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Energy Intensity and Economic Growth in Sub-Saharan Africa: A Dynamic Panel Approach

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Authors' contributions

This work was carried out in collaboration among all authors. Author AKO designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Author OA and Author OAY managed the analyses of the study. Author SDK managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The study examined the impact of energy intensity in sub-Saharan Africa from 1970 to 2019.The study broke sub-Saharan Africa into regional bloc since there may be policy variation across the regional bloc of SSA. A dynamic panel data approach was employed to unravel the relationship between energy intensity and economic growth. The study conducted a panel unit root Test to confirm the stationarity of the series. The results of the unit root showed that the Levinlin and Chu statistics with their corresponding p-values in reference to each variable is smaller than the alpha value at 10%. A post estimation test was also conducted using a dynamic panel approach via the system GMM. The result of the system GMM showed a robust negative correlation between energy intensity and economic growth in SSA and all its regional bloc. The coefficient of energy intensity is highly insignificant which implies that reductions in energy intensity are not linked to higher GDP growth. This is evident from the coefficient of the lag values of energy intensity of one period value

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of -3.321. The rationale for negative correlation might be connected to common patterns of structural change, paired with rising after tax energy price. The study, therefore recommend that energy conservation should be a focus in SSA as a whole and its regional bloc since this would promote economic growth.

Keywords: Energy intensity; economic growth; unit root; dynamic panel; GMM; SSA.

1. INTRODUCTION

"Although global energy intensity defined as ratio of energy per unit of GDP has been declining, Africa is still one of the regions with high energy intensity. Available data shows that energy intensity in Africa has remained high compared to other developing energy efficient countries in Latin America and Asia" (World Energy Commission, 2013). The high energy intensity may be the reason for the slow growth when making international comparison in sub-Sarahan Africa [1-3] argued that the efficient use of energy can contribute to steady and higher economic growth by reducing the amount of energy required per unit of output which will in turn lead to a reduction in energy demand and, hence, prices.

Also, energy efficiency enables countries to improve energy security and access as well as help household to save cost [4]. "Furthermore, global energy demand is expected to grow by 1.6 percent on annual basis on average between 2006 and 2030 to an overall increase of 45 percent. A major cause of this is the rising demand for energy coupled with increased use of inefficient technologies" [2], (IEA, 2016). These factors will lead to increase in fossil fuel production (IEA, 2008), this can increase carbon-dioxide emissions which is the major cause of climate change with adverse effect on sustainable development. Hsueh and Yan, [5] posit that sustainable economic development can be achieved by reducing carbon-dioxide to zero benchmarks. "It is therefore important to implement energy efficient practices which result in large energy savings technologies" [2].

Though, it has been argued that if well operated, markets can eliminate the problem of energy inefficiency [6]. They posited that there are important market barriers which justify the use of government policies in promoting energy efficiency [41-51]. Moreover, investment in energy efficiency often does not rank high up in the agenda for many consumers. Certain section of the population cannot afford investment in energy efficient technologies due to low creditworthiness and inability to access financial markets [52-59].

Since achieving energy efficiency goal poses a serious problem for most economies like sub-Saharan Africa towards the realization of sustainable economic growth [7,4]. Understanding more about the relationship between energy efficiency and economic growth might help offer an explanation for the inefficient utilization of energy in sub-Saharan Africa as observed by their high level of energy intensity when compared with other developing countries energy efficient nations such as in Latin America, China, Asia and Middle East [8].

Outstanding studies on the relationship between energy efficiency and economic growth are Cantore, [9] Daniel, [10]; Guanyung and Lixin, [11]; Matisoff, [12]; Otsuka, [13]; Sergey, [14]; Xiliu, [15]; Yang-Yang, 2016). While Yingchang (2009) used multilevel decomposition methodology to examine the relationship between energy efficiency and economic growth but reveal negative findings, Sung and Zhang [16] study on the relationship between energy efficiency and economic growth using a decomposition method revealed that energy efficiency is positively related to economic growth. Nicola Cantore [9] study on the relationship between energy efficiency and economic growth came up with the result that a lower level of energy intensity is however associated with higher factor productivity. So also, Kenneth [17] study on the relationship between energy efficiency and economic growth using a theoretical analysis with a conclusion of positive association between energy intensity and economic growth.

