Energy Consumption and Economic Growth: Evidence from the West African Sub Region

D. K. Twerefou[1*], K. S. Iddrisu[1] and E. A. Twum[2]
[1] *Dept. of Economics, University of Ghana, Legon, Ghana*
[2] *United Nations University - Institute for Natural Resources in Africa (UNU-INRA)*
* Corresponding author: Email: *dktwerefou@ug.edu.gh, twerefou@yahoo.co.uk*

Abstract

The availability of reliable energy supply to meet the demand of the growing population in West Africa is important for achieving not only economic growth but also meeting the sustainable development aspirations of the subregion. However, conflicting conclusions have been espoused on the energy-growth nexus with little information on the nexus in the sub-region. In this study we employ the panel cointegration techniques and data on total energy consumption, electricity consumption and petroleum consumption to establish the causal relationship between energy consumption and economic growth for the seventeen countries in the West African sub region. The results indicate that in the short run, there is no causal relationship running from total energy, electricity and petroleum consumption to growth. However, there is a unidirectional relationship running from growth to electricity consumption indicating that conservation policies in electricity may not have effect on economic growth. In the long run however, electricity and petroleum consumption were found to have a positive and significant impact on growth suggesting that policy choices should focus on enhancing the generation of these types of energy.

Introduction

It is widely accepted that the availability of efficient energy services is an essential driver of economic growth and development in that access to enhanced health, education and better economic opportunities are dependent on efficient energy supply (Pokharel, 2007; Augutis *et al*., 2011). The West Africa sub region is well endowed with energy resources such as solar, wind, hydro, biomass, among others that can be harnessed to meet domestic energy requirements and enhance growth. Notwithstanding this energy potential in the subregion, energy consumption, more specifically, electricity consumption is very low (Economic Commission for Africa, 2004) with more than two-thirds of its populace not having access to modern energy (International Energy Agency, 2014). In the midst of this energy challenge, growth in the sub-region has been slow in the 1990s averaging about 3% partly as a result of slow growth rate experienced by large economies such as Nigeria and political instabilities in some of these countries, but has improved to about 6 % in 2014.

Stern (2006) has provided a comprehensive analysis of the economics of climate change which reveals that impacts will be high if measures are not taken to curb greenhouse gas (GHG) emissions. According to the International Energy Agency, one major source of emission is the energy sector as it accounts for about two-thirds of global GHGs emissions (International Energy Agency, 2017) and a significant input to every production process. Ensuring that the sub-region pursues its growth aspiration without excessively increasing GHGs emissions, especially in the energy sector through efficient policy mix on energy conservation will require a careful analysis of the causal relation between energy consumption and economic growth.

Behera (2015) provides four theoretical causal relations between energy consumption and economic growth. The first is a unidirectional causality running from energy consumption to growth which could imply that energy is an important element in the growth process and therefore a reduction in energy generation as

West African Journal of Applied Ecology, vol. 26(SI), 2018: 242 - 258

TABLE 1
Summary of empirical results of growth - energy consumption nexus

Author(s)	Time span	Countries	Methodology	Results
Masih & Masih (1996)	1955-1990	6 Asian countries	Error Correction model	TE→GDP in India, GDP→ TE in other countries.
Lee and Chang (2008)	1971-2002	16 Asian countries	Panel Cointegration and ECM.	GDP→ TE
Huang et al., (2008)	1971-2002	82 low, middle and high income countries	Panel GMM	GDP→ TE for middle high income countries. Neutrality in low income countries.
Apergis & Payne (2009)	1980 - 2004	6 Central American countries	Panel ECM	TE→GDP
Ozturk et al., (2010)	1971-2005	51 developing countries	Panel ECM	GDP~TE
Lu (2016)	1998-2014	17 Taiwanese industries	Panel Cointegration and ECM	ELEC ⇔ GDP
Yasar (2017)	1975-2015	119 countries	Panel ARDL	Mixed results.
Wolde-Rufael (2006)	1971-2001	17 African countries	ARDL	GDP→ ELEC for six countries, ELEC→GDP for 3 countries and bidirectional for 3 countries.
Akinlo (2008)	1980-2003	11 SSA countries	ARDL	GDP→ TE for 2 countries, bidirectional for 3 countries, GDP~TE for 5 countries.
Esso (2010)	1970–2007	7 SSA countries	Panel Cointegration	GDP→ TE
Ouedraogo (2013)	1980-2008	15 West African countries	Panel ECM	GDP→ ELEC
Bildirici (2013)	1970-2010	Cameroon, Cote D'Ivoire, Congo, Ethiopia, Gabon, Ghana, *Guatemala,* Kenya, Senegal, Togo and Zambia	ARDL bounds test and Vector error correction	ELEC ⇔GDP in Ghana, Gabon and Guatemala. ELEC→ GDP in Cameroon, Congo Rep., Ethiopia, Kenya, Mozambique and GDP→ELEC in Senegal and Zambia.
Enu & Havi (2014)	1980-2010	Ghana	Vector error correction model	ELEC→ GDP
Behmiri & Manso (2013)	1985-2011	23 sub-Saharan African countries	Panel Granger causality	CO ⇔ GDP
Nondo et al., (2010)	1985-2008	19 African countries	Vector error correction model	GDP~TE

Source: Update from Ozturk et. al (2010)

Note: GDP→ELEC means causality runs from GDP growth to electricity consumption. ELEC→GDP means causality runs from electricity consumption to GDP growth.
ELEC⇔ GDP means bi-directional causality exists between electricity consumption and growth. GDP~TE means no causality exists between growth and total energy consumption.
GDP→TE means causality running from growth to total energy consumption, TE→GDP means causality running from total energy consumption to growth. CO ⇔ GDP means bi-directional causality between crude oil consumption and growth.

well as inconsistent and insufficient energy supply would have dire consequences on economic growth. Where such a causal relation exists, policies that would ensure sustained energy supply are desirable. Secondly, there can be a unidirectional causality running from growth to energy consumption. The policy implication is that energy conservation measures can be implemented as it would have an insignificant effect on growth. The third is bi-directional causality running from energy consumption to economic growth and from economic growth to energy consumption concurrently. This implies that policies that would heighten energy consumption could be implemented as it will spur economic growth together with energy conservation measures. Fourthly, there could be a neutral relationship which would imply that promotion of energy consumption measures would have no influence on economic growth.

