Rethinking the Growth-Energy Consumption Nexus: What Evidence Exists in Sub-Saharan Africa?

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Abstract

With renewed emphasis on greener economies in recent times, the need to re-evaluate energy demand and consumption as it relates to the growth trajectory of an economy cannot be overemphasized. This study investigates the growth-energy consumption nexus in 10 emerging economies in Africa given the huge energy demand-supply gap in the continent, by employing energy consumption data between 1980 and 2020 alongside RGDPPC (real GDP per capita) in a nonlinear econometric framework. The panel autoregressive distributed lag (ARDL)/pooled mean group (PMG) technique establishes a positive effect of energy consumption on economic growth. The study also found that a long-run relationship as well as a bidirectional causality exist between energy consumption and economic growth in Sub-Saharan Africa. Overall, there is strong evidence that energy consumption has growth-stimulating properties, which thus prompted the study to recommend that efforts should be rigorously exerted in the energy sector in order to maximize the growth-energy consumption framework.

Keywords: Growth, Energy, Africa, Consumption.

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1. Introduction

The role of energy in the development process of any economy cannot be overemphasized. It is basically the fulcrum on which other economic activities revolve. The viability and productivity of other sectors such as health, industrial, education, et cetera highly depend on an efficient and effective energy sector (Augutis et al., 2011). A well-functioning energy sector is thus sacrosanct to the growth of a society and in some case the level of development (Pokharel, 2007). Undoubtedly owing to its global importance, energy is considered as a production input and a strategic commodity which highly regulate international and local competitiveness across economies. As such, the economic development of a country can be measured by employing energy consumption per capita as a determinant. The importance of energy utilization in the pursuit of growth cannot be overemphasized given that it constitutes the fulcrum on which economic and industrial activities operate. Africa is endowed with various energy sources, making the continent a potential future global energy giant. However, energy has been highly unharnessed in the continent, leading to huge energy demand-supply gap. With the potential energy crisis on the horizon, the need to take proactive measures to ensure energy sustainability cannot be overemphasized.

Specifically, in comparison with other regions, Sub-Saharan Africa is highly endowed with several energy sources including biomass, hydro, wind, solar, just to mention few. If properly harnessed, the region has the capacity to generate more energy supply that exceeds local consumption, opening the economic opportunity of trading on the excesses. In spite of this potential, the region has one of the lowest accessibility to energy (International Energy Agency, 2014), even though energy consumption is higher in advanced countries than developing countries. Most countries in Africa Sub-Sahara zone still rely largely on conventional energy supply like Premium Motor Spirit (PMS) to power internal combustion engines. Most households in rural or suburb communities have a high energy reliance on consuming firewood for cooking and lighting. These sources of energy contribute to greenhouse effect which can highly impact global warming and climate change. It is thus important to examine the level of regional energy utilization (consumption) vis-à-vis economic growth.

In the same vein, a recent study showed that the sub-Sahara African region is sliding dangerously towards a potential crisis. Current statistics showed that a large proportion of an estimated 600 million individuals who would have no access to clean energy source in 2030 would be domiciled in the sub-region. The report also showed that in 2019 close to 900 million residents of the region already lack accessibility to cooking gas, with the region boasting of occupying 10 slots of the top 20 countries in the world lacking access to green energy sources for cooking (World Bank, 2021). These countries are Congo DR, Ethiopia, Ghana, Kenya, Madagascar, Mozambique, Niger, Nigeria, Tanzania, and Uganda.

Generally, there is an upward trajectory in energy consumption in Sub-Saharan Africa between 1980 and 2020. For instance, in Angola, energy consumption rose from 0.06 quad btu between 1980 and 1985 to 0.36 quad btu between 2016 and 2020. Within this time period, energy consumption in Benin increased from 0.06 quad btu to 0.104 quad btu. The trend was not different for Cameroon, Congo DR, Cote d'Ivoire, Ethiopia, Ghana, Kenya, Nigeria and South Africa. Between 1980 and 2020, South Africa recorded the highest energy consumption rate. South Africa's energy consumption rose from 3.07 quad btu to 5.67 quad btu, an increase of over 84.5 percent. The high demand for energy in South Africa was possibly due to the country's advanced technological and industrial infrastructure.

However, the increase in energy consumption in Sub-Sahara African countries is accompanied with periodic negative economic growth. For instance, the average energy consumption of 5.67 quad btu recorded in South Africa in the 2016-2020 era was accompanied by a 1.95 percent slump in economic growth. During the same period, Nigeria's 1.67 quad btu energy consumed was accompanied by a 2.26 percent drop in economic growth. Even though Sub-Sahara African countries recorded several negative growth rates, there may be a smoothing-out effect on the economic growth-energy consumption nexus in the long-run which should be formally analyzed.

The above dismal scenario was worsened by the emerging Covid-19 pandemic which has eroded the sluggish progress made in the energy sector as regard energy production, and accessibility (IEA, 2020a). This was due to financial resources, many of which were redirected to cushion the dire effects emerging from Covid-19 health crisis on the economy given emerging economic challenges (IEA, 2020b). In fact, the Covid-19 pandemic highly distorted activities as well as energy sector performance and trajectory in Africa.

