Energy Consumption and Economic Growth Nexus in Africa Countries: A Simultaneous Equations Model Approach

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ABSTRACT

By adopting the Cobb-Douglas production function, this study examined the relationship between energy consumption, GDP, capital stock, and labour in 22 African countries from 1990 to 2018. To achieve this goal, the simultaneous equations were analysed after utilizing the Generalized Method of Moments (GMM)/Dynamic panel data estimation approaches. To determine the most fitted model between the fixed and random model, the study employed the Hausman model and its approved the random model as the best fitted model. According to the empirical results, energy consumption has a strong positive influence on GDP. This suggests that as the economy expands, so will energy consumption. The coefficients of labour and capital are significant, though labour implies negative effects. Also, GDP has a firm positive influence on energy consumption. This suggests that as the economy expands, so will energy consumption. Capital has a positive coefficient. This means that the countries are capital-intensive. The Labour coefficient is negative and statistically significant, indicating that capital is more energy intensive than labour-intensive generates the majority of GDP. This also implies that capital replaced labour in those countries. Further, the Dumitrescu Hurlin Panel Causality Tests revealed a bidirectional relationship between GDP and energy consumption. Thus, there is a bidirectional relationship between energy consumption and GDP across the entire continent. Energy policy formulations are likely to be the best long-term economic growth strategy in African countries.

Keywords: Panel approach, Economic growth, Fixed and Random effect, Energy consumption, Africa, GMM/DPD

INTRODUCTION

The significant connection between economic growth and energy consumption in African nations cannot be overstated. African nations are gaining recognition rapidly in the global energy markets. Their business in energy use has recently climbed significantly. This growing tendency is remarkably seen by the African countries especially, in the North Africa, Nigeria, and South Africa, and is expected to continue far into the next decade given their economic frameworks.

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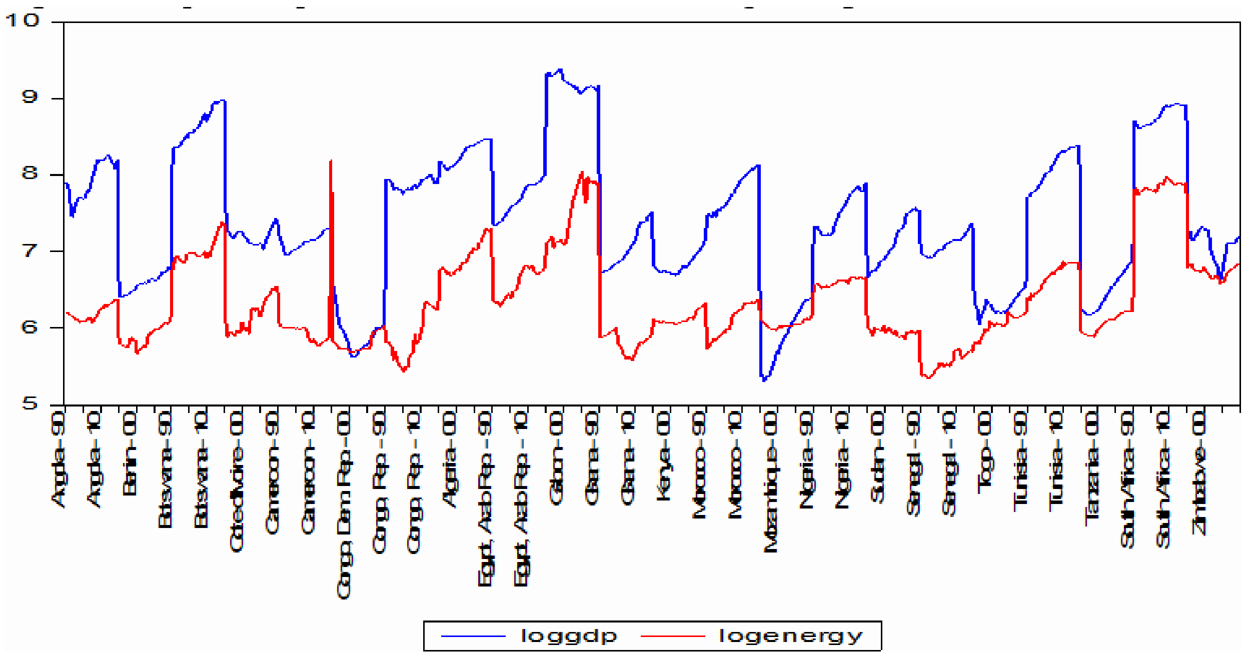
Africa's primary energy consumption in 2018 was larger than 830 million tonnes of oil equivalent, with 24% to North Africa, 19% to Nigeria, and 16% to South Africa accounting for more than 60% of the primary energy consumption, while having only 35% of its population (IEA, 2019). However, the primary energy consumption will heavily be induced by some factors such as expected income levels, coordinated energy policies, and the rate at which economic activities shift toward energy-intensive activities because of other factors such as urbanization and industrialization, increased motorization and household use of electrical appliances, and the continued trending away from traditional non-commercial energy sources, in Africa.