In order to validate the relationship between energy intensity and economic growth in sub-Saharan Africa this study will use Dynamic Panel method (DPD) [60-66]. The dynamic panel method based on system Generalised Method of Moment (GMM) will be used for better understanding of the dynamic of adjustment [18,19].

2. LITERATURE REVIEW

2.1 Theoretical Review

2.1.1 The natural Resource and Economic Growth Theory (The REXS theory)

In a rigorous exercise, Warr and Ayres (2006) proposed a model that best explain the impact of natural resource consumption and technological change on economic growth. This model was based on the theory of resource energy service (REXS). The REXs theory suggests a simple model that represents dynamics of technological change in terms of decreasing energy intensity and increasing energy efficiency of conversion of raw energy inputs (fuel) to primary exergy services (useful work). Khazzoom (1991), Brooks (1992) and Saunders [20], where energy augmented production function was nested in the CES production function in which capital-energy goods feature as important production variable, the REXS model make normative assumption of energy augmenting technological progress to drive the economy and maintain future levels of economic growth. A typical CES type of REXS is given in equation 1 below:

$$Q(t) = \left[A(t)(K((t)^{\alpha} L(t)^{1-\alpha})^{\gamma} + B(t)((F(t)^{\chi} + N(t)^{x})^{1/\chi})^{\gamma}\right]^{1/\gamma} \quad (1)$$

Where $Q(t)$ is aggregate output of the economy; $A(t)$ is technological progress for capital and labour; $K(t)$ is the capital stock; $L(t)$ is labor input assumed to be homogenous; $B(t)$ is the technological progress of energy; $F(t)$ is fossil energy input; $N(t)$ is the non-fossil energy input and all other terms are parameters. Clearly there are two factor-augmenting , A and B. the parameters are assumed to be constant and they describe the share of capital in the capital-labour composition and the elasticity of substitution between fossil and non-fossil energy use and then the elasticity of substitution between capital-labour on the other hand and the fossil and non-fossil fuel on the other. But suppose technological change is structural change, then using CES production function to explain growth rate is misleading.

However, the REXS theory eliminates the assumption of exogenouly driven exponential growth. The traditional assumption of exogenous technological progress increasing at a constant rate is replaced by two learning processes. The first is the fact that production experience drives down energy intensity of output. Second is the fact that experience gained in supplying energy is supplied to the economy in useful form which in turn drives output and hence energy demand. The innovation of REXS include (i) using energy services or useful work to describe the productive inputs demand from energy into the economy, (ii) redefining technological progress as a measure of efficiency of conversion of energy into useful form and (iii) selecting alternative to the neoclassical (energy augmented) production function which will be capable of forecasting past and future rates of economic growth.

The generic energy-power feedback is well articulated in Salter (2001) where cheaper energy due to discoveries of technology leads to economies of scale and technological progress in energy conversion and delivered at lower cost also leads to reduction in energy price, reduction in price elasticity of energy, increase energy demand, increase economic activity, increase payments to labour and then stimulates further substitution of fossil energy and mechanical power to human labour leading to increase in economies of scale, to reduction in cost and so on. The end result is that once energy is assumed to be complementary in the production function, energy efficiency will increase economic growth and energy demand.

2.2 Empirical Review

Yingchang (2009) examined the relationship between energy efficiency and economic growth for 129 countries in the world. He builds up a global panel database and uses multilevel decomposition methodology as well as panel data regression to discover the fundamental relationship between economic growth and energy efficiency and before carrying out the regression analysis, the data was divided into two groups namely Advanced Economies (AE) and Emerging and Developing economies. The major findings from his analysis is that the relationship between energy efficiency and economic growth is negative. It is discovered that the negative relationship is stronger for Advanced Economies than the negative relationship in Emerging and developing Economies. The Advanced Economies model shows the originality of the regression because the intercept is zero. This may be interpreted that the Advanced Economies must pursue economic growth and energy efficiency simultaneously. Which implies that energy conservation policy is a no-regrets policy. On the other hand, the intercept for Emerging and Developing Economies is positive number of 1.3082 which suggests the existence of a survival threshold for EDES. This suggest that emerging and developing economics need aid from Advanced Economies to enable them to scale through the process of economic development.

Song and Zhang [21] examined" the relationship between energy efficiency and economic growth by using decomposition analysis with econometric model and found out that there exist a significant impact of energy efficiency on rising economic growth as well as limited effect of energy price on the reduction of energy intensity".