With this, African sub region moving on a knife-edge in terms of energy production and utilization, so much will be at stake if viable policy-mix elude governments in the region in the planning process. Thus, it becomes imperative to access the energy consumption-economic growth nexus to evaluate long-run implication. The results of this study are highly policy-oriented, geared at improving energy consumption levels in Sub-Saharan Africa with an objective of stimulating optimal growth. There are five sections in the remaining part of the paper. Sequence to the introductory section, a brief review of related literature within and outside the African continent is presented in section 2. Section 3 summarizes the theoretical perspectives and model specification, while Section 4 presents obtained empirical results of the study and discusses their economic implications. The study is concluded in Section 5 with pertinent policy remarks.

2. Literature Review

The need to appraise empirical studies bothering on the growth-energy consumption relationship has taken front prominence as observed in symposia, conferences and summits in recent decades. Since there are marked differentials in each country's energy sector and administration as regards energy sources, energy regulations, institutional framework, cultural and energy trajectory, utilizing generic metrics are highly inappropriate and inadequate in evaluating the growth-energy consumption nexus. Naturally, conflicting conclusions will be arrived at when the nexus is appraised utilizing different methodologies.

However, due to renewed sensitization of greenhouse gas emissions, the need to evaluate the economic growth-energy consumption nexus has taken renewed attention in recent years. Specifically, in evaluating the growth-energy consumption relationship, there are basically four schools of thought, namely: growth, neutrality, conservation and feedback hypotheses (Ozturk 2010; Apergis & Payne, 2009; Squalli, 2007; and Chen et al., 2007).

The first school of thought is termed growth hypothesis. This school opined that energy is both an input and output factor. Energy is regarded as one of the factors of production in this thought process and an output factor consumed as a resource (Iyke, 2015; Apergis & Payne, 2010; Odhiambo, 2009; Stern, 2000). The second school of thought is called the neutrality hypothesis. Adherents hold the view that as a factor, energy's role in the economic and development process is minimal or even neutral (Ozturk et al., 2010; Altinay & Karagol, 2004; Hondroyiannis et al., 2002), implying that a proposed or existing energy policies have no growth-stimulating effect or externalities.

The third school of thought called conservation hypothesis proposes a unidirectional causal nexus between energy consumption and economic growth, with the nexus taking an energy consumption growth-to-economic growth trajectory. It implies that economic growth stimulates energy consumption, and vice versa. The fourth school of thought termed the feedback hypothesis forms the basis on which this study revolves. The feedback hypothesis asserted that there is a bidirectional nexus in the energy consumption-economic growth trajectory, with each variable complementing the other. This hypothesis is highly relevant to Sub-Saharan Africa. Countries within the region has experienced growth due to energy consumption through the years. In most cases, advancement in economic growth has also stimulated demand for more energy. The reverse has also been true in recent years. Thus, expansionary as well as conservative energy policies have impacted economic growth, as well as, the other way round.

The axioms of the above schools of thought have been empirically examined in several studies with differing results. For instance, Khan et al. (2020) estimated, using the ARDL method, the growth-energy consumption nexus and effect in Pakistan in the period 1965-2015. Energy consumption was found to growth-stimulating and performance-enhancing in the long run. Interesting, the scope was expanded in the study of Gessesse and He (2020) that found a short run and long run co-integration between the variables (growth and energy consumption) in China employing a nonlinear approach.

A Bulgarian study explicitly investigated the growth-energy consumption relationship between 1990 and 2016 employing the ARDL bound test and the Toda-Yamamoto method. The emphasis was on renewable energy. Energy consumption was found to cause economic growth, although no long run relationship was established among the variables (Can & Korkmaz, 2019). While employing a simultaneous equation system, Soukiazis et al. (2019) established that energy consumption stimulates growth positively among 28 OECD countries between 2004 and 2015. Another study on 29 OECD countries between 1980 and 2011 showed a two-way causal relationship in the growth-energy consumption nexus (Shafiei & Salim, 2014). Hung-Pin (2014) also carried out a study among nine OECD countries between 1982 and 2011 to establish the nature of short run and long run causality in the growth-energy nexus utilizing a nonlinear framework. The results obtained found co-integration and causality in five countries, namely, USA, Japan, Germany, United Kingdom and Italy.

In the same vein, utilizing a dataset ranging from 1970 to 2012 in investigating the short run and long run relationships between economic growth and energy consumption in Austria, Benavides et al. (2017) confirmed a long run granger causality as well as a unidirectional causality between the variables. Esen and Bayrak (2017) examine whether or not there is any energy consumption-economic stimulating effect among countries that rely on energy imports. Utilizing a panel of 75 countries that largely rely on imported energy for consumption between 1990 and 2012, the study established a statistically positive long run economic growth-energy consumption nexus relationship among the economies under consideration. This result was in consonance with the study of Kasperowicz (2014) which employed the data of 12 European countries spanning fourteen years (2000-2013) and established a positive economic growth-energy consumption nexus across the countries.