Despite having 20% of world population, Africa scores only 6% of global energy consumption and demanded only 3% of power. The average energy consumption per capita in majority of the African countries is significantly less than the global average of about 2 tonnes of oil equivalent (toe) per capita just like the India average of 0.7 toe/per capita. Bioenergy is currently Africa's most important source of energy, with the demand for primary energy accounting 45% and more than equal of the total energy consumption. In 2018, the largest per capita energy consumer was South Africa in the Sub-Saharan Africa with 2.3 toe/capita, followed by Nigeria, which had 0.8 toe. Majority of the African Sub-Saharans recorded about 0.4 toe/capita consumption due to relatively inefficient solid biomass utilization (African Energy Outlook, 2019).

Because of the expected rapid growth in personal and commercial transportation needs, as well as further electrification of the economies' production and consumption sectors, the trend in Africa's energy consumption is likely to spike especially in the case of petroleum products and electricity. The graph below depicts a trend analysis of the interrelationship between GDP and energy consumption.

Figure 1: Graphical representation of the interrelationship among the variables



However, there appear to be numerous differences between the zeal to boost accelerated phase of economic growth and the accelerated phase in energy consumption in these countries, raising some fundamental questions. To begin, how should these countries' current energy systems transition to more affordable, efficient energy consumption without jeopardizing the fundamental goal of achieving high levels of economic growth? Second, how can large amounts of investment be designated to the procedure and developing a growth-driven sustainable energy scheme in these economies? Third, what are the fundamental

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differences between the countries? Finally, is it possible that some market-oriented policies, such as sound pricing policies, some of which are quite exorbitant, and consumption management policies, which may necessitate an increase in prices of energies, could be utilized to change individuals' behaviour in those economies to eventually conform to price signals, and be energy efficient, resulting in significant energy consumption?

The main source of concern is whether these countries' energy policymakers will have the courage to formulate policies that could reach the four goals of energy policy, which are security, social concerns, the environment, and competitiveness, without fear of backlash from the people and trade unions in these countries. The efficacious energy policy options are critical for delivering Africa's inclusive growth desires (such as the outline in the continent's commitment for 2063, strategic framework) and assisting in the achievement of other major sustainable energy and development goals.

According to the reviewed literature, there are a handful of popular studies that have tried to examine these problems separately in African economies employing panel analysis. One of them is this. Capturing the relationship between energy consumption and economic growth inside those economies is critical for research workers, policymakers, and investors. For instance, the outcome of the result of this study would aid the significance of the global energy agenda and how to formulate energy policies in accordance with global best practices, as well as adding to the existing depository knowledge in energy economics.