Rohit et al. [22] examined "the relationship between energy efficiency and economic growth in the context of Technophilic optimism view. They conducted an econometric analysis using archival data. Their results suggest an increase in per capita energy consumption will lead to increase in economic output but this will not lead to an increase in emission. He however concluded that this result could negate environmental benefits arising from energy efficiency".

In a study conducted by Nicola Cantore, Massimiliano and Dirk Willemte Verde (2016) on the relationship between energy efficiency and economic growth for a large sample of manufacturing firms across 29 developing countries to determine the relationship between energy efficiency and economic growth. The results reveal, that a lower levels of energy intensity are associated with higher total factor productivity for the majority of these countries. The estimates also shows similar robustness at the macro levels as wells. However, the paper mainly consider the sectoral level visa vis manufacturing sector.

In another study conducted by Kenneth Gillingham, David Raspson and Gernot Wagner (2015) "on energy efficiency and economic growth. This study discuss how some studies in the literature consider rebound effect that results from a costless exogenous increase in energy efficiency, where as others examine the effects of a specific energy efficiency policy. This study presents a new way out about the size of energy efficiency rebound effect. It concludes that overall, the existing studies provides little support for the growth effect of energy efficiency. However, the paper failed to give quantitative estimate of this relationship".

In a study conducted by Obindah, Morgan and Romanus [23] "on the relationship between energy intensity and economic growth in selected West African countries over the period 1988 to 2013 given data availability. The study adopted a panel fully modified least squares and panel dynamic least square. Their results indicate a positive association between energy intensity and economic growth (GDP) and GDP and electricity on the other hand. The study found that energy conservation and efficiency are needed to decide investment for the West African Power Pool (WAPP) and that energy efficiency policies and measures are also important even in countries with low access thereby increasing productivity per unit of energy consumed. The study concentrated on measurement only rather than relationship between energy intensity and economic growth. It also failed to consider an alternative measure of energy efficiency".

Philip and Xiujian [24] investigated how China was able to achieve medium term strong economic growth with desirable target for energy efficiency. The study covers the period 2017 to 2030. A large version of computable general equilibrium was used as a means of estimation. Their results indicate that without additional action the share of coal consumption in total energy consumption will be on the increase and that the renewable forms of energy will penetrate the energy market at a slow speed. The study concluded that a well designed energy policy is needed by the Chinese economy to meet the challenges of strong economic growth.

Pan, Chen, Ying and Zhang [25], analysed "the trend of energy utilization efficiency from 1990 to 2013 with a focus on 35 European countries. Empirical result revealed that Labour correlate negatively with energy efficiency. The result also showed that price fluctuation will increase price of energy with a resultant effect of reducing the country's energy efficiency. The study also found that energy efficiency and economic development revealed a quadratic U-shaped relationship suggesting that a long term energy efficiency of the country will first decline and then rise during economic activities".

The study conducted by Katherine, Pauline, Enrique and Michelle [26] on the need to enhance energy efficiency to increase affordability in residential lighting at Peru. The study used energy efficiency initiative to reduce expenditure by consumers for the same products or services. The initiatives include replacement of domestic appliance and equipment and the improvement of dwelling characteristics. The result of their study clarifies that the energy efficiency initiatives in developed economies varies from that of developing economies. The study observed that in developed countries, the initiatives design to improve energy efficiency will be successful if energy consumption is reduced. But in developing countries, the use of energy efficient technologies can lead to a higher consumption of energy which is a sign of affordability of energy services. The study focus only on measurement on energy efficiency. In another study conducted by Kwaku, Eric and Evelyn [27] on the energy efficiency assessment of 46 African countries. The study made use of three different methods namely the slack based measure, bootstrapped truncated regression and two stage least squares. The results from their study indicate that African countries was on the average of 50 percent energy efficient during the study period and that based on sub-regional comparison other African sub-regions could adopt the energy efficiency policy of North Africa as a bench mark to improve energy efficiency. It was also discovered that economic development and technological progress have a significant positive effect on energy efficiency on African economies, while higher energy price lead to higher inefficiency. The study focus only on measurement.

Nelson, Amowine, Zhiquangma, Mingxing and Zhixiang [28] conducted "a study on measuring dynamic energy efficiency for 25 selected African countries from 2007-2014 using a slack based approach. Their results suggest that the 25 selected African countries are far away of being energy efficient. The study concluded that both adjustments and projections on the inputs, output should be considered to enhance energy efficiency. The study focus on measurement only".