A cluster of empirical studies exists in developing economies aimed at establishing the nature of the growth-energy consumption nexus. For example, Thapa-Parajuli et al. (2021) appraised the short run and long run relationship in the growth-energy consumption debate in Nepal spanning a period of 1980 to 2018. A nonlinear model confirmed a long-run relationship as well as a positive association in the growth-economic consumption nexus. The study also revealed that causality only runs in the energy consumption-growth direction. This corroborated a previous study in Nepal (Paudel et al., 2020). The empirical findings of Hossain and Saeki (2011) were no different employing a panel granger causality between Bangladesh, India, Iran, Nepal, Pakistan and Sri Lanka in the 1971-2007-time period. A similar study was carried out by Dhungel (2017). The study which covers a scope of 2000 and 2011 employed a panel of 5 South Asian economies. By employing a co-integration test geared at establishing the growth-energy consumption nexus with GDP being the proxy for growth, the resultant statistics confirmed a long run association. And as later found in Thapa-Parajuli et al. (2021), the causality only runs in the energy consumption-growth direction. The study measured energy consumption by electricity units consumed.

There are several studies carried out in Sub-Saharan Africa geared at establishing the nature and direction of the growth-energy consumption nexus. For instance, the study of Odhiambo (2021) disaggregated energy consumption into the different energy sub units such as electricity, gas/diesel, motor gasoline, liquefied petroleum gas, fuel oil, as well as total oil consumption in Botswana. The study employed the autoregressive distributed lagged bound test approach. Contrary to Thapa-Parajuli et al., Odhiambo confirmed that the causality only runs in the growth-energy consumption direction. A previous study by Imandojemu and Akinlosotu (2018) investigated the growth-energy consumption nexus in Nigeria between 1990 and 2017 utilizing the OLS alongside Granger causality methods. The study found that consumption level of energy positively and significantly impacts growth. The study also opined that the causality only runs in the growth-energy consumption direction.

Twerefou1 et al., (2018) examined growth-energy consumption nexus in West Africa, employing the data of seventeen countries. Results showed no causal relationship in the short run, but the reverse was the case in the long run where energy consumption impact growth positively and significantly. Whereas, energy consumption according to Nyiwul (2017) exerted a non-significant influence on growth in Sub-Saharan African (SSA) region. Olayeni (2012) also showed that economic growth rates vary across countries in Sub-Saharan Africa due to different energy conservation policies adopted. For instance, while energy policies adversely impact growth in Cote d’Ivoire, Gabon and Nigeria, the reverse was the case in Benin, Kenya and Sudan. The study employed the hidden cointegration approach using Sub-Saharan African energy and economic data between 1971 and 2008. As for Ouedraogo (2013), conscientious efforts were made to establish direction/nature of the growth-energy consumption nexus for ECOWAS countries spanning between 1980 and 2008, utilizing the FMOLS model. FMOLS estimates reveal that there exists a positive significant relationship. Attiaoui et al. (2017) utilized a panel of twenty-two African countries using data of 1990 to 2011 in a nonlinear framework to estimate the growth-energy consumption nexus. The estimates confirmed a positive relationship in the panel. The result was not significantly different from those of da Silva et al. (2018) as was the case of Amoah et al. (2020) which employed data over a period of 1996 to 2017, utilizing a panel dataset of 32 African economies in a dynamic OLS framework.

Odugbesan and Rjoub (2020) examined the growth-energy consumption nexus among the MINT countries, using data of 1993 to 2017. The economies that constitute MINT countries are Indonesia, Mexico, Nigeria and Turkey. The study established a unidirectional nexus for Nigeria and Indonesia, and a bi-directional association was confirmed for Mexico and Turkey. The variables estimated all exerted a long run nexus among the economies under consideration. Fotourehchi (2017), utilizing a panel of forty-two developing economies between 1990 and 2012 found a unidirectional causality running only in the growth-to-energy consumption direction.

A South African study which seeks to appraise the nature and direction of the growth-energy consumption nexus established a unidirectional causality and long run relationship in the estimates (Menyah & Wolde-Rufael, 2010). Previously, a study by Khobai and Le Roux (2018) in South African data spanning between 1990 and 2014 established a long-run relationship in the growth-energy consumption nexus and also confirmed a unidirectional causality between the variables. On the part of Ibrahiem (2015), time series data spanning between 1980 and 2011 showed that energy consumption (specifically, electricity) exerted a stimulating economic growth effect in Egypt. The study also found a bidirectional causality in the growth-energy consumption nexus.

Interestingly, some studies argued a non-existent relationship in the growth-energy consumption nexus. Such studies included Bélaïd and Youssef (2017) which explored the relationship in Algeria between 1980 and 2012; Ben-Jebli and Ben-Youssef (2015) which employed data for sixty-nine countries between 1980 and 2010; Menegaki (2011) which focused on twenty-seven European countries between 1997 and 2007; among others.