In three important ways, this paper builds on previous research on the energy-growth nexus. To begin, while this is not the initial literature to focus on growing economies in Africa, it is possible that this study improves on past literature by analysing data in both the group and individual country analysis formats, which is a little departure from the majority of past literature. Second, this paper considers the heterogeneousness of those economies in terms of income and energy consumption by comparing GDP, energy consumption, and economic growth trends (early studies on African economies were bivariate, by looking at only the correlationship between income or output and energy consumption). For instance, see (Interalia & Payne, 2010; Asafu-Adjaye, 2000; Aqeel, & Butt, 2001; Glasure, & Lee, 1998; Masih, & Masih, 1996; Sa'ad, 2010; Yang, 2000; Kraft, & Kraft, 1978).

Lastly, in contrast to recent literature that employed time series data analysis and traditional panel analysis, this literature used panel analysis and was supplemented by analysing the individual countries using a robust methods of analysis, as well as the inclusion of additional variables of labour and capital. The remaining paper outlines are as follows. Section two examines previous works in the energy literature on the relationships between energy use and income. The third section discusses the econometric methodology used in the study. Fourth, econometric results are outlined and talked through. Lastly, Section 5 contains the findings' conclusions and policy implications.

A rigorous analysis of prior studies finds that growing economies, particularly those in Africa, have received insufficient attention. To our knowledge, empirical studies in African countries have paid little attention to re-examining the energy-growth nexus using simultaneous equations models and the inclusion of additional labour and capital variables. To the best of our knowledge, Anis, (2013) is the only literature that has used the simultaneous equation model for 14 MENA countries.

Summary of Literature Review on Energy Consumption and Economic Growth

Authors	Country	Period	Variables	Methodology	Findings/Results
Ibrahim D. Raheem, Agboola H. Yusuf (2015)	15 African countries	1980 – 2010	ENC, GDP	ARDL	$E \leftarrow Y, E \rightarrow Y$

Mustafa Saatci and Yasemin Dumrul (2013)	Turkey	1960 – 2008	ENC, GDP	Structural Breaks Modelling Approach	*E←Y*
Dipa Adhikari and Yanying Chen (2013)	80 developing countries	1990 – 2009	ENC, GDP	Panel Dynamic Ordinary Least Squares (DOLS)	*E←Y, E→Y*
Nunung Nuryartono and Muhamad Amin Rifai (2017)	4 ASEAN countries	1975 – 2013	ENC, GDP, CO2	Granger Causality and VECM	*E←Y*
Pao, H.-T., & Tsai, C.-M. (2010)	BRIC countries	1971 – 2005	ENC, GDP, CO2	Error correction model	*E↔Y*
Charles B.L. Jumbe (2004)	Malawi	1970–1999	ENC, GDP	Granger-causality(GC) and error correction (ECM)	*E↔Y*
Sa'ad, Suleiman. (2010)	Nigeria	1971–2006	ENC, GDP	VECM	*E←Y*
Idrissa M. Ouédraogo (2010)	Burkina Faso	1968–2003	ENC, GDP	ARDL Bounds approach	*E↔Y*
Rafindadi and Ozturk (2017)	South Africa	1961 – 1990	ENC, GDP, P, EX	VECM	*E↔Y*
Jaganath B. (2015)	India	1970 -2 011	ENC, GDP	VAR	*E↔Y, E←Y*
Okyay U., Ebru A., Fatih Y. (2014)	15 European Union countries	1990 – 2011	ENC, GDP	VECM Granger Causality	*E←Y, E↔Y*
Ilhan O., Alper A., Huseyin K. (2010)	51 countries	1971 – 2005	ENC, GDP	Panel cointegration & Panel Granger Causality	*E←Y, E↔Y, E→Y*
Ibrahim D. Raheem, Agboola H. Yusuf (2015),	15 countries in Africa	1980 – 2010	ENC, GDP	OLS approach. Threshold Regression Model	*E←Y, E↔Y, E→Y*
Yemane Wolde-Rufael (2005)	19 African countries	1971 – 2001	ENC, GDP	Cointegration and Granger Causality	*E←Y, E→Y*
Mohamed E. A., Adel B. Y., Hatem M., Christophe R. (2014)	sixteen African countries	1988 – 2010	ENC, GDP	bootstrap panel analysis of causality and VAR	*E←Y E→Y, E↔Y*
Obas John Ebohon (1996)	Nigeria and Tanzania	1960 – 1984	ENC, GDP	Granger Causality.	*E←Y, E→Y*
Hamisu S. A., Zulkornain B. Y., Law S. H. (2015)	Nigeria	1972 – 2011	ENC, GDP, FD, P	Autoregressive Distributed Lag Bound Test Framework	*E↔Y, E→Y*