You, Lin, Kwang, and Wee [29] study "on the linkage between energy efficiency and economic growth in Malaysia from 1971-2013. The study used an autoregressive distributed lagged model. Their results indicate that energy efficiency granger cause economic growth at the aggregate level, but not in each of the three main sectors namely primary, secondary and tertiary of the economy. The result concluded that the policy maker in Malaysian should design appropriate policies in each sector that would lead to robust growth in the economy. Again, the policy maker should also look for an alternative strategy to achieve a long-run economic growth in the economy. The study is flawed because is sectorial in nature".

Rabia, Akram, Fuzhong, Fahad, Zhiweiye, and Mohammad [30] study on the heterogeneous effect of energy efficiency and renewable energy on economic growth in BRICS countries from 1990 to 2014.The study used panel quantile regression analysis. Their results reveal that the effect of energy efficiency on economic growth is significantly positive across all quantiles, but the effect is more pronounced at 50th and 60thquantiles of economic growth in BRICS countries. It was also discovered that the heterogonous panel causality test result confirmed the existence of feedback hypothesis between energy efficiency and economic growth in the BRICS countries. The findings also confirmed the existence of bi-directional causal relationship between renewable energy consumption and economic growth and a uni-directional causality existence between energy efficiency and renewable energy consumption. The study concluded that there should be more prolific use of energy in order to stimulate economic growth in BRICS countries through improvement in energy efficiency and renewable energy. It ignored non renewable energy.

In a study conducted by Leiw and Lixure (2020) "on the relationship between energy efficiency and energy consumption and its influencing factors in China. The study adopts HP filter analysis from 2002-2015. Their findings revealed that China's energy efficiency and economic growth is non-linear and that before the reform and opening up, China's output energy efficiency changed greatly. The growth energy efficiency remains stable in the long-run. While in the short run output energy efficiency relationship was influenced by fluctuation factors. The study projected that in preparing policy objectives and means of energy efficiency the long-run and the short-run must be separated. And that from the angle of sector specific based analysis, the loss of energy efficiency must be attributed to a short-run fluctuation factors, thus ensuring a stable economy is conducive to improving energy efficiency. The study is country specific in nature".

Navdeep, Bhadbhade, SelinYilmaz, Jibran, Wolfgang, Chhmmer and Martin [31] study on the evolution of energy efficiency in Switzerland in the period 2000-2016. The study made use of ODYSSEE energy efficiency index. a physical energy efficiency was analysedi.e the contribution of technical progress to energy efficiency improvement. The result found out that Switzerland improved its physical energy efficiency by 1.4 percent per annum in the period 2000-2016 with household being the fastest and the industry being the slowest improving sector. The study concluded that Switzerland needed to increase their rate of energy efficiency improvement in order to meet 2050 targets of Swiss energy strategy 2050. This study is country specific.

3. METHODOLOGY

3.1 Model Specification

Following the work of Huang [32] the study will consider a five-variable panel VAR comprising economic growth, capital stock, price level, employment, and a measure of energy efficiency. This study will consider two measures of energy efficiency. The first is energy intensity which is the share of energy consumed in GDP. The second measure is energy waste, which is the amount of energy wasted in economic activity.

The type of 5-variable panel VAR employed benefit from the work of Huang [32]. The five variables that will be employed are economic growth, energy intensity, labour, capital accumulation and price level. in the Huang [32], the subscripts i represents country both in SSA and in each of the regional blocs and represents the time period. Taking into consideration the individual effect, the 5-variable panel VAR model is specified as follows in equation 2:

$$Y_{i,t} = \sum_{i=1}^{p} \alpha Y_{j,t-i} + \beta''(L) X_{i,t} + \eta_{i,t} + v_{i,t} \quad (2)$$