A comprehensive literature survey on the energy consumption-growth nexus has been provided by Ozturk (2010) suggesting that the topic is of interest and has been well investigated. Summary of the empirical literature on the topic as presented in Table 1 reveals that results have been mixed and that many of the studies especially those in Africa had focused more on the causal relationship between electricity consumption and total energy consumption. Little emphasis has been paid to the causal relationship between petroleum consumption and growth even though data from the International Energy Statistics shows that petroleum consumption constitutes an important source of energy consumed in West African. In addition, none of the studies had comprehensively disaggregated total energy into the various components. This study fills this gap by disaggregating total energy into electricity and petroleum and investigating the causal relationship between these energy types and economic growth in West Africa, thus, allowing us to provide a comprehensive picture of the causal relationship.

Analysis on this issue is important because, even though the contribution of the sub-region to global GHGs emissions is insignificant, projections by Marchal et al. (2011), indicate that it will increase by about 50% in 2050 in the absence of emission reduction policies while Adom and Amuakwa-Mensah (2016) argue that rapid economic growth and urbanization has the potential to significantly increase emissions. It therefore becomes imperative to access the causal relationship between energy consumption and economic growth in order to enable the sub-region identify the right energy conservation policy choices that will ensure growth without compromising environmental quality.

Methodology

Theoretical framework

The study employs the Solow (1956) and Swan (1956) growth model in a Cobb Douglas form that explains how factors of production drive growth and specified as:

$$Y_t = K_t^{\alpha}(A_t L_t)^{1-\alpha} \ldots\ldots\ldots..(1)$$

where Y is output, K is capital, L is labour and A is efficiency. The level of efficiency A is explained by the equation;

$$A = A_0 e^{g_t + \rho_t \theta} \ldots\ldots..(2)$$

where g is the rate of technological progress assumed to be constant; ρ is the vector representing all the other factors such as energy consumption that may possibly influence the level of technology and productivity in the economy; θ is the vector of coefficients associated with these variables; A_0 is a constant; and the subscript t denotes time.

Using Solow (1956) output model, the efficiency level and investments, it can be established that

$$\ln\left(y_{i,t}\right)^* = \ln\left(A_{0,t}\right) + \theta_i ENER_{i,t} + \frac{\alpha}{1-\alpha}\ln\left(s_{k_{i,t}}\right) - \frac{\alpha}{1-\alpha}\ln\left(n_{i,t} + g + \delta\right) \ldots\ldots(3)$$

(see Amar, 2013 for details)

where $\frac{Y_i}{L_i} = y_i^*$ is the output per labour at equilibrium for every country and ENER represents energy consumption.

The Empirical Model

Based on the theoretical framework (equation 3), we specify our empirical model that establishes the linkage between total energy consumption and growth as:

$$LGDPC_{it} = \alpha_i + \beta LENER_{it} + \varepsilon_{it} \ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

Where LGDPC is natural logarithm of GDP per capita; and LENER represents total energy consumption; *i* is individual country identifier; and *t* denotes time.

Olofin et al. (2014) argue that the various types of energy consumed could have different impacts on growth. Thus, we estimate a second model (equation 5) that disaggregates energy consumption into electricity and petroleum as:

$$LGDPC_{it} = \alpha_i + \beta ELEC_{it} + \delta PE + \varepsilon_{it} \ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

Where ELEC is electricity consumption and PE is petroleum consumption.

Following the work of Odhiambo (2008), equation (4) and (5) are estimated separately to reduce the incidence of multicollinearity.

Description of variables and estimation techniques

The variables employed in the study are outlined in Table 2. Following the work of Ozturk et al. (2010) and Esso (2010), this study employs a panel approach in investigating the relationship between energy consumption and economic growth due to its ability to account for individual unique characteristics as well as detecting and controlling for multicollinearity (Baltagi, 2005).

We use the Im, Pesaran and Shin (IPS) (2003) test and Levin, Lin and Chu (LLC) (2002) panel unit root test to test for the stationarity of the series and three panel cointegration test: Pedroni (1999), Kao's (1999) and Fisher's tests to estimate for the long run relationship between the variables.

TABLE 2
Variables definition and justification

Variables	**Definition of variable**	**Empirical justification of variable**
GDP Per Capita (in constant 2005 US dollars).	Total production of goods and services in an economy over a period of a year divided by the total population	Ouedraogo (2013), Akinlo (2008),
Total Energy consumption	Consumption of primary energy	Odhiambo (2008), Huang et al., (2008)
Electricity consumption (billion kwt hr)	Total amount of electricity consumed in a country for various purposes	Sama & Tah (2016), Lu (2016).
Petroleum consumption (mtoe)	Consumption of petroleum energy in the domestic country	Sama & Tah (2016), Behmiri & Manso (2013); Olusanya (2012).

Source: Constructed by Authors

Estimating the long run relationship

In panel data analyses, once the regressors are not strictly exogenous, using ordinary least squares to estimate long run relationship may lead to biased estimates of the parameters. The study therefore employs the Fully Modified Ordinary Least Squares (FMOLS) and the Dynamic Ordinary Least Squares (DOLS) proposed by Pedroni (2001) to establish the long run relationship between the variable once cointegration is established. The FMOLS estimators is given as:

$$\beta^{*}_{FMOLS} = N^{-1}\sum_{1}^{N}\left(\sum_{t=1}^{T}(ENER_{it}-\overline{ENER}_{i})^{2}\right)^{-1}\left(\sum_{t=1}^{T}(ENER_{it}-\overline{ENER}_{i})y^{*}_{it}-T\frown\gamma_{i}\right)..(6)$$

while the DOLS estimators is computed as:

$$\beta^{*}_{DOLS} = N^{-1}\sum_{i=1}^{N}\left(\sum\nolimits_{t=1}^{T} Z_{it}Z^{i}_{it}\right)^{-1}\left(\sum_{t=1}^{T} Z_{it}Y^{*}_{it}\right)\dots\dots\dots.(7)$$

Where Z_{it} is a $2(K+1)$ vector of regressors (Ouedraogo, 2013).

