluating the short and long-term connection between electricity consumption, internet access, and EG. The research findings show that energy consumption and EG have direct connection both in the short and long run. In the same manner, Inani and Tripathi (2017) work on Indian economy to evaluate the cointegration between Information and Communication Technology, electricity consumption, and EG variables using ARDL techniques. The results reveal that energy consumption has direct and significant effect on EG, both in the short and long term.

Having reviewed series of empirical literature, this current study introduces a new variable to gauge the modelling of AE consumption, which is TFP, which is totally lacking in Nigeria study and scanty empirically worldwide. Hence, this study contributes to the debate on ELGH, and thereby employed advance econometric techniques to measure the effects among these variables.

3. DATA AND METHODOLOY

3.1. ARDL Bounds Testing Approach

The study employs ARDL approach which is developed by Pesaran et al. (2001) to test the long run dynamics between the variables of interest. ARDL methodology can be employed irrespective of the integration order of the variables (e.g. I(0) or I(1) or (mixed) but not I(2) variables.

The ARDL method has a number of advantages over the conventional econometric techniques: (i) it is valid irrespective of whether the variables are purely integrated at level or first differences or mutually cointegrated, (ii) provides consistent empirical results for small data samples, (iii) allows simple interpretation due to its simple equation set up, (iv) unlike the traditional approach it is valid by using different number of lags for the variables, (v) provides effective results of long run parameters, (vi) eliminates the problems of autocorrelation and endogeneity, and (vi) a dynamic model (error correction model) can be derived from the ARDL methodology through a simple linear transformation.

A model of aggregate energy consumption is established whereby aggregate energy consumption is a function of energy price, real GDP per capita and total factor productivity. As seen in the previous section, many empirical literatures on aggregate energy consumption exist, however, most methodology on aggregate energy consumption and asymmetric price response for OECD countries was implemented by Adeyemi et al. (2010). However, to the best of our knowledge, there are very few studies that link aggregate energy consumption with total factor productivity within a growth framework in Nigeria. In this paper we use TFP as independent variable, independently enhancing economic growth and together influencing energy consumption.

Following Shin and Yoo (2021), we specify the equation in a function form as follow:

$$\text{AGEC} = f(\text{EP, GDP TFP}) \quad (1)$$

where AGEC = aggregate energy consumption, GDP = gross domestic product per capita and TFP = total factor productivity.

$$\text{LogAGEC} = \beta_0 + \beta_1\text{LogEP} + \beta_2\text{LogGDP} + \beta_3\text{LogTFP} + \varepsilon_t \quad (2)$$

Where LogAGEC = the natural logarithm of aggregate energy consumption, LogEP = the natural logarithm of energy price, LogGDP = the natural logarithm of economic growth, $£_1$ = the estimated coefficient of EP, $£_2$ = the estimated coefficient of GDP, $£_3$ = The estimated coefficient of TFP and φ_t = the error term. The $£_1$ to $£_3$ are expect to be positive meaning that total factor productivity and economic growth have a positive impact on aggregate energy consumption in Nigeria.

Equation (2) may not establish the level of adjustment the specified model returns to the long run equilibrium. As a result, the error correction model (ECM) is estimated to capture the speed of adjustment among the short and long run equilibrium levels of aggregate energy consumption:

$$\Delta LogAEC_t = \sum_{t=1}^{X}\Delta\beta_0 LogAEC_{t-1} + \sum_{t=0}^{J}\Delta LogEP_{t-i} + \sum_{t=0}^{P}\Delta\beta_2 LogGDP_{t-i}\sum_{t=0}^{V}\Delta\beta_3 LogTFP_{t-i} + \beta_5 \bigcup_{t-1} + \varepsilon_t \quad (3)$$

$$\Delta LogAEC = \beta_0 + \beta_1 LogAEC_{t-1} + \beta_2 LogGDP_{t-1}\beta_3 LogEP_{t-1} + \beta_4 LogTFP_{t-1} + \sum_{t=1}^{X}\Delta\beta_0 LogAEC_{t-1} + \sum_{t=0}^{J}\Delta LogEP_{t-i} + \sum_{t=0}^{P}\Delta\beta_2 LogGDP_{t-i}\sum_{t=0}^{V}\Delta\beta_3 LogTFP_{t-i} + \varepsilon_t \quad (4)$$

The (Δ) signify the difference operator in equation 4, AEC, EP, GDP and TFP are the variables of the study. The white noise error term $\varepsilon 1t$ is serially independent with zero mean and finite covariance matrix. The optimal lag length, *x*, *j*, p and v was selected by the minimum values of criteria AIC, SC and HQ.