Where $\eta_{i,t}$ is the unobserved country-specific and time-invariant effect with $E(\eta_{i,t}) = \eta$ and $Var(\eta_{i,t}) = \varepsilon_{\eta}^{2}$. The $v_{i,t}$ are assumed to be independently and identically distributed across countries with zero mean but with the presence of heteroscedasticity across countries and time. Since $\eta_{i,t}$ is assumed to follow a stochastic process of an individual effect, $E(Y_{i,t-1}\eta_i) \neq 0$ and $E(X_{i,t}\eta_i) \neq 0$, $\beta(L)$ is a polynomial lag operator (Huang, 2008). Consequently, equation 4 is expected to deviate from the OLS and hence the estimator is prone to biasedness. To deal with this problem, the equation is differenced as specified in equation 3

$$\Delta Y_{i,t} = \sum_{i=1}^{p} \alpha \Delta Y_{j,t-i} + \beta''(L) \Delta X_{i,t} + \eta_{i,t} + v_{i,t} \quad (3)$$

Although equation 5 was able to remove biasedness arising from the correlation between individual effect and explanatory variables, there is another problem generated, that is the correlate in between the lagged dependent and error term. This rendered the equation inconsistent and so, the Arellano and Bond [33] GMM is specified to overcome the problem. The basic panel VAR model is specified explicitly in equation 4

$$\begin{aligned}
\Delta Y_{i,t} &= \beta_1 \Delta Y_{it-1} + \beta_2 \Delta E_{it-1} + \beta_3 \Delta K_{it-1} + \beta_4 L_{it-1} + \beta_5 \Delta P_{it-1} + \varepsilon_{1it} \\
\Delta E_{i,t} &= \varphi_1 \Delta E_{it-1} + \varphi_2 \Delta Y_{i7-1} + \varphi_3 \Delta K_{it-1} + \varphi_4 \Delta L_{it-1} + \varphi_5 \Delta P_{it-1} + \varepsilon_{2it} \\
\Delta K_{i,t} &= \phi_1 \Delta K_{it-1} + \phi_2 \Delta Y_{it-1} + \phi_3 \Delta E_{t-1} + \phi_4 \Delta L_{it-1} + \phi_5 \Delta P_{it-1} + \varepsilon_{3it} \\
\Delta L_{i,t} &= \vartheta_1 \Delta L_{it-1} + \vartheta_2 \Delta Y_{t-1} + \vartheta_3 \Delta E_{t-1} + \vartheta_4 \Delta K_{it-1} + \vartheta \, \Delta P_{it-1} + \varepsilon_{4it} \\
\Delta P_{i,t} &= \zeta_1 \Delta P_{t-1} + \zeta_2 \Delta Y_{it-1} + \zeta_3 \Delta E_{it-1} + \zeta_4 \Delta K_{it-1} + \zeta_5 \mathrm{B} \Delta L_{it-1} + \varepsilon_{5it}
\end{aligned} \quad (4)$$

Where Y,E,K,L and P represent the GDP, energy efficiency (energy intensity and energy waste), capital accumulation, labour (employment) and price level respectively. It must be noted that all the variables will be transformed to their logarithmic form. The Δ stands for difference and the other letters are parameters. Equation 4 will be estimated for SSA as a whole and for each of the regional blocs. Hence, the implies country either in SSA (in the SSA model) or country belonging to a particular regional bloc.

The SYS-GMM for estimating 4 is specified in equation 5

$$\Delta Y_{i,t} = \alpha_0 + \beta_1 \Delta Y_{it-1} + \beta_2 \Delta E_{it} + \beta_3 \Delta K_{it} + \beta_4 L_t + \beta_5 \Delta P_{it} + v_{it} \quad (5)$$

Equation 5 is estimated for SSA as a whole and for each of the regional bloc.

4. RESULTS AND INERPRETATION

The results of the Unit Root test presented in Table 1, showed the Levin Lin and Chu statistics with their corresponding P-values. Result showed that the probability value in reference to each variable is smaller than the alpha value at 10%. Thus, the null hypothesis that the panel contains a unit root is rejected at 10% level of significance. Thus, all the specified variables (that is, EI, EW, GFCF, PL, LF are I (1) variables, while GDP is I(0) variable. Based on the Unit Root test, these variables would yield plausible regression output.