Testing for causality

Having established the presence of Cointegration among the variables, it becomes imperative to carry out the granger causality test to ascertain the causal relationship among the variables. The expression for the granger causality test which is based on an error correction model is specified as:

Where Δ denotes the difference operator; EC_{t-1} is the lagged error correction term derived from the long-run cointegration relationship; α_i, β_i, and λ are adjustment coefficients; q is the number of lags determined by the Alkaike Information Criterion (AIC) and Schwarz information criterion (SIC) and μ is the serially uncorrected error term.

The study involves all the seventeen countries in West Africa: Benin, Burkina Faso, Cote d'Ivoire, Cabo Verde, The Gambia, Ghana, Guinea, Guinea Bissau, Niger, Nigeria, Mali, Mauritania, Senegal, Liberia, Sao Tome and Principe, Sierra Leone and Togo. Data on electricity consumption and petroleum energy consumption were obtained from the United

$$\Delta LGDPC_{it} = \alpha_{1i} + \sum_{k=1}^{q}\beta_{11ik}\Delta LGDPC_{it-k} + \sum_{k=1}^{q}\beta_{12ik}\Delta LENER_{it-k}$$
$$\lambda EC_{it-1} + \mu_{it}$$

$$\Delta LENER_{it} = \alpha_{1i} + \sum_{k=1}^{q}\beta_{11ik}\Delta LENER_{it-k} + \sum_{k=1}^{q}\beta_{12ik}\Delta LGDPC_{it-k}$$
$$+\lambda EC_{it-1} + \mu_{it}$$

$$\Delta LGDPC_{it} = \alpha_{1i} + \sum_{k=1}^{q}\beta_{11ik}\Delta LGDPC_{it-k} + \sum_{k=1}^{q}\beta_{12ik}\Delta ELEC_{it-k}$$
$$+\sum_{k=1}^{q}\beta_{13ik}\Delta PE_{it-k} + \lambda EC_{it-1} + \mu_{it}$$

$$\Delta ELEC_{it} = \alpha_{1i} + \sum_{k=1}^{q}\beta_{11ik}\Delta ELEC_{it-k} + \sum_{k=1}^{q}\beta_{12ik}\Delta LGDPC_{it-k}$$
$$+\sum_{k=1}^{q}\beta_{13ik}\Delta PE_{it-k} + \lambda EC_{it-1} + \mu_{it}$$

$$\Delta PE_{it} = \alpha_{1i} + \sum_{k=1}^{q}\beta_{11ik}\Delta PE_{it-k} + \sum_{k=1}^{q}\beta_{12ik}\Delta LGDPC_{it-k}$$
$$\sum_{k=1}^{q}\beta_{13ik}\Delta ELEC_{it-k} + \lambda EC_{it-1} + \mu_{it}$$

States Energy Information Administration while that for GDP per capita and total energy consumption were sought from the World Development Indicators (2016). The data spans from the period 1980 to 2015.

Results and Discussion

Panel unit root test results

The results of the IPS panel unit root test are reported in Table 3 and that of the LLC as Appendix 1.

The IPS test concluded that the null hypothesis of unit root cannot be rejected at 1% significance level for all the variables. Therefore, the variables are non-stationary at levels but become stationary at first difference. Similar results were obtained for the LLC test (Appendix 1)

Results of Cointegration

The results of cointegration are presented for total energy consumption and GDP Per Capita as well as electricity consumption, petroleum consumption and GDP Per Capita. The results from the Pedroni panel cointegration test for total energy consumption (Table 4) lead to the conclusion of no long run relationship between GDP Per Capita and total energy consumption since the probability values generated by the within and between dimensions of the Pedroni test are all not significant and hence the null hypothesis of no cointegration is not rejected. Similar result was obtained for the Kao residual cointegration test (see Appendix 2).

The AIC and SIC performed to determine the optimal lag length in performing the Fisher

TABLE 3
IPS Unit root test

Variables	At levels		At first difference		Order of integration
	W - statistics	Probability value	t statistics	Prob. value	
GDP Per Capita	2.24502	0.9876	-14.5679***	0.0000	I(1)
Total Energy Consumption	0.87863	0.8102	-4.87547***	0.0000	I(1)
Electricity Consumption	9.86622	1.0000	-21.4229***	0.0000	I(1)
Petroleum Consumption	6.17016	1.0000	-17.7604***	0.0000	I(1)

Source: Computed by Authors using Eviews 9.
Note: ***, ** and * indicate the statistical significance of the estimated parameters at 1%, 5% and 10% respectively.

TABLE 4
Results of Pedroni Panel test Cointegrating (GDP Per Capita and Total Energy Consumption)

Alternative hypothesis: common AR coefs. (within-dimension)				
	Statistic	Prob.	Weighted Statistic	Prob.
Panel v-Statistic	0.429698	0.3337	-0.370485	0.6445
Panel rho-Statistic	-0.059573	0.4762	0.162618	0.5646
Panel PP-Statistic	-0.155580	0.4382	0.095177	0.5379
Panel ADF-Statistic	0.270005	0.6064	0.381884	0.6487

Alternative hypothesis: individual AR coefs. (between-dimension)		
	Statistic	Prob.
Group rho-Statistic	1.035942	0.8499
Group PP-Statistic	-0.556300	0.2890
Group ADF-Statistic	-0.358336	0.3600

Source: Computed by Authors using Eviews 9.

test indicated an optimal lag length of one. The results of the Fisher test for cointegration (Table 5) rejected the null hypothesis at 1% level of significance indicating that the variables have a long run relationship with at most two cointegration equations.