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Muhammad S., Muhammad Z., Syed Jawad H. S., Mantu K. M. (2018)	Top 10 energy-consuming countries	1960 – 2015	ENC, GDP	Quantile-on-Quantile Approach	*E↔Y, E→Y, Y→E*
Paresh K. N., and Russell S. (2009)	6 Middle East countries	1974 – 2002	ENC, GDP & Exports	Panel co-integration and causality tests	*E↔Y*
Anthony N. Rezitis, Shaikh Mostak Ahammad (2015)	Nine South and Southeast Asian countries	1990-2012	ENC, GDP, L, K	Panel Vector Autoregression Approach and Causality Analysis	*E↔Y*
Faisal, F., Türsoy, T., & Reşatoğlu, N. G. (2017)	Pakistan	1971 – 2013	ENC, GDP, FD	ARDL, VECM.	*E←Y*
Kais Saidi, Sami Hammami (2014)	Tunisia	1974 – 2011	ENC, GDP	Johansen cointegration technique	*E↔Y*
Yildirim, E., Aslan, A., & Ozturk, I. (2014)	4 Asian countries	1971 – 2009	ENC, GDP, L, K	Heterogeneous panel causality analysis	*E→Y, E←Y*
Chandran, V. G. R., & Tang, C. F. (2013).	ASEAN-5 economies	1971 – 2008	GDP, FDI, ENC	Cointegration and Granger causality methods	*E→Y, E←Y*

METHODOLOGY

The econometric modelling

As previously stated, most existing literature assumes that energy consumption is frequently the key causal factors of growth. Thus, it is crucial to examine the interrelatedness between the variables by looking at them all at once in modelling a framework. To accomplish the goal, the study used the production function of Cobb-Douglas to re-examine the relationships between the consumption of energy and economic growth while accounting for labour and capital as additional production factors. Shahbaz et al. (2012), Menyah and Wolde-Rufael (2010), Ang (2008), Sharma (2010), and Anis Omri (2013), to name a few, have used empirical modelling to investigate the impact of energy consumption on growth. The equation of Cobb-Douglas production function is specified as:

$$Y_{it} = AE^{\alpha it} L^{\alpha it} K^{\alpha it} \epsilon^{\mu it} \quad (1)$$

The log transformation is introduced in Eq. (1) to produce Eq. (2) is given as:

$$ln(Y_{it}) = \alpha_0 + \alpha_{1i} ln(ENC_{it}) + \alpha_{2i} ln(L_{it}) + \alpha_{3i} ln(K_{it}) + \varepsilon_{it} \quad (2)$$

Where $\alpha_0 = A_0$ which is intercept; the subscript i = 1, ….., N denotes the country and t = period. Y represents the gross domestic product per capita; E = energy consumption per capita, K = real capital and L = labour, respectively. A represents the level of technology, and the residual term is assumed to be identically, independently, and normally distributed. The scale returns for energy consumption, capital, and labour are denoted by 1, 2, and 3, respectively. To convert the nonlinear Cobb-Douglas function to linear, we turned all of the series into logarithms. It is worth noting that simple linear specification does not appear

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to produce consistent results.