The SYS-GMM result in Table 2, the number of observations for the models ranges between 148 (Southern Africa) and 250 (West Africa) while the observation for the full sample (SSA) is 777. The result shows clearly the effect of each of the variables on economic growth when the proxy for energy efficiency is energy intensity. Using this proxy, energy efficiency did not significantly affect economic growth either in SSA as a whole or any of the regional bloc at 5% level of significance. Other variables in the growth model such as capital stock proxy by capital formation, employment and price level also fail to influence economic growth [124-133]. Meanwhile, price level positively impacted on the economic growth of East Africa. The result of the dynamic approach using the system –GMM provide a robust

Table 1. Results of the panel unit root test on Gross Domestic Product (GDP), Energy Intensity (EI), Energy Waste (EW), Labour Force (LF), Gross fixed capital formation (GFCF) and Real Price Level (PL)

Variable	95% Critical value of ADF	LLC test statistics	P-Value	Order of Integration	Remarks
D(EI)	164.209	-7.9334*	0.0000	I(1)	Stationary
D(EW)	184.377	-9.2328*	0.0000	I(1)	Stationary
(GDPGR)	129.668	-5.4072*	0.0000	I(0)	Stationary
D(GFCF)	228.836	-11.743*	0.0000	I(1)	Stationary
D(LF)	59.6404	0.7203***	0.0763	I(1)	Stationary
D(PL)	50.3167	1.8399***	0.0671	I(1)	Stationary

Source: Author's computation, using E-view 10, 2021
*Note: * = significant at 1%, ** = significant at 5%, *** = significant at 10%*

Table 2. Dynamic panel data (Sys-GMM) showing the effect of energy efficiency (energy intensity) on economic growth

Variables	SSA	West Africa	East Africa	Southern Africa	Central Africa
Growth rate$_{-1}$	0.193*** (7.49)	0.0943 (0.77)	0.0563 (1.02)	0.0535 (0.35)	0.172 (1.62)
Energy intensity$_{-1}$	-3.321 (-1.83)	-1.448 (-1.77)	-0.665 (-0.48)	-2.429 (-0.95)	-3.24 (-0.64)
Price$_{-1}$	-0.186 (-0.32)	0.763 (0.88)	1.730*** (4.14)	-0.749 (-1.21)	-6.517 (-1.43)
Capital formation$_{-1}$	6.208 (1.63)	-0.105 (-0.10)	-0.247 (-0.21)	0.666 (0.35)	7.789 (1.74)
Labour force$_{-1}$	-0.943 (-1.02)	0.00488 (0.01)	0.623 (1.52)	2.344 (1.57)	-0.846 (-0.63)
Constant	7.209 (0.51)	4.513 (0.70)	-11.77 (-1.92)	-26.51 (-0.97)	-13.24 (-0.49)
Observations	777	250	220	148	159
Number of groups	42	14	12	8	8
Wald test	299.1	23.21	180.1	88.38	27271.3
Number of instrument	324	259	237	183	189
Sargan (probability)	0.39	0.61	0.58	0.94	0.27

Source: Author's Computations using Stata 13.1, 2021
Note: values in the parentheses are t-value
****, **, * indicate significant at 1%, 5% and 10% respectively*

negative correlation between energy intensity and economic growth in SSA and all other regional bloc. The coefficient of energy intensity is highly insignificant which implies that reductions in energy intensity are not linked to higher GDP growth. This is evident from the coefficient of the lag values of energy intensity of one period value of -3.321.

Though, previous studies has long discussed negative correlation between energy intensity and economic growth for developed countries [67-78]. Our findings confirm such a negative relation not only for sub-Sahara Africa but also at each regional bloc. The rationale for negative correlation might be attributed to common patterns of structural change, paired with rising after tax energy prices, bring about an efficient use of energy along the balanced growth path, that is, at given rates of technological progress [79-84].

This economic transition has been on since the oil shocks of 1970s such that a lower energy taxation is consistent with a small government size. In the same vein, the previous studies such as [34,35] has presumed a production technology that incorporates imperfect substitution between capital and energy [134-141]. Summarily, the result suggests that capital deepening at a given rate of technological progress might bring about efficient use of energy along the trajectory to the balanced growth the path.

5. DISCUSSION

The study conducted a unit rot test using Levin Lui Chu statistics and it found that there were variation in the order of integration in term of I(0) and I(1) which implies that the series were stationary at levels and at first difference and as a result the study went further to conduct a post estimation test using dynamic panel method via the system GMM showing the impact of energy intensity on economic growth in selected countries in sub- Saharan-Africa [111-123].

It can be inferred that the coefficient value of energy intensity at lag order (1) is negatively correlated with economic growth in sub-saharan Africa as a whole and each of its regional bloc which indicates that a reduction in energy intensity does not boost economic growth. These findings corroborate the work of (Atkenson, Kehoe, Diaz and Puch, 2016). It can also be deduced that price level impacted on economic growth positively but insignificant in East Africa due to the peculiarities of East African economy [85-110]. From the result it showed that the lower level of energy intensity is associated with higher total factor productivity in East Africa.