The results from the Pedroni panel cointegration test between GDP and Electricity consumption, and petroleum consumption (Table 6) indicate that seven out of the eleven test statistics have probability values less than 0.1 and therefore the variables have a long run relationship. Conversely, the Kao residual cointegration test between GDP, electricity and petroleum consumption (Appendix 3) concludes that the variables have a long run relationship since the probability value of 0.0019 implies that the null hypothesis of no cointegration cannot be rejected at 1% significance level.

The AIC and SIC indicate an optimal lag length of one. The results of the Fisher test for conitegration (Table 7) rejected the null hypothesis at a 1% level of significance indicating that the variables have a long run relationship with at most two cointegration equations.

Estimating the long run Relationship and Policy Implications

Having established the existence of long run relation between the variables, we use the FMOLS and the DOLS to estimate the nature of this long run relationship. Ouedraogo (2013) argues that the FMOLS produces more robust results and requires less assumptions compared to the DOLS, and therefore forms the focus of our discussion. The results of the DOLS is reported in Appendix 4.

Results of the FMOLS (Table 8) show that in the long run, total energy consumption has a negative and significant impact on GDP. A 1% increase in energy consumption in the long

TABLE 5

Fisher Cointegration test (GDP and total energy consumption)

Hypothesized No of CE.	Fisher stats (Trace test)	Prob. value	Fisher test (Max-eigen value)	Prob. value
None	37.15***	0.0000	38.86***	0.0004
At most 1	12.58***	0.5595	12.58***	0.5595

Source: Computed by Authors using Eviews 9.

Note: ***, ** and * indicate the statistical significance of the estimated parameters at 1%, 5% and 10% respectively

TABLE 6

Pedroni Cointegration test (GDP, Electricity consumption and petroleum consumption)

Alternative hypothesis: common AR coefs. (within-dimension)				
	Statistic	Prob.	Weighted Statistic	Prob.
Panel v-Statistic	2.826710	0.0024***	0.618473	0.2681
Panel rho-Statistic	-0.719868	0.2358	-0.510445	0.3049
Panel PP-Statistic	-1.445245	0.0742*	-1.571804	0.0580*
Panel ADF-Statistic	-2.156041	0.0155**	-1.617479	0.0529*

Alternative hypothesis: individual AR coefs. (between-dimension)		
	Statistic	Prob.
Group rho-Statistic	0.821504	0.7943
Group PP-Statistic	-1.361984	0.0866*
Group ADF-Statistic	-1.502827	0.0664*

Source: Computed by Authors using Eviews 9

TABLE 7
Fisher Cointegration test (GDP, electricity and petroleum consumption)

Hypothesized No of CE	Fisher stats (Trace test)	Prob. value	Fisher test (Max-eigen value)	Prob. value
None	98.11***	0.0000	82.64***	0.0004
At most 1	43.16***	0.1348	39.42***	0.2403
At most 2	40.07	0.2190	40.07	0.2190

Source: Computed by Authors using Eviews 9

TABLE 8
FMOLS Results

Dependent variable	Independent variables		
GDP Per Capita	Total Energy	Electricity	Petroleum Consumption
	-0.139887***	0.107273***	0.058452***
	(0.0000)	0.0010	0.0023

Source: Computed by Authors using Eviews 9
Note: ***, ** and * indicates the statistical significance of the estimated parameters at 1%, 5% and 10% respectively

run reduces growth by 0.14%. This results contradicts the findings of Ouedraogo (2013); Ozturk et al (2010).

A plausible explanation for this finding is that in West Africa, a look at the components of total energy consumed reveals that traditional biomass constitutes a greater proportion. Specifically, about 80% of energy consumed is traditional biomass (Adenikinju, 2008). This trend is unlikely to change substantially in the long run notwithstanding the attempt to introduce the consumption of modern fuels in the form of LPG gas, kerosene among others and to increase access to electricity (Karekezi et al., 2008). The consumption of biomass has several negative effects ranging from health to environmental problems (Ravindranath & Rao, 2005). The incomplete and inefficient burning of wood fuels indoors by households is the cause of diseases such as pneumonia which is estimated to be the major cause of premature deaths (Bruce et al., 2000; Ruta, 2010). The WHO (2006) argues that indoor air pollution causes about 1.5 million premature deaths and a greater proportion of these deaths (more than 85%) are due to the use of biomass. Arbex et al., (2004) have argued that the burning of biomass indoors for cooking and the smoke generated through this activity has led to diseases such as pulmonary infections and this primarily affects developing countries. The United Nations Environment Programme stipulates that the continued use of biomass in Africa exposes an estimated 90 percent of the populace to the undesirable health effects of biomass use. For this reason, the continued consumption of biomass is likely to endanger the health of the population in the long run. As stipulated by Cole & Neumayer (2006), poor health in a country has negative consequences on productivity.

More so, the use of biomass has undesirable effects on the environment. Ravindranath & Rao, (2005) argue that the use of biomass leads to deforestation. The Food and Agriculture Organization (2010) also stipulates that the tropical forest is diminishing at a rate of 5 percent per annum as they are cleared to serve as agricultural land, provide biofuels, among others, while Houghton (2005) estimates that about two billion tonnes of carbon are released into the atmosphere due to the activities of deforestation. A ramification of deforestation is the increase in GHGs which causes climate change (Chakravarty et al., 2012) and has the potential to affect productivity negatively.

Thus, the negative effects of traditional biomass use is likely to reduce GDP in the long run.

Electricity consumption has a positive and statistically significant impact on GDP in the long run. Specifically a 1% increase in energy consumption in the long run increases growth by 0.11%. This finding is corroborated by Bildirici (2013); Enu & Havi (2014); Lu (2016). A plausible explanation for the long run positive impact of electricity consumption on growth is that, growth is driven by the services sector in most West African countries and to some extent the industrial sector. According to Hollinger and Staatz (2015), the services sector dominates the economy, contributing 42% to GDP on average for the past decade. The agricultural sector accounts for 35% and then the industrial sector (23%). Energy use in agriculture is significantly low in the sub region due to the fact that agriculture is mainly subsistence (Breman, 2003). Conversely, electricity is used predominantly in the services and the industrial sector as electricity is needed to drive processes in those sectors (Bergasse et al., 2013; Cali et al., 2008). For this reason, the services and industrial activities which drive growth will increase electricity consumption.