The connection amongst the variables are empirically re-investigated by using the two simultaneous equations which are:

$$ln(GDP_{it}) = \beta_0 + \beta_{1i} ln(ENC_{it}) + \beta_{2i}\, ln(L_{it}) + \beta_{3i} ln(K_{it}) + \mu_{it} \quad (3)$$

$$ln(ENC_{it}) = \alpha_0 + \alpha_{1i} ln(GDP_{it}) + \alpha_{2i}\, ln(L_{it}) + \alpha_{3i} ln(K_{it}) + \varepsilon_{it} \quad (4)$$

Eq. (3) re-observed the effect of energy use with some variables on growth. A hike in energy consumption may extents to an increase in GDP per capita, that is, the degree of energy consumption rises parallel to GDP per capita (Sharma, 2010). Sharma implied that energy is one of the key factors in the process of production, as it is being utilized in both commercialize and non-commercialize (i.e, transport and public sector) functions. However, that shows energy has a straight connection to GDP of a country. The connection could efficaciously be via consumption, investment or exports and imports, as aggregate demand in most cases is being affected by energy output and consumption. In addition, capital and labour force are included in the determinants of economic growth (De Mello, 1997).

Similarly, Eq. (4) re-investigated the causal factor of energy utilization (ENC). Economic growth, proxied by GDP per capita, may induce positive effect on energy demand, whereby a rise in GDP may increase energy demand (Lotfalipour et al., 2010; Belloumi, 2009; Halicioglu, 2009; Zhang and Cheng, 2009). Then, capital and labour are also included as a causal factors of energy demand (Sari et al., 2008; Lorde et al., 2010).

The Estimation method

The Panel Generalized Method of Moments (GMM)/Dynamic Panel Data (DPD) is a method which is widely used in models with panels and in the multiplicity of ways connected to certain variables, Omri (2013). The way followed a set of implemental variables to address the endogeneity issues. Subsequently, the GMM gives a coherent and effective estimates in the midst of arbitrary heteroskedasticity. In addition, many of the post-mortem tests talked about in this study can be featured in a GMM framework. Hansen’s test was utilized to identify the restrictions in order to give some facts about the tools’ validity. The tools’ validity is examined using the Hansen test in which the null hypothesis states of discovering the restrictions is accepted. That is, the null hypothesis of the tool is appropriate cannot be rejected. Also, the Durbin-Wu-Hausman test examined the presence of endogeneity. The null hypothesis of biasedness and inconsistent in the OLS is rejected, as such, the OLS was not an appropriate estimation technique.

Therefore, the study employed the GMM model to examine the relationship between energy consumption and economic growth by employing an annual time series data ranging from 22 African economies spanning 1990-2018. The GMM method in this study turn out to be of great advantage to the OLS method in certain ways. First of all, the pooled data, that is the combination of both cross-section and time series data gives the room to analyse for multiple of countries, on energy-growth nexus for a long period of time. Secondly, any single country issue can be checked by utilizing an appropriate GMM process. And finally, the panel analysis process can check for possible endogeneity that may regress from independent variables.

Data and Descriptive Statistic

This literature employed panel data that is observed annually ranging from 1990-2018 and it comprises the real per capita GDP (constant 2010 US$), consumption in energy (oil equivalent in kg, per capita), Gross fixed capital formation(Current US$), and sum of labor force (% of aggregate population) for 22 African economies such as: Algeria, Botswana, Egypt, Morocco, Sudan, Togo, Gabon, Tunisia, Angola, Côte d'Ivoire, Democratic Republic of the Congo (DR Congo), Ghana, Kenya, Mozambique, Congo, Rep., Benin, Nigeria, Cameroon, Senegal, South Africa, Tanzania, and Zimbabwe. The sources of the data are: World Bank's World Development Indicators (2019). The countries and the data periods are selected based on accessibility of data.