ARDL techniques enable us to establish a dynamic error correction model (ECM) through a systematic linear transformation. The following ECM integrates the short run dynamic with the long run equilibrium, without losing long run information:

$$\Delta LogAEC_t = \sum_{t=1}^{X}\Delta\beta_0 LogAEC_{t-i} + \sum_{t=0}^{J}\Delta LogEP_{t-i} + \sum_{t=0}^{P}\Delta\beta_2 LogGDP_{t-i}\sum_{t=0}^{V}\Delta\beta_3 LogTFP_{t-i} + \pi ECT_{t-1} + \varepsilon_t \quad (5)$$

Where Δ = the difference operator, $\mu t-1$ = is the lagged error correction term (ECTt-1) from equation (2). As indicated by Gujarati (2003) the coefficient of ECTt-1 should be negative and statistically significant.

3.2. Testing Stability in ECM

The presence of cointegration between variables does not mean the systematic stability of the model. Pesaran et al. (2001) proposed checking the stability of the autoregressive model by using Brown et al. (1975) tests based on the cumulative sum of recursive residuals (CUSUM) and cumulative sum of recursive residuals of squares (CUSUMQ).

4. EMPIRICAL RESULTS

4.1. Unit Root Analysis

We perform the unit root test to establish order of integration of the variables. As confirmed by both ADF, PP, ERS Point Optimal

Table 1: Unit root testing

Variables	ADF trend and intercept				PP trend and intercept				ERS point optimal trend and intercept				DF trend and intercept			
Order	t	P	t*	P	t	P	t*	p	t	P	t*	P	t	P	t*	P
AE	1.778	0.383	6.783	0.00	2.988	0.157	7.954	0.00	7.67	5.72	5.339	5.72	3.097	3.190	6.803	3.190
EP	2.355	0.394	6.486	0.00	2.406	0.369	6.514	0.00	11.58	5.72	5.226	5.72	2.354	3.190	6.727	3.190
GDP	1.176	0.898	3.629	0.04	1.593	0.772	3.561	0.05	28.49	5.72	6.972	5.72	1.744	3.190	3.745	3.190
TFP	2.361	0.391	2.496	0.05	2.057	0.547	2.343	0.04	13.40	5.72	10.23	5.72	2.137	3.190	3.542	3.190

Source: Computed by authors. t and t* represent @level, @ 1st difference respectively @prob of 5%

Table 2: The Result of ARDL Cointegration Test

Bound testing to cointegration			Diagnostic test		
Estimated model	Optimal lag	F-stat	Prob-nor	Prob. arch	Prob. serial
(AE, EP, GDP TFP)	(3,2,4,1)	7.85^{ui}	0.05	0.056	0.742
Significant level			Lower Bound		Upper Bound
10% level			2.72		3.77
5% level			3.23		4.35
1% level			4.29		5.61

Source: Computed by authors. The maximum lag selection is based on AIC. The ui means significant level @1%

Table 3: Long run coefficient using ARDL approach

Variables	Coefficient	SE	t-Statistic.	Prob.
$LnAE_{t-1}$	0.008996	0.181597	0.049536	0.9612
$LnAE_{t-2}$	0.039322	0.178796	0.219927	0.8293
$LnAE_{t-3}$	0.416180	0.168996	2.462655	0.0285
LnEP	0.029494	0.055499	0.531425	0.6041
$LnEP_{t-1}$	–0.030210	0.053576	–0.563877	0.5824
$LnEP_{t-2}$	–0.131087	0.043192	–3.035008	0.0096
LnGDP	0.121916	0.042718	2.853969	0.0136
$LnGDP_{t-1}$	–0.008912	0.045492	–0.195896	0.8477
$LnGDP_{t-2}$	–0.043720	0.033078	–1.321712	0.2091
$LnGDP_{t-3}$	–0.052735	0.031130	–1.694038	0.1141
$LnGDP_{t-4}$	0.032818	0.023783	1.379917	0.1909
LnTFP	–0.222726	0.177348	–1.255871	0.2313
$LnTFP_{t-1}$	0.500841	0.203973	2.455435	0.0289
C	9.345226	2.181229	4.284385	0.0009
R-square	0.936659			
Adjusted R	0.873318			
F-Statistic	14.78753			