Also, petroleum consumption has a positive and statistically significant relationship with GDP. An increase in petroleum consumption by one unit increases GDP Per Capita by 6%. This finding is similar to that of Behmiri & Manso (2013); Olusanya (2012). Petroleum is used mainly in the transport sector and in the generation of electricity through thermal plants. In West Africa, road transport is the most dominant mode of transportation as it facilitates movement of persons and goods in Africa and accounts for an estimated 80% of goods and 90% of passenger traffic (UNECA, 2009). For this reason, an increase in GDP will consequently result in an increase in transport services (Muktar, 2011). More so, an increase in transport services subsequently results in an increase in fuel consumption as a significant component of energy supply is consumed by the transport sector (Alam et al., 2013; Kahn-Ribeiro et al., 2007).

Furthermore, in West Africa, public transport remains poorly organized and under-developed. Most of the countries lack a proper and formal public transport system (Trans-Africa consortium, 2008). A ramification of the lack of a mass transport system coupled with the lack of comfortability, accessibility with regards to the existing public transport system is the proliferation of private cars which could result in an increase in fuel consumption. This is because private cars are less fuel efficient compared to mass transportation using commercial vehicles (Akoena and Twerefou, 2000). The increase in petroleum consumption, all others things being equal, increases GDP.

Again, Porter (2012) argues that many roads in West Africa are in poor conditions notwithstanding the colossal investments in road network that have been made over the years. This poor nature of roads has led to the excessive use of Sport Utility Vehicles (SUV) which are known to consume more fuel relative to saloon cars. The increase in use of SUV's therefore increases petroleum consumption which, all other things being equal, will increase GDP. Also, Coffin et al., (2016) find that in low income countries, there is a taste or preference for used vehicles. Again, fuel efficiency worsens with the age of vehicles (Sustainable Energy Consumption in Africa, 2004). As used vehicles are relatively older than new vehicles, it is expected that used vehicles are more fuel inefficient. Therefore, the prevalent use of used vehicles tend to increase fuel consumption which increases GDP.

Again, electricity consumption is expected to increase in the long run if growth is to be propelled by the services and the industrial sector as has been argued earlier. In recent times, there is gradual shift from the generation of electricity using hydro power to the generation of electricity using thermal plants (Acheampong, 2016). Also, Harto et al. (2012) stipulate that issues of climate change that have consequently led to unexpected drought at certain times has affected hydro generation of electricity than thermoelectric generation. Additionally, the high initial cost of renewable energy such as solar and wind has significantly resulted in relatively lower investments in renewables (Vandaele & Porter, 2015). Therefore, increase in growth will lead to an increase in electricity consumption which will consequently increase petroleum consumption.

Short run analysis and discussions

From the short run results (Table 9) total energy consumption has an insignificant impact on growth together with electricity and petroleum consumption. However electricity consumption has a positive and statistically significant relationship with GDP in the short run as a 1% increase in GDP increases electricity consumption by 0.0008 billion kilowatt-hour. Also, electricity consumption has a statistically significant positive relationship with petroleum consumption in the short run as a unit increase in electricity consumption increases petroleum consumption by approximately 0.06 units. Evidently, none of the error terms is negative and statistically significant indicating that there is no long run causal relationship running from total energy

TABLE 9
Results of short run analysis

Dependent variable	Independent variables					
$DLGDPC_t$	$DLGDPC_{t-1}$	$DLENER_{t-1}$	$DELEC_{t-1}$	DPE_{t-1}	ECT_{t-1}	ECT_{t-1}, LGDPC, ELEC, PE
	----	0.044435	-0.004800	0.006214	-0.000254	2.35
		(0.2650)	(0.3334)	(0.4816)	(0.8034)	0.1077
$DLENER_t$	$DLENE_{t-1}$	$DLGDPC_{t-1}$			ECT_{t-1}	
	----	0.010498			0.002762	
		(0.8171)			(0.0406)	
$DELEC_t$	$DELEC_{t-1}$	$DLGDPC_{t-1}$		DPE_{t-1}	ECT_{t-1}	
	-----	0.080375		0.001437	0.001021	
		(0.0564)*		(0.9688)	0.0000	
DPE_t	DPE_{t-1}	$DLGDPC_{t-1}$	$DELEC_{t-1}$			
	-----	0.031051	0.056492		0.000393	
		(0.2965)	(0.0687)*		(0.0001)	

Source: Computed by Authors using Eviews 9.

Note: ***, ** and * indicate the statistical significance of the estimated parameters at 1%, 5% and 10% respectively; p-values are given in brackets and ECT shows the estimated error-correction term.

TABLE 10
Error correction based Causality test

	Dependent variable D(LGDPPC)	Causality direction
D(LENER)	1.248978 (0.2650)	ENER↮GDP
D(ELEC)	0.937307 (0.3334)	ELEC↮GDP
D(PE)	0.495921 (0.4816)	PE↮GDP
	Dependent variable D(LENER)	
D(LGDPPC)	0.053622 (0.8171)	GDP↮ENER
	Dependent variable D(ELEC)	
D(LGDPPC)	3.655941 (0.0564)	GDP→ELEC
D(PE)	0.001533 (0.9688)	PE↮ELEC
	Dependent variable D(PE)	
D(LGDPPC)	1.092166 (0.2965)	GDP↮PE
D(ELEC)	3.328293 (0.0687)	ELEC→PE

Source: Computed by Authors using Eviews 9
Notes: Figures represent F-statistic values; p-values are given in brackets, ECT represents the estimated error-correction term, "X"↮ "Y" indicates no causal relationship between "X" and "Y", "X" → "Y" indicates causality running from "X" to "Y, and ***, ** and * indicated the statistical significance of the estimated parameters at 1%, 5% and 10% respectively

consumption to growth or from growth to total energy consumption as well as from electricity and petroleum consumption to growth.