The statistics of the raw data for mean, standard deviation and variation for both the single and group variables are shown in Table 2. The table consist of the summary statistics related to real values of a given data for every country. The highest average of energy consumption per capita (2588.59), and real GDP per capita (10045.80) are South Africa and Gabon respectively. The lowest average of real GDP per capita (377.81) and energy consumption per capita (255.60) are in Congo, Dem. Rep. and Senegal respectively. Furthermore, Botswana is the most volatile state (described by the standard deviation) in real GDP per capita (1274.96) and Gabon is the highest volatile country with std. dev. of energy consumption per capita (698.08), while the least volatility countries with respect to standard deviation in energy consumption and GDP per capita are Sudan (16.23) and Togo (59.72), respectively.

Summary statistics (before taking logarithm), 1990-2018.

	Descriptive statistics	GDP per capita (constant 2010 US$)	Energy use (kg of oil equivalent per capita)	Labour force, total	Gross fixed capital formation(Current US$)
Angola	Means	2854.53	491.32	8089915.48	14497442498.64
	Std. Dev.	697.94	46.93	2427575.83	13444823840.17
	CV	24.45	9.55	30.01	92.74
Benin	Means	724.85	359.35	3164135.66	1164492155.26
	Std. Dev.	82.11	45.63	818132.15	837987977.46
	CV	11.33	12.70	25.86	71.96
Botswana	Means	5863.62	1116.39	733844.24	2829404184.99
	Std. Dev.	1274.96	180.17	210583.24	1675655358.26
	CV	21.74	16.14	28.70	59.22
Cote d'Ivoire	Means	1343.56	483.11	6371491.17	2770113395.98
	Std. Dev.	134.92	109.11	1067760.57	2287365332.27
	CV	10.04	22.58	16.76	82.57
Cameroon	Means	1247.88	377.14	7865850.00	4392041652.40
	Std. Dev.	132.04	34.84	1715568.19	2406351573.88
	CV	10.58	9.24	21.81	54.79
Congo, Dem. Rep.	Means	377.81	329.27	20518231.86	3556987244.09
	Std. Dev.	98.81	37.89	4319073.82	3673721885.96
	CV	26.15	11.51	21.05	103.28
Congo, Rep.	Means	2644.65	364.92	1448603.07	1682725502.98
	Std. Dev.	186.80	117.39	375860.06	1361837622.79
	CV	7.06	32.17	25.95	80.93
Algeria	Means	4019.08	1040.59	9674824.38	34683545928.59
	Std. Dev.	581.11	217.76	1804082.65	25519402524.55
	CV	14.46	20.93	18.65	73.58

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Egypt	Means	2176.08	729.97	23163754.10	24872667118.36
	Std. Dev.	452.03	136.62	5360725.27	12738628995.49
	CV	20.77	18.72	23.14	51.22
Gabon	Means	10045.80	1958.58	423929.93	2600467007.36
	Std. Dev.	1004.79	698.08	143851.43	1603677116.46
	CV	10.00	35.64	33.93	61.67
Ghana	Means	1165.90	333.86	9168371.97	4793170197.88
	Std. Dev.	320.23	42.28	1811598.31	4985271793.90
	CV	27.47	12.66	19.76	104.01
Kenya	Means	922.53	456.90	13881194.17	5710156597.14
	Std. Dev.	112.67	34.67	3359106.48	4770938050.83
	CV	12.21	7.59	24.20	83.55
Morocco	Means	2415.07	450.08	10205465.69	19256560950.25
	Std. Dev.	564.41	94.00	1456355.38	10359232178.37
	CV	23.37	20.89	14.27	53.80
Mozambique	Means	378.89	423.67	9201296.03	1900599313.36
	Std. Dev.	135.63	19.09	2023572.03	1930901897.79
	CV	35.80	4.51	21.99	101.59
Nigeria	Means	1861.20	736.40	42934494.10	42666180520.85
	Std. Dev.	451.67	35.49	9392713.09	22750034188.18
	CV	24.27	4.82	21.88	53.32
Sudan	Means	1283.80	384.44	8468142.93	6999765612.92
	Std. Dev.	397.78	16.23	1708245.27	6181697214.18
	CV	30.98	4.22	20.17	88.31
Senegal	Means	1199.32	255.60	3087708.07	2617028678.55
	Std. Dev.	148.46	32.71	621338.49	1420414260.46
	CV	12.38	12.80	20.12	54.28
Togo	Means	542.89	421.63	2526432.21	522787054.62
	Std. Dev.	59.72	50.22	594270.08	419935924.07
	CV	11.00	11.91	23.52	80.33
Tunisia	Means	3378.96	804.11	3407690.17	6908629420.68
	Std. Dev.	766.32	132.14	479462.44	2452370326.54
	CV	22.68	16.43	14.07	35.50
Tanzania	Means	648.91	433.06	18224346.59	7044754317.15
	Std. Dev.	157.43	51.28	4115534.39	6254853177.26
	CV	24.26	11.84	22.58	88.79
South Africa	Means	6591.79	2588.59	17512237.07	44194840536.37
	Std. Dev.	799.00	154.40	2905849.86	22257704175.33
	CV	12.12	5.96	16.59	50.36
Zimbabwe	Means	1224.03	839.90	5765852.28	1336158613.43
	Std. Dev.	221.69	58.20	703167.72	839957407.73
	CV	18.11	6.93	12.20	62.86