An appraisal of the existing empirical studies reveals that the growth-energy consumption nexus debate is far from conclusive with contrasting findings. While some studies show a positive growth-energy consumption nexus, others either show a negative or a neutral relationship. Also, some studies show that the causality in the growth-energy consumption nexus is unidirectional while others show a bidirectional causality. There is thus need to appraisal the status quo in Sub-Saharan Africa especially with the changing and emerging energy environment in the region and country-specific conservative policies.

3. Methodology

3.1. Model specification

Following the empirical studies of Twerefou et al. (2018) and Akinlo (2008), the following empirical model is specified to capture the energy consumption-economic growth relationship:

$$EG_{it} = \pi_i + \pi_1 EC_{it} + \pi_2 OPN_{it} + \pi_3 INF_{it} + \pi_4 FDI_{it} + \pi_5 EXD_{it} + \varepsilon_{it} \quad (1)$$

Where EG is economic growth (proxied by real per capita GDP); OPN represents trade openness (proxied by total trade as a percent of GDP); INF is inflation; FDI is foreign direct investment; EXD is external debt (measured as total external debt as a percent of GDP); EC is total energy consumption. Subscripts i and t are individual country and time respectively; and ε is the error term which is assumed to be distributed identically and independently.

3.2. Panel cointegration tests

The study employs the Pedroni (1999, 2004) and Kao (1999) panel cointegration tests. These tests are designed to reveal whether or not there is a long-run relationship among variables. Specifically, these the test is adopted to show the presence or otherwise of a long-run relationship between economic growth and energy consumption. Pedroni (1999) considers the panel regression below:

$$y_{i,t} = \alpha_i + \delta_i t + \beta_{1i} x_{1i,t} + \beta_{2i} x_{2i,t} + \cdots + \beta_{Mi} x_{Mi,t} + e_{i,t} \quad (2)$$

$for\ t = 1, \ldots, T; i = 1, \ldots, N; m = 1, \ldots, M$

In Equation (2), T represents number of observations, N represents the number of individual countries in the panel, and M is the number of regression variables. The Pedroni cointegration test uses seven (7) statistics (four panel cointegration statistics and 3 group-mean panel cointegration statistics) with a null hypothesis (H0) of cointegration. The Kao (1999) cointegration test is a parametric test which is residual-based. It consists of five (5) tests with that are based on spurious least squares dummy variable panel regression equation with a single regressor.

3.3. Panel autoregressive distributed lagged (ARDL) model

Basically, the study adopted the panel ARDL technique for two main reasons. The method can be fully utilized irrespective of stationarity levels of the variables as long as stationarity is established at level [I(0)] or one [I(1)] or a mixture of both. Another advantage of the ARDL method is that even in the presence of limited data, cointegrating relationships estimates do not suffer from low power estimation (Narayan, 2005). The unrestricted error correction ARDL model is specified thus;

$$EG_{i,t} = \sum_{j=1}^{p} \gamma_{i,j} EG_{i,t-j} + \sum_{j=0}^{q} \sigma_{ij} X_{i,t-j} + \mu_i + \varepsilon_{it} \tag{3}$$

Where, i refers to country group and t is the time period. X is the vector of regressors as previously identified. Fixed effects are captured by μi. Equation (3) can be reparameterized in consonance with the study as:

$$\Delta EG_{i,t} = \omega_i EG_{i,t-1} + \alpha_i X_{it} + \sum_{j=1}^{p-1} \gamma_{i,j} \Delta EG_{i,t-j} + \sum_{j=0}^{q-1} \sigma_{ij} \Delta X_{i,t-j} + \mu_i + \varepsilon_{i,t} \tag{4}$$

Where,

$$\left.\begin{aligned} \omega_i &= -\left(1 - \sum_{j=1}^{p} \gamma_{i,j}\right) \\ \alpha_i &= \sum_{j=0}^{q} \sigma_{i,j} \\ \gamma_{it} &= -\sum_{r=j+1}^{p} \gamma_{ir}, \quad j = 1,2,3, \dots, \quad p-1 \\ \sigma_{it} &= -\sum_{r=j+1}^{q} \sigma_{ir}, \quad j = 1,2,3, \dots, \quad q-1 \end{aligned}\right\} \tag{5}$$

Note that ω in Equation (4) captures the speed of adjustment. In other words, it shows the speed of convergence to equilibrium.

3.4. Data and Sources

The study covers data of 1980 to 2020 for ten (10) countries in Sub-Saharan Africa; Nigeria, Côte d'Ivoire, South Africa, Angola, Benin, Congo DR, Kenya, Ethiopia, Cameroon and Ghana. Other than the fact that these countries are emerging economies in the region in terms of economic growth, the scope of the study is constrained to these countries due to unavailability of energy statistics in Sub Saharan Africa. The data included real GDP per capita (calculated as total annual production of goods and services as a ratio of total population) and total energy consumption (captured by consumption of primary energy). The data for the study were elicited from the Energy Information Agency (EIA) and the World Development Indicators (WDI) databases.

4. Results and Discussion

4.1. Cross-sectional Dependence and Homogeneity Tests

In order to avoid arriving at partial results, it is imperative to ascertain the cross-sectional dependence properties of the variables (Pesaran, 2004). In testing for homogeneity, the Blomquist and Westerlund (2013) and Pesaran and Yamagata (2008) techniques were adopted. The tests results are present in Table 1.