From the causality results (Table 10), two significant outcomes are revealed. The existence of a causal relationship running from growth to electricity consumption in line with the work of Akinlo (2008), Wolde-Rufael (2004) and Wolde-Rufael (2009) and a short run causal relationship running from electricity consumption to petroleum consumption. These results are also consistent with the short run vector error correction model estimates.

One possible reason for the causal relationship running from GDP to electricity consumption is that, as the economy grows, GDP per capita increases and people are able to afford services that require additional energy (Ouedraogo 2013). With regards to the existence of a short run causal relationship running from electricity consumption to petroleum consumption, increasing electricity consumption leads to increasing generation which is mainly from thermal plants that uses petroleum.

The non-existence of a short run causal relationship between total energy consumption and growth as well as between growth and total energy consumption (Table 10) indicates that total energy consumption has no impact on growth in the short run. This finding is consistent with Nondo et al., (2010); Ciarreta and Zarraga (2008); Fatai (2014). An explanation for the existence of the neutrality hypothesis running from total energy consumption to GDP could be the nature of the energy consumption mix in the sub region. Biomass constitutes a significant proportion of the total energy consumed in West Africa, mainly used for cooking. Adenikinju (2008) estimates that biomass constitutes about 80% of total energy consumed in West Africa. Household cooking could have indirect impact on growth as cooking provides food which serves as a source of energy for labour used in production. However, there is no established direct link between household cooking and growth.

Electricity consumption has an insignificant impact on output in the short run as the coefficient for electricity consumption on GDP is highly insignificant indicating that there is no short run causality running from electricity consumption to GDP and from growth to electricity. This result is in line with that of Ouedraogo (2013) and could be due to the fact that in West Africa, as argued by the African Development Bank (2014), more than an estimated 57% of the populace do not have access to electricity. It is also evident from the data that access to electricity in some countries such as Sierra Leone, Liberia and Burkina Faso is very low. The low access to electricity restricts the opportunities available for people to increase their productivity and their incomes (Scott, 2015). Again, it is also probable that household electricity consumption constitutes a higher proportion of total electricity consumption which are not necessarily productivity enhancing. For example in Ghana, about 61 percent of electricity is consumed by households possibly for leisure related activities which have little direct relation with productivity.

Conclusion and recommendations

The study investigated the causal relationship between energy consumption and economic growth in the West African sub region using the panel cointegration techniques. The results indicate that in the long run, petroleum and electricity consumption have a statistically significant and positive impact on growth while total energy consumption had a statistically significant negative relationship with economic growth.

Analysis of granger causality indicates that in the short run, total energy consumption, electricity consumption and petroleum consumption had statistically insignificant relationship with growth. However, a unidirectional relationship running from GDP to electricity consumption was observed. Also, electricity consumption was found to have a statistically significant positive relationship with petroleum consumption. The long-run positive relations between electricity consumption and economic growth indicates that energy policy choices should focus on increasing access to electricity such as the West African Gas Pipeline and Power Pool Projects as well as implementing the Economic Community of West African States Renewable Energy Policy since they have the potential to improve efficiency in electricity generation that has the propensity to drive growth. Also, shifting from the use of woodfuel to the use of Liquefied Petroleum Gas for cooking could lead to a reduction in biomass use which inhibits growth.

References

Acheampong T. (2016). The Implications of Changing Power Generation Mix on Energy Pricing and Security in Ghana. *Energy Ghana Magazine*, 2, 27-31.

Adenikinju A. (2008). West African Energy Security Report. University of Ibadan, the Centre for Energy Economics at the University of Texas at Austin, and the Kumasi Institute of Energy. *Technology and Environment, Ibadan, Nigeria*.

Adom P. K. and Amuakwa-Mensah F. (2016). What drives the energy saving role of FDI and industrialization in East Africa?.

Renewable and Sustainable Energy Reviews, 65, 925-942.

African Development Bank (2014). Annual Report. Retrieved online from htttps://www.afdb.org/fileadmin/uploads/afdb…/Annual_Report_2014_-Full.pdf, September 2017.

Akinlo A. E. (2008). Energy consumption and economic growth: evidence from 11 Sub-Sahara African countries. *Journal of Energy Economics*, 30 (2), 2391–2400.

Akoena S. K. K. and Twerefou D. K. (2002). Improving Road Transport fuel Efficiency and Consumption in Ghana. *GIMPA Journal of Leadership, Management and Productivity*, 1(2), 1-19.

Alam J. B., Wadud Z. and Polak J. W. (2013). Energy demand and economic consequences of transport policy. *International Journal of Environmental Science and Technology*, 10(5), 1075-1082.

Apergis N. and Payne J. E. (2009). Energy consumption and economic growth in Central America: evidence from a panel cointegration and error correction model. *Energy Economics*, 31(2), 211-216.

Arbex M. A., Cançado, J. E. D., Pereira L. A. A., Braga A. L. F. and Saldiva P. H. D. N. (2004). Biomass burning and its effects on health. *Jornal Brasileiro de Pneumologia*, 30(2), 158-175.

Augutis J., Krikštolaitis R., Pečiulytė, S. and Konstantinavičiūtė I. (2011). Sustainable development and energy security level after Ignalina NPP shutdown. *Technological and economic development of economy*, 17(1), 5-21.

Amar M. B. (2012). Energy consumption and economic growth: The case of African countries. *The Journal of Energy and Development*, 38(1/2), 65-78.

Baltagi B. H. (2005). Econometric Analysis of Panel Data 3rd Edition. England JW &Sons.

Behera J. (2015). Energy consumption and economic growth in India: A reconciliation of disaggregate analysis. *Journal of Energy Technology and Policy,* 5(6): 15-27.