Table 4: Short run coefficient using ARDL approach

Variables	Coefficient	SE	t-statistic	Prob.
$\Delta LnAE_{t-1}$	0.376858	0.244484	1.541443	0.1472
$\Delta LnAE_{t-2}$	0.416180	0.168996	2.462655	0.0285
ΔLnEP	0.029494	0.055499	0.531425	0.6041
$\Delta LnEP_{t-1}$	0.131087	0.043192	3.035008	0.0096
ΔLnGDP	0.121916	0.042718	2.853969	0.0136
$\Delta LnGDP_{t-1}$	0.043720	0.033078	1.321712	0.2091
$LnGDP_{t-2}$	0.052735	0.031130	1.694038	0.1141
$LnGDP_{t-3}$	–0.032818	0.023783	–1.379917	0.1909
ΔLnTFP	–0.222726	0.177348	–1.255871	0.2313
CointEq(-1)	–0.988190	0.201761	–4.897828	0.0001

Table 5: Toda and yamamoto causality test

Dependent Var. inference	MWALD Test LAE	LEP	LGDP	LTFP	Causality inference
LAE	-	0.0724	2.3593	0.0473	
		(0.2013)	(4.1347)	(0.0004)	LAE→LTFP
LEP	0.6706	-	7.7278	4.5901	
	(0.045)	-	(6.6309)	(0.0001)	LEP→LTFP
LGDP	0.0301	0.0072		4.8500	LGDP→LAE
	(0.0203)	(0.0149)		(0.0332)	LGDP→LEP
LTFP	0.3381	0.2055	0.1340		LGDP→LTFP
	(0.1842)	(0.1298)	(0.2667)		No Causality

Figure 1: Plot of CUSUM

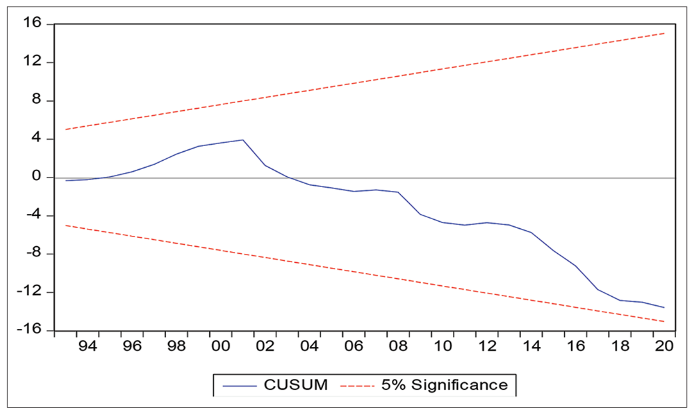
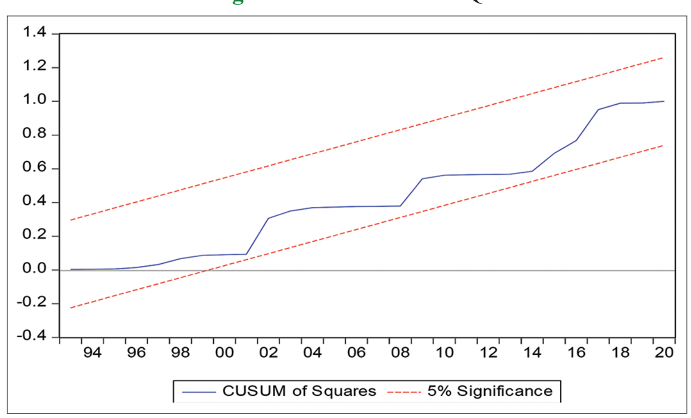