The results in Panel A showed strong evidence of cross-sectional dependence among the variables at 1 percent significance level. Given the statistics in Panel B, the null hypothesis of homogeneity of the slope coefficients is rejected. Rather, the alternative hypothesis that assumes heterogeneity of the slope coefficients cannot be rejected.

4.2. Panel Unit Root (PUR) Tests

The study adopted a vector of panel unit root tests to ascertain the stationarity properties of dataset employed. The tests included Levin, Lin and Chu (LLC), Im, Pesaran and Shin (IPS), and ADF-Fisher tests (Levin et al., 2002; Maddala & Wu, 1999; Im et al., 2003). Table 2 presents estimated results. Estimates presented in Table 2 show that the variables are a mixture are integrated of levels zero and one [that is, I(0) and I(1)]. Other than OPN which is stationary at first difference, the variables are stationary at level. This makes the application of a panel ARDL appropriate.

4.3. Panel cointegration tests

Since not all the variables are stationary at level, it is essential to ascertain the long-run relationship between the variables. The results of Pedroni (1999) and Kao (1999) panel cointegration tests are presented in Table 3;

The results of the panel cointegration tests in Panel A (Pedroni, 1999) and Panel B (Kao, 1999) reveal the existence of cointegration relationship between the variables on the basis of their statistical significance levels. This implies that there is a long-run relationship between the economic growth and energy consumption.

4.4. Panel ARDL Method

Given variables that are only integrated of order I(0) and I(1), the application of a panel ARDL model is essential. This technique, while estimating short- and long-run dynamics simultaneously, also account for inherent heterogeneity issues that are country-specific. It is argued that this technique has the ability to correct for endogeneity alongside serial correlation in both large and small sample alike. Specifically, the Pooled Mean Group (PMG) from this technique fully integrates cross sectional variations across units. The PMG results are reported in Table 4.

A cursory view of the results shows that EC (energy consumption) has a long run positive effect on economic growth. Specifically, in the long run, the estimated coefficient of 0.413 is obtained for the energy consumption variable and is statistically significant. This implies that a 1 percentage point upsurge in energy consumption will boost economic growth by 0.413 percentage point. This positive effect is also obtained in previous studies such as Thapa-Parajuli et al. (2021), Soukiazis et al. (2019) and Kasperowicz (2014).

The variables OPN and FDI positively influence economic growth in the long run. Interestingly, the positive effect was observed in both the short run as well. A 1 percentage point upsurge in OPN and FDI positively stimulated economic growth by 0.029 percentage point and 0.115 percentage point, respectively, ceteris paribus. Conversely, in the long run, inflation (INF) and external debt (EXD) negatively impact economic growth. It should be noted that the model reported a relatively high coefficient for the speed of adjustment variable (63.4 percent) in the event of a disequilibrium.

4.5. Causality Test

As asserted by the feedback hypothesis, while energy consumption could impact economic growth, the possibility of a reverse impact of economic growth on energy consumption is highly plausible. The study therefore utilized the novel Granger non-causality test by Juodis, Karavias and Sarafidis (2021). This technique has the capacity to accommodate both homogenous and heterogeneous panel data. As can be observed in Table 5, the test presents a 2-way causality between economic growth and energy consumption.

In Panel A, the dependent variable EC, alongside the independent variable (EG) are presented, while in Panel B, there is a reversal in the role with EG being the dependent variable and EC is the independent variable. From Panel A, it is deduced that the null hypothesis that EG does not Granger-cause EC is rejected at the 5 percent level of significant. This implies that there is a causality running from EG to EC in at least one of the sampled Sub-Sahara African countries. In the same vein, the null hypothesis that EC does not Granger-cause EG is rejected at the 1 percent significance level. This implies that energy consumption can potentially help predict future economic growth, ceteris paribus. It also validated the feedback hypothesis in Sub Saharan Africa. This finding corroborates previous studies (Ibrahiem, 2015; Shafiei & Salim, 2014).

5. Conclusions

The study analyzes the growth-energy consumption nexus for 10 Sub-Sahara African economies from 1980 to 2020 utilizing the panel autoregressive distributed lag (ARDL)/pooled mean group (PMG) technique alongside causality tests. The study was mainly driven by existing and emerging energy issues in the region. The study provided new empirical insights in the energy-consumption-economic growth nexus which have important policy implications. The study empirically establishes that in the long run, energy consumption positively affects economic growth. The feedback hypothesis which states that there is a bidirectional causality between energy consumption and economic growth was validated in the study. This finding implies that conscientious efforts should be made to design and apply energy conservation programmes and policies that will ultimately stimulate economic growth positively, thus reducing an adverse effect of any energy-economic growth tradeoff. This may include adopting green technologies capable of reducing C02 emissions and invariably greenhouse effect. In this regard, the use of cleaner and efficient alternative energy sources cannot be overemphasized for countries in Sub-Sahara Africa. In addition, efforts should be made to stimulate the energy sector of these economies in order to optimally maximize the economic potentials of this sector.