Behmiri N. B. and Manso J. R. P. (2013). How crude oil consumption impacts on economic growth of Sub-Saharan Africa?. *Energy*, 54, 74-83.

Bergasse E., Paczynski W. and Dabrowski M., & Dewulf L. (2013). The relationship between energy and socio-economic development in the Southern and Eastern Mediterranean. Paper produced for the MEDPRO project, 2013.

Bildirici M. E. (2013). The analysis of relationship between economic growth and electricity consumption in Africa by ARDL method. *Energy Economics Letters*, 1(1), 1-14.

Breman H. (2003). West Africa's Subsistence farming. IFA-FAO Agriculture conference; Global food security and the role of sustainable fertilization. Rome- Italy.

Bruce N., Perez-Padilla R. and Albalak R. (2000). Indoor air pollution in developing countries: a major environmental and public health challenge. *Bulletin of the World Health organization,* 78(9), 1078-1092.

Burgess D. F. (1984). Energy prices, capital formation, and potential GNP. *The Energy Journal*, 5(2), 1-27.

Cali M., Ellis K. and Te Velde D. W. (2008). The contribution of services to development and the role of trade liberalization and regulation. Working paper 298. Overseas Development Institute.

Chakravarty S., Ghosh S. K., Suresh, C. P., Dey, A. N and Shuka G. (2012). Deforestation: causes, effects and control strategies. Pp 3-29 in Okia CA. eds.

Global Perspectives on Sustainable Forest Management in Tech.

Ciarreta Antunano A. and Zarraga A. (2008). Economic growth and electricity consumption in 12 European countries: A causality analysis using panel data. Facultad de Ciencias Economicas. Avda. Lehendakari Aguirre, 83 48015 BILBAO. Retrieved online from http://www.addi.ehu.es

Coffin D., Horowitz J., Nesmith D. and Semanik M. (2016). Examining barriers to trade in used vehicles. Office of industries; Working paper ID-044.

Cole M. A. and Neumayer E. (2006). The impact of poor health on Total Factor productivity. *Journal of development studies*. 42(6), 918-938.

Engle R. E. and C. W. J. Granger (1987). Cointegration and error-correction: representation, estimation, and testing. *Econometrica* 55: 251-276.

Enu P. and Havi E. D. K. (2014). Influence of electricity consumption on economic growth in Ghana: an econometric approach. *International Journal of Economics, Commerce and Management,* 2(9), 1-20.

Esso L. J. (2010). Threshold Cointegration and Causality Relationship between Energy Use and Growth in Seven African Countries. *Energy Economics*, 32: 1383-1391.

Food and Agricultural Organization (2010). Global Forest Resources Assessment, 2010-Main Report. *FAO Forestry Paper 163.* Rome, Italy. 340p.

Fatai B. O. (2014). Energy consumption and economic growth nexus: Panel co-integration and causality tests for Sub-Saharan Africa. Journal of Energy in Southern Africa, 25(4), 93-100.

Hollinger F. and Staatz J. M. (2015). Agricultural Growth in West Africa. *Market and policy drivers. FAO, African Development Bank, ECOWAS. Pobrano październik.*

Houghton, R. A. (2005). Tropical deforestation as a source of greenhouse gas emissions.

Harto C. B., Yan Y. E., Demissie Y. K., Elcock D., Tidwell V. C., Hallett K. and Tesfa T. K. (2012). *Analysis of drought impacts on electricity production in the Western and Texas interconnections of the United States* (No. ANL/EVS/R-11/14). Argonne National Laboratory (ANL).

Houghton R. A. (2005). Tropical deforestation as a source of greenhouse gas emissions. *Tropical deforestation and climate change,* 13, 1-132.

Huang B. N., Hwang M.J . and Yang C. W. (2008). Causal relationship between energy consumption and GDP growth revisited: a dynamic panel data approach. *Ecological Economics*, 67, 41–54.

Im K. S., Pesaran M. H. and Shin Y. (2003). Testing for unit roots in heterogeneous panels. *Journal of econometrics*, 115(1), 53-74.

International Energy Agency (2014). Africa energy outlook: A focus on energy prospects in sub-Saharan Africa.World Energy Outlook 2014, IEA, Paris, November. http://dx.doi.org/www.dx.doi.org/10.1787/weo-2014-en.

International Energy Agency (2017). CO2 Emissions from Fuel Combustion Highlights. IEA, Paris. Retrieved from https://www.iea.org/publications/freepublications/n/2EmissionsfromFuelCombustionHighlights2017.pdf

Kao C. (1999). Spurious regression and residual-based tests for cointegration in panel data. *Journal of econometrics*, 90(1), 1-44.

Kahn-Ribeiro S., Kobayashi S., Beuthe M., Gasca J., Greene D., Lee D.S., Muromachi Y., Newton P. J., Plotkin S., Wit R. C. N. and Zhou P. J., (2007). Transportation and its infrastructure. In: 'Mitigation of Climate Change' Fourth Assessment Report Working Group III, Intergovernmental Panel on Climate Change. Cambridge University Press, UK.

Karekezi S., Kithyoma W., Muzee K. and Annah O. (2008). Scaling up bioenergy in Africa. Presented during the International Conference on Renewable Energy in Africa, Dakar 16-18.

Lee C. C. and Chang C. P. (2008). Energy consumption and economic growth in Asian economies: a more comprehensive analysis using panel data. *Resource and energy Economics*, 30(1), 50-65.

Levin A., Lin C. F. and Chu C. S. J. (2002). Unit root tests in panel data: asymptotic and finite-sample properties. *Journal of econometrics,* 108(1), 1-24

Lu W. C. (2016). Electricity consumption and economic growth: Evidence from 17 Taiwanese industries. *Sustainability,* 9(1), 50.

Marchal V., Dellink R., Van Vuuren D., Clapp C., Chateau J., Magné B. and van Vliet J. (2011). OECD environmental outlook to 2050. *Organization for Economic Co-operation and Development.*

Masih A. M. and Masih R. (1996). Energy consumption, real income and temporal causality: results from a multi-country study based on cointegration and error-correction modelling techniques. *Energy economics*, 18(3), 165-183.