Figure 2: Plot of CUSUMQ

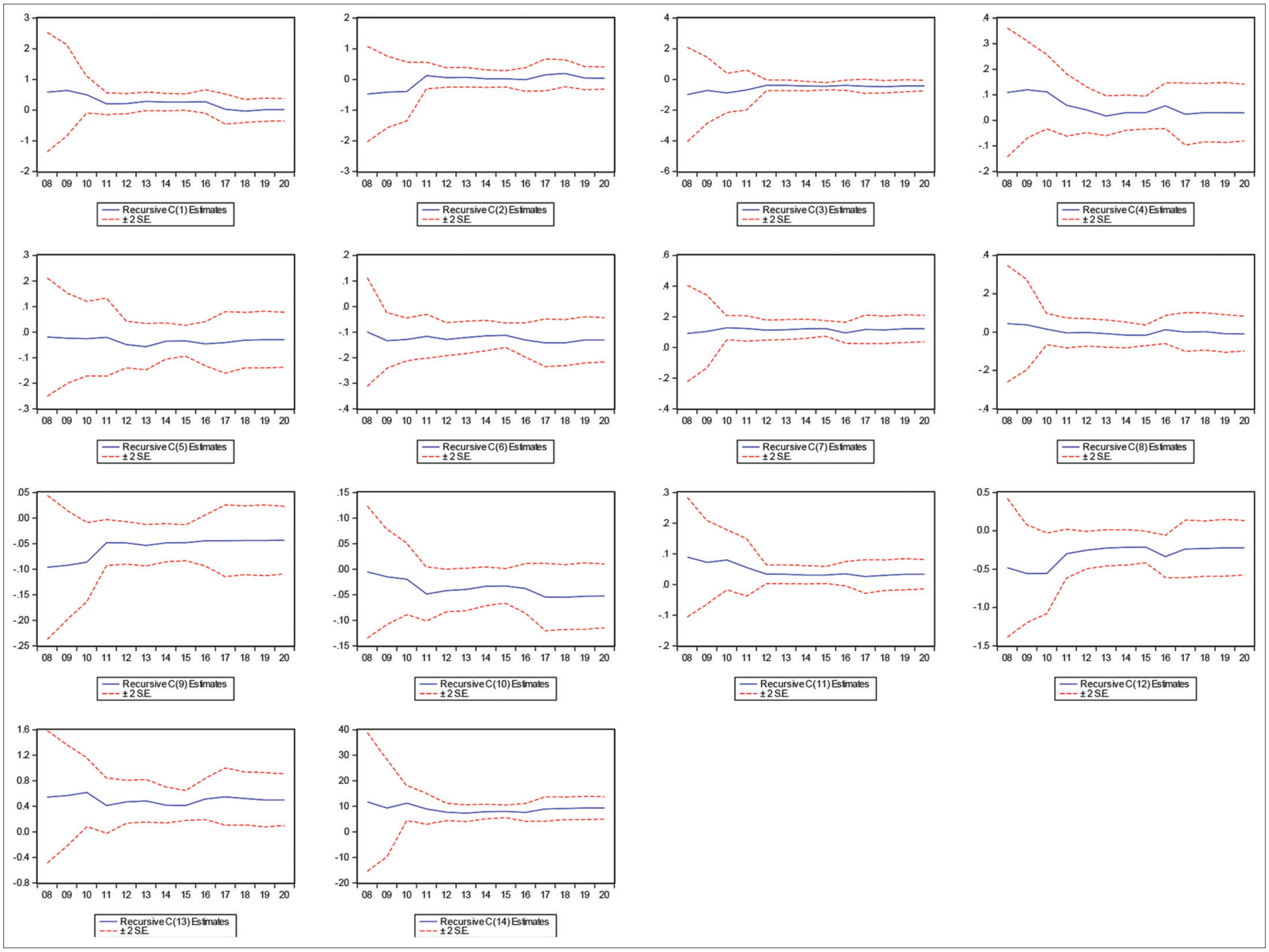


and DF test. Table 1 presents the unit root testing, it is seen that the variables are I(0) and I(1) order.

The concise presentation of the bound test results is displayed in Table 2 above as suggested by Pesaran et al. (2001). The connected F-statistic of ARDL bounds testing is 7.85 confirming the existence of long run relationship among the series (F value exceeds upper critical bounds at 1% significance level) which fulfill sufficient condition for ARDL usage on the variables.