References

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

Altinay, G., and E. Karagol, (2004), "Structural break, unit root, and the causality between energy consumption and GDP in Turkey," *Energy Economics*, 26(6), 985-994.

Amoah, A., E. Kwablah, K. Korle, and D. Offei, (2020), "Renewable energy consumption in Africa: The role of economic well-being and economic freedom," *Energy, Sustainability and Society*, 10(32), 1-17.

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

Apergis, N., and J. E. Payne, (2010), "Energy consumption and growth in South America: Evidence from a panel error correction model," *Energy Economics*, 32(6), 1421-1426.

Attiaoui, I., H. Toumi, B. Ammouri, and I. Gargouri, (2017), "Causality links among renewable energy consumption, CO2 emissions, and economic growth in Africa: Evidence from a panel ARDL-PMG approach," *Environmental Science & Pollution Research*, 24(14), 13036-13048

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

Bélaïd, F., and M. Youssef, (2017), "Environmental degradation, renewable and non-renewable electricity consumption, and economic growth: Assessing the evidence from Algeria," *Energy Policy*, 102, 277-287.

Benavides, M., K. Ovalle, C. Torres, and T. Vinces, (2017), "Economic growth, renewable energy and methane emissions: Is there an Environmental Kuznets Curve in Austria?" *International Journal of Energy Economics and Policy*, 7(1), 259-267.

Ben-Jebli, M., and S. Ben-Youssef, (2015), "Output, renewable and non-renewable energy consumption and international trade: Evidence from a panel of 69 countries," *Renewable Energy*, 83, 799-808.

Blomquist, J., and J. Westerlund, (2013), "Testing slope homogeneity in large panels with serial correlation," *Economics Letters*, 121, 374-378.

Can, H., and O. Korkmaz, (2019), "The relationship between renewable energy consumption and economic growth: The case of Bulgaria," *International Journal of Energy Sector Management*, 1-18.

Chen, S. T., H. I. Kuo, and C. C. Chen, (2007), "The relationship between GDP and electricity consumption in 10 Asian countries," *Energy Policy*, 35, 2611-2621.

da Silva, P. P., P. A. Cerqueira, and W. Ogbe, (2018), "Determinants of renewable energy growth in Sub-Saharan Africa: Evidence from panel ARDL," *Energy*, 156, 45-54.

Dhungel, K. R., (2017), "Linkages between electricity consumption and economic growth: Evidences from South Asian economies," *Hydro Nepal: Journal of Water, Energy Environment*, 20, 18-22.

Esen, O., and M. Bayrak, (2017), "Does more energy consumption support economic growth in net energy-importing countries?" *Journal of Economics, Finance and Administrative Science*, 22(42), 75-98.

Fotourehchi, Z., (2017), "Renewable energy consumption and economic growth: A case study for developing countries," *International Journal of Energy Economics and Policy*, 7(2), 61-64.

Gessesse, A. T., and G. He, (2020), "Analysis of carbon dioxide emissions, energy consumption, and economic growth in China," *Agricultural Economics*, 66, 183-192.

Hondroyiannis, G., S. Lolos, and E. Papapetrou, (2002), "Energy consumption and economic growth: Assessing the evidence from Greece," *Energy Economics*, 24(4), 319-336.

Hossain, M. S., and C. Saeki, (2011), "Does electricity consumption panel granger cause economic growth in South Asia? Evidence from Bangladesh, India, Iran, Nepal, Pakistan and Sri-Lanka," *European Journal Social Sciences*, 25, 316-328.

Hung-Pin, L., (2014), "Renewable energy consumption and economic growth in nine OECD countries: Bounds test approach and causality analysis," *The Scientific World Journal*, 1-6.

Ibrahiem, D. M., (2015), "Renewable electricity consumption, foreign direct investment and economic growth in Egypt: An ARDL approach," *Procedia Economics and Finance*, 30, 313-323.

Cozzi, L., (2014), Africa energy outlook: a focus on enrgy prospects in sub-Saharan Africa. In *Sustainable Energy Policy and Strategies for Europe, 14th IAEE European Conference.*

IEA., (2020), World energy outlook 2020. *International Energy Agency: Paris, France.*

IEA., (2020), The Covid-19 crisis is reversing progress on energy access in Africa. *International Energy Agency: Paris, France.*

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

Imandojemu, K., and N. T. Akinlosotu, (2018), "Renewable energy consumption and economic growth in Nigeria: A co-integration and granger causality approach," *CBN Bullion*, 42(2), 50-67.

Iyke, B. N., (2015), "Electricity consumption and economic growth in Nigeria: A revisit of the energy growth debate," *Energy Economics*, 51, 166-176.

Juodis, A., Y. Karavias, and V. Sarafidis, (2021), "A homogeneous approach to testing for granger non-causality in heterogeneous panels," *Empirical Economics*, 60, 93-112.

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

Kasperowicz, R., (2014), "Economic growth and energy consumption in 12 European countries: A panel data approach," *Journal of International Studies*, 7(3), 112-122.