6. CONCLUSION

The study investigated the effects of energy efficiency on economic growth. A 5-variable VAR model was employed alongside SYS-GMM to estimate our augmented growth model that incorporates energy efficiency as one of the sources of economic growth. The result covered all the 48 countries of SSA between 1970 and 2019. The countries were decomposed into four regional blocs, namely Eastern Africa, Central Africa, Southern Africa and West Africa.

The result shows different causation between energy efficiency and economic growth. This diverse results was consistent with the study of Ayres (2010) among others. Bi-causal relationship was more pronounced in the Central Africa when energy intensity was used as a proxy. A negative bi-causal relationship was noticed in the region and this suggests that energy intensity causes and is caused by economic growth. Thus it can be concluded that in the Central Africa, when energy intensity is a proxy for energy efficiency, both variables (economic growth and energy intensity) reinforces each other. This result is consistent with the findings of Soytas [36] where it was found that bi-causal relationship exists between energy efficiency and economic growth in Argentina. It also conformed with the works of Lee [37] which shows a bidirectional relationship between energy efficiency and economic growth in the US.

Regional bloc that exhibits unidirectional relationship running from energy efficiency to economic growth is West Africa and Southern Africa. These regional blocs have more countries endowed with energy than others and it is not surprising to discover that energy drive growth in the regions. The unidirectional causation running from energy intensity to economic growth in West Africa and Southern Africa region supported the works of Soytas [39] in the case of Turkey, Lee [38] in the case of developing countries and Lee [40] in the case of Canada, Belgium, Netherlands, and Switzerland. The unidirectional causality from energy intensity to economic growth implies that reducing energy intensity does not adversely affect GDP in the shortrun but would in the longrun. Thus West Africa and Southern Africa have enough fossil fuel resources to meet the regional energy needs. On this note, the two regions should adopt a more vigorous energy policy.

In Southern Africa, there was a bi-causal relationship between energy waste and economic growth. The negative sign suggests that in this region, decrease in energy waste and economic growth reinforces each other. The bi-directional causality between energy waste and economic growth implies that energy conservation may be viable without being detrimental to economic growth. Thus the focus should be energy waste reduction rather than energy intensity reduction. No causality was found between energy waste and economic growth in West Africa, East Africa and Central Africa. This result was in line with the findings of Hendonoyiannis et al (2002) and Huang et al. (2008). The fact that causality runs in different form and direction across the regional blocs implies that recommendations should be provided on regional-specific basis.

7. RECOMMENDATIONS

The essence of this research work is to examine the effect of energy efficiency on economic growth in SSA as a whole and each of the SSA regional bloc. The discovery is expected to allow for policy recommendations which will aid policy directive on whether growth should be focused in order to achieve energy conservation or the other way round. Going by our results, policy recommendations will be regional based because energy efficiency and economic growth causes each other in different forms across the regional blocs.

Our results show that energy intensity is important for growth in some regional blocs while in others, reduction in energy waste is good for economic growth. Yet in some other situation, growth improvement does not influence energy efficiency. Yet in some regions, where energy intensity does not influence economic growth, reduction in energy waste does.

A regional bloc that exhibit bi-causal relationship when energy intensity was proxy for energy efficiency is Eastern Africa. Meanwhile, direction of causation is not the same. Specifically, increase in energy intensity causes economic growth while increase in economic growth causes reduction in energy intensity. Thus, it is recommended that the Eastern Africa policy makers should embark on policies that will raise economic growth rather than focusing on energy conservation. In West Africa and Southern Africa, energy conservation will reduce economic growth. Since there is no causation running from economic growth to energy intensity in these regions, they should also focus on economic growth rather than energy conservation policy.

The case of Central Africa is different in the sense that the direction of causation is negative, suggesting that reduction in energy intensity causes economic growth. Therefore, the authorities are advised to implement policy of energy conservation in this region.

8. LIMITATION OF THE STUDY

The study is limited on the ground that since energy efficiency has no universal measurement, the study measurement was only limited to energy intensity, meanwhile there are other measurement which the study ignores as proxy variables and this includes energy waste and energy productivity.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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