Table 3 presents the results of long run relationship between the variables estimated using the ARDL (4, 3, 3) model.

Figure 3: General plot of CUSUM and CUSUM sum of square



From the results of the Table 3 we can see that the coefficients are significant for the variables AE, EP GDP and TFP at different lag. Energy price (EP) at lag two period signify inverse relationship with aggregate energy used in Nigeria. Any 1% changes in EP leads to 13.1% decrease in AE consumption, this conforms to apriori expectation of the study. The gross domestic product per capita (GDP) show a positive and significant relationship with AE used. This further indicate that any 1% change in GDP cause AE to change by 12% in Nigeria. The total factor productivity (TFP) shows a positive relationship with AE and conform with apriori expectation of the study. The ARDL (3, 4, 2, 2) dynamics is tested to explore the short run tendency of the model. The outcome of the short run equation is estimated below in Table 4.

It is cleared that the value of ECT coefficient is 0.98.8 which signifies that in the short run, the aberrations from the long run equilibrium are adjusted by 99% every year.

The results of Table 5 provide evidence of six unidirectional causalities running from EP, GDP, TFP to AE at 5% level of significance. The findings also support the existence of a unidirectional causality between foreign AE, EP, GDP and TFP, with causality from AE to GDP @ 5% level of significance. Consequently, we may conclude that the growth GDP, TFP and EP are the reasons for AE consumption in Nigeria. The results of Table 5 support the energy-led growth hypothesis in Nigeria. The knowledge about the direction of causality will help policy makers to develop a proper economic policy for sustainable growth. Furthermore, the Granger causality test reveals the existence of two unidirectional causalities running from GDP, EP and TFP and toward AE consumption, as well as a unidirectional causality relation running from EP, TFP and AE. Essentially, growth GDP, TFP and EP stimulate AE consumption in Nigeria.

4.2. Stability of the Model

Cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) are used to justify the existence of long run relationship among specified variables. This is shown in Figures 1-3, hence, we concluded that our model is stable and reliable.

5. CONCLUSION AND POLICY RECOMMENDATION

This paper model the connection among aggregate energy consumption, energy price, total factor productivity and economic growth for Nigeria, using annual time series data span over the period of 1990-2020. Specifically, the study examines the long-run relationship of TFP, EP GDP and AE consumption in Nigeria.

The application of advanced technique is used in the study such as Toda-Yamamoto (1995), ARDL bounds testing approach is used to determine cointegration and error correction model to restore stability in the long run.

The empirical results of various technique and test reveal valid justification for cointegration among observed variables, and signify long run equilibrium relationship among AE consumption, EP, TFP and GDP. The coefficient of ECM is statistically significant. Additionally, the estimated model captures stability tests and reliability.

The empirical results of the study support the energy-led growth hypothesis. This means that energy sector is an agent for higher growth rates in Nigeria. So, the country's policy makers should give more emphasis on improving the aggregate energy in the country. The key factors of enhancing the energy related substructures include separation of generation from distribution, construction of isolated power station far from the grid and promotion of wind power generation by independent power producers all these factors will stimulate economic growth.

The energy-led hypothesis is accepted by the findings of the study. Nigeria economy system shows to be energy dependent which means that much attention should be given to energy related area by the policymaker in order to improve economic growth and development. Essentially, the study concluded that alternative energy source should be discovered and implemented in order to increase aggregate energy consumption, thereby resulting to reduction in energy price and hence facilitating growth and development of the economy.

It is important that policy should be geared toward sustainable financing of alternative energy by facilitating existing global financial instrument as well domestic tools with moderate tax and regulatory control (Stamatiou, 2022). Globally, countries are encouraging green and clean energy know-how, so Nigeria should not be left out with grouping of suitable environmental regulation and control to geared the economy towards growth path. The adoption of energy clean technologies in tourism sector is necessary.

Although the results of the analysis are of immense importance to public authorities, they represent some limitations, which should address and extend for future research. This paper is base on single country analysis future research should adopt cross-countries analysis. Furthermore, structural break in time-series analysis should also be observed to avoid spurious results.

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