Muktar M. (2011). Impact of transportation on economic growth: An assessment of road and rail transport systems. Retrieved from http://mustaphamuktar.blogspot.com/2011/01/impact-of-transportation-oneconomic.html.

Nondo C., Kahsai M. S and Schaeffer P. V. (2010). Energy consumption and economic growth: Evidence from COMESA countries. Research paper 2010-1. Available at: http://rri.wvu.edu/wp-content/uploads/2012/11/wp2010-11.pdf.

Odhiambo N. M. (2008). Energy consumption and economic growth nexus in Tanzania: An ARDL bounds testing approach. *Energy Policy*. 37, 617–622.

Olofin P. O, Olayeni O. R and Abogan O. P. (2014). Economic Consequences of Disaggregate Energy Consumption in West African Countries: Canadian Center of Science and Education. *Journal of Sustainable Development*. 7(3), 71

Olusanya S. O. (2012). Long run Relationship between Energy Consumption and Economic Growth: Evidence From Nigeria. Journal of Humanities and Social Science. 3(3), 40-51.Ouedraogo N. S. (2013). Energy consumption and economic growth: Evidence from the economic community of West African States (ECOWAS). *Energy Economics*, 36, 637–647.

Ozturk I. (2010). A literature survey on energy-growth nexus. *Energy Policy* 34(1), 3400-349

Ozturk I., Aslan A. and Kalyoncu H. (2010). Energy consumption and economic growth relationship: Evidence from panel data for low and middle income countries. *Energy Policy*, 38, 4422–4428.

Pedroni P. (1999). Critical values for cointegration tests in heterogeneous panels with multiple regressors. *Oxford Bulletin of Economics and statistics*, 61(S1), 653-670.

Pedroni P. (2001). Purchasing power parity tests in cointegrated panels. *Review of Economics and Statistics*, 83(4), 727-731.

Pokharel S. (2007). An econometric analysis of energy consumption in Nepal. *Energy policy*, 35(1), 350-361.

Porter G. (2012). Reflections on a century of road transport developments in West Africa and their (gendered) impacts on the rural poor. *EchoGeo,* (20), 1-17.

Ravindranath K. and Rao U. (2005). Environmental effects of energy from biomass and municipal wastes. retrieved online from https://www.eolss.net.../E4-23-04-05.pdf.

Ruta G. (2010). Monitoring Environmental sustainability: Trends, challenges and the way forward; 2010 Environmental strategy; the World Bank Group.

Sama, M. C. and Tah, N. R. (2016). The Effect of Energy Consumption on Economic Growth in Cameroon. *Asian Economic and Financial Review,* 6(9), 510.

Scott A. (2015). Building electricity supplies in Africa for growth and universal access. Background paper for Power, People, Planet: Seizing Africa's energy and climate opportunities. New climate economy, London and Washington DC: Available at:http://newclimateeconomy.report/misc/woking-papers.

Stern N. (2006). Stern review report on the economics of climate change. London: HM Treasury, 2006.

Solow R. M. (1956). A contribution to the theory of economic growth. *The quarterly journal of economics*, 70(1), 65-94.

Sustainable Energy Consumption in Africa (2004). UN-DESA final report. Retrieved online from http://www.un.org/esa/.../ Energy Consumption.

Swan T. W. (1956). Economic growth and capital accumulation. *Economic record,* 32(2), 334

Twerefou D. K., Agyire-Tettey F. K. and Mawutor, G. (2007). Energy Consumption and Economic Growth: Evidence from Ghana. *West Africa Journal of Monetary and Economic Integration*, 7 (2), 91-119.

United Nations Economic and Social Council for Africa (2009). The Transport situation in Africa. Sixth session of the Committee on Trade, Regional Cooperation and Integration; Addis Ababa. Available online at http://uneca.org/eca_resources/Publications/UNEA-Publication-toCSD15.pdf.

Vandaele N. and Porter W. (2015). Renewable Energy in Developing and Developed Nations: Outlooks to 2040. *University of Florida, Summer*.

Wolde-Rufael Y. (2006). Electricity consumption and economic growth: a time series experience for 17 African countries. *Energy policy*, 34(10), 1106-1114.

Wolde-Rufae, Y. (2004). Disaggregated industrial energy consumption and GDP: the case of Shanghai, 1952–1999. *Energy economics,* 26(1), 69-75.

Wolde-Rufael Y. (2009). Energy consumption and economic growth: the experience of African countries revisited. *Energy Economics,* 31(2), 217-224.

World Health Organization (2006).

APPENDICES

APPENDIX 1

Levin, Lin & Chu Panel Unit root test

Variables	At levels		At first difference		Order of integration
	T - statistics	Probability value	t statistics	Prob. val-ue	
GDP Per Capita	0.77054	0.7795	-14.9561***	0.0000	I(1)
Total Energy Consumption	1.73905	0.9590	-74.2759***	0.0000	I(1)
Electricity Consumption	7.94968	1.0000	-21.9985***	0.0000	I(1)
Petroleum Consumption	6.67136	1.0000	-16.1627***	0.0000	I(1)

Source: Computed by Author using Eviews 9 and data from EIA.
Note: ***, ** and * indicates the statistical significance of the estimated parameters at 1%, 5% and 10% respectively

APPENDIX 2

Kao Cointegration test (GDP and total energy consumption)

	t-Statistic	Prob.
ADF	3.677032	0.0001

APPENDIX 3

Kao cointegration test (GDP, Electricity and petroleum consumption)

	t-Statistic	Prob.
ADF	-2.900750	0.0019

APPENDIX 4

Dynamic Ordinary Least Squares Estimates

Dependent variable	Independent variables		
GDP Per Capita	Total Energy	Electricity consumption	Petroleum consumption
	-0.159404***	0.049647	0.026938
	(0.1121)	(0.0000)	(0.2168)