Khan, M. K., M. I. Khan, and M. Rehan, (2020), "The relationship between energy consumption, economic growth and carbon dioxide emissions in Pakistan," *Financial Innovation*, 6(1), 1-13.

Khobai, H., and P. Le Roux, (2018), "Does renewable energy consumption drive economic growth: Evidence from granger-causality technique," *International Journal of Energy Economics and Policy*, 8(2), 205-212.

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

Maddala, G. S., and S. Wu, (1999), "A comparative study of unit root tests with panel data and a new simple test," *Oxford Bulletin of Economic & Statistics*, 61(S1), 631-652.

Menegaki, A. N., (2011), "Growth and renewable energy in Europe: A random effect model with evidence for neutrality hypothesis," *Energy Economics*, 33(2), 257-263.

Menyah, K., and Y. Wolde-Rufael, (2010), "Energy consumption, pollutant emissions and economic growth in South Africa," *Energy Economics*, 32(6), 1374-1382.

Narayan, P. K., (2005), "The saving and investment nexus for China: Evidence from cointegration tests," *Applied Economics*, 37(17), 1979-1990.

Nyiwul, L., (2017), "Economic performance, environmental concerns, and renewable energy consumption: Drivers of renewable energy development in Sub-Sahara Africa," *Clean Technologies and Environmental Policy*, 19(2), 437-450.

Odhiambo, N. M., (2009), "Energy consumption and economic growth nexus in Tanzania: An ARDL bounds testing approach," *Energy Policy*, 37(2), 617-622.

Odhiambo, N. M., (2021), "Energy consumption and economic growth in Botswana: Empirical evidence from a disaggregated data," *International Review of Applied Economics*, 35, 3-24.

Odugbesan, J. A., and H. Rjoub, (2020), "Relationship among economic growth, energy consumption, CO_2 emission, and urbanization: Evidence from MINT countries," *SAGE Open*, 1-15.

Olayeni, O. R., (2012), "Energy consumption and economic growth in Sub-Saharan Africa: An asymmetric cointegration analysis," *International Economics*, 129, 99-118.

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*, 38, 340-349.

Ozturk, I., A. Aslan, and H. Kalyoncu, (2010), "Energy consumption and economic growth relationship: Evidence from panel data for low and middle income countries," *Energy Policy*, 38(8), 4422-4428.

Paudel, R. C., R. Thapa-Parajuli, and M. Alharthi, (2020), "Electricity consumption and export performance: Evidence from Nepal," *International Journal Energy Economic Policy*, 10, 529-530.

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., (2004), “Panel cointegration: Asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis,” *Econometric Theory*, 20(3), 597-625.

Pesaran, M. H. (2021). General diagnostic tests for cross-sectional dependence in panels. *Empirical economics*, 60(1), 13-50.

Pesaran, M. H., and T. Yamagata, (2008), “Testing slope homogeneity in large panels,” *Journal of Econometrics*, 142, 50-93.

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

Shafiei, S., and R. A. Salim, (2014), “Non-renewable and renewable energy consumption and CO2 emissions in OECD countries: A comparative analysis,” *Energy Policy*, 66, 547-556.

Soukiazis, E., S. Proenca, and P. A. Cerqueira, (2019), “The interconnections between renewable energy, economic development and environmental pollution: A simultaneous equation system approach,” *The Energy Journal*, 40(4).

Squalli, J., (2007), “Electricity consumption and economic growth: Bounds and causality analyses of OPEC countries,” *Energy Economics*, 29, 1192-1205.

Stern, D. I., (2000), “Multivariate cointegration analysis of the role of energy in the US macroeconomy,” *Energy Economics*, 22(2), 267-283.

Thapa-Parajuli, R., S. Aryal, M. Alharthi, and R. C. Paudel, (2021), “Energy consumption, export performance and economic growth in a landlocked developing country: The case of Nepal,” *AIMS Energy*, 9(3), 516-533.

Twerefou1, D. K., K. S. Iddrisu, and E. A. Twum, (2018), “Energy consumption and economic growth: Evidence from the West African sub region,” *West African Journal of Applied Ecology*, 26(SI), 217-233.

World Bank, (2021), “Report: Universal access to sustainable energy will remain elusive without addressing inequalities,” Washington, D.C.

Appendix

Table 1. Results of Cross-Sectional Dependence & Homogeneity Tests

Panel A: Cross sectional dependence test **H0:** ***No cross-section dependence***						
Test	**EG**	**EC**	**OPN**	**INF**	**FDI**	**EXD**
Breusch-Pagan LM	132.14 (0.0000)	143.21 (0.0000)	109.33 (0.0000)	151.28 (0.0000)	134.22 (0.0000)	100.17 (0.0000)
Pesaran Scaled LM	19.04 (0.0000)	113.63 (0.0001)	53.01 (0.0000)	88.04 (0.0000)	93.17 (0.0000)	48.11 (0.0000)
Bias-corrected scaled LM	16.07 (0.0000)	102.48 (0.0000)	51.38 (0.0001)	62.99 (0.0001)	69.72 (0.0000)	22.91 (0.0000)
Pesaran CD	7.34 (0.0000)	41.87 (0.0000)	8.61 (0.0001)	11.31 (0.0000)	35.19 (0.0000)	19.38 (0.0001)

Panel B: Homogeneity test		
Statistics	Blomquist & Westerlund (2013)	Pesaran & Yamagata (2008)
Delta	5.913 (0.000)	11.312 (0.000)
Delta_adj.	7.422 (0.000)	14.853 (0.000)

Source: Authors' compilation

Note: p-value in parenthesis

Table 2. Panel Unit Root Results

		Level		***First Difference***		
Tests	**Variables**	**C**	**C +T**	**C**	**C & T**	**Decision**
LLC	EG	-9.34***	-6.21***	-	-	Stationary
	EC	-15.07***	-13.11***	-	-	″
	OPN	6.20	4.01	-17.63***	-12.15***	″
	INF	-3.02***	-2.99***	-	-	″
	FDI	-13.39***	-9.21***	-	-	″
	EXD	-5.18***	-2.44***	-	-	″
IPS	EG	-2.65**	-2.08**	-	-	″
	EC	-10.28***	-9.40***	-	-	″
	OPN	8.06	5.34	-21.64***	-34.07***	″
	INF	-10.42***	-7.63***	-	-	″
	FDI	-5.76***	-3.01***	-	-	″
	EXD	-2.09**	-1.81**	-	-	″
ADF-Fisher Chi-square	EG	113.14***	109.04***	-	-	″
	EC	133.95***	241.31***	-	-	″
	OPN	15.97	24.37	230.05***	227.18***	″
	INF	82.10***	80.37***	-	-	″
	FDI	118.33***	121.89***	-	-	″
	EXD	209.73***	211.27***	-	-	″

Source: Authors' compilation; Note: ***, ** denotes significance at the 1 percent and 5 percent level, respectively, C denotes Constant; C+T denotes Constant & Trend

Table 3. Results of Panel Cointegration Test

Panel A: Pedroni (1999) test	**Coefficient**
Panel v-statistic	5.19***
Panel ρ-statistic	-11.83**
Panel non-parametric (PP) t-statistic	-4.31
Panel parametric (ADF) t-statistic	-118.26***
Group ρ-statistic	-13.35***
Group non-parametric t-statistic	-4.47***
Group parametric t-statistic	-3.69***
Panel B: Kao (1999) test	
DF	-1.41*
DF^{ρ}	-3.57***
DF^{t}	-5.21***
$DF^{\rho *}$	-3.69***
ADF^{t*}	-1.99***

Source: Authors' compilation

Note: ***, **, ** denote statistical significance at 1 percent, 5 percent and 10 percent, respectively.

Table 4. Results of Pooled Mean Group (PMG) Estimation

Variable	**Coefficient**
Dependent Variable: EG	
Long Run Equation	
EC	0.413*** (0.071)
EXD	-0.092*** (0.018)
FDI	0.115*** (0.040)
INF	-0.007** (0.003)
OPN	0.029*** (0.010)
Short Run Equation	
ECM(-1)	-0.634*** (0.082)
ΔEG(-1)	0.048*** (0.012)
ΔEC	0.176*** (0.046)
ΔEC(-1)	0.519** (0.180)
ΔEXD	-0.006* (0.003)
ΔEXD(-1)	-0.034 (0.031)
ΔFDI	0.011*** (0.005)
ΔFDI(-1)	0.275 (0.289)
ΔINF	-1.023 (1.079)
ΔINF(-1)	-0.347 (0.244)
ΔOPN	0.243*** (0.075)
ΔOPN(-1)	0.071 (0.047)

Source: Authors' compilation

Note: ***, **, * denotes significance at the 1 percent, 5 percent and 10 percent level, respectively.

Table 5. Results of Granger Non-Causality Test

Number of units = 8.621874;		T = 40;		Number of lags: 1		
Panel A						
BIC = -817.81421;		HPJ Wald test: 2.0811907;		p-value_HPJ: 0.0419		
H0: EG does not Granger-cause EC						
H1: EG does Granger-cause EC for at least one panel var						
Results for the Half-Panel Jackknife estimator						
Cross-sectional heteroscedasticity-robust variance estimation						
EG	Coefficient	SE	z	P>z	[95% Confidence Interval	
EG						
L1.	0.0148	0.0056	2.62	0.042	-0.0019	0.0210
Panel B						
BIC = -113.01732;		HPJ Wald test: 81.642218;		p-value_HPJ: 0.0000		
H0: EC does not Granger-cause EG						
H1: EC does Granger-cause EG for at least one panel var						
Results for the Half-Panel Jackknife estimator						
Cross-sectional heteroscedasticity-robust variance estimation						
EC	Coefficient	SE	z	P>z	[95% Confidence Interval	
EC						
L1.	-0.6225	0.0716	-8.69	0.000	-0.7938	-0.4152

Source: Author’s compilation

Note: L1 denotes number of lags; standard error is given as SE