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Panel	Means	2405.05	699.04	10265355.05	10772750841.45
	Std. Dev.	2391.39	583.19	9978642.13	16667143995.32
	CV	99.43	83.43	97.21	154.72

Source: Authors' Computation. Notes: Std.Dev. Signifies standard deviation, CV Indicates coefficient of variation.

RESULTS AND DISCUSSIONS

Pre-Estimation Analysis: Unit Root Test and cross-sectional dependence test

The results of the unit root tests are shown in Tables 3. For the four variables, the H_0 of the unit roots cannot be rejected in level. These results firmly indicate that the variables in levels are non-stationary but are stationary at first-difference (at the 5% significance level). Thus, the study decides that whether cross-sectional dependence is recorded (or not) into account all our series are non-stationary and integrated of order one.

Table 3

Panel unit root test: Summary

Null: Unit root (assumes common unit root process)

Series	Methods	Statistic	Prob**	cross section	obs
D(GDP)	Levin, Lin & Chu t*	-9.58884	0.0000	22	583
	Im, Pesaran and Shin W-stat	-10.7121	0.0000	22	583
	ADF - Fisher Chi-square	194.792	0.0000	22	583
	PP - Fisher Chi-square	218.874	0.0000	22	594
D(ENERGY)	Levin, Lin & Chu t*	-19.8724	0.0000	22	589
	Im, Pesaran and Shin W-stat	-17.9466	0.0000	22	589
	ADF - Fisher Chi-square	327.713	0.0000	22	589
	PP - Fisher Chi-square	349.117	0.0000	22	594
D(LABOUR)	Levin, Lin & Chu t*	-3.4543	0.0000	22	586
	Im, Pesaran and Shin W-stat	-4.56895	0.0000	22	586
	ADF - Fisher Chi-square	95.9217	0.0000	22	586
	PP - Fisher Chi-square	99.5706	0.0000	22	594
D(CAPITAL)	Levin, Lin & Chu t*	-17.5113	0.0000	22	589
	Im, Pesaran and Shin W-stat	-16.0561	0.0000	22	589
	ADF - Fisher Chi-square	307.633	0.0000	22	589
	PP - Fisher Chi-square	335.262	0.0000	22	594

** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.

Source: eviews10 Output

Estimation.

The simultaneous equation is estimated by making use of generalized method of moments (GMM). While estimating the energy consumption-economic growth connection, Capital and Labour are captured as control variables. The study employed the Hausman test to capture for endogenic relationship. The H_0 of the Hausman state that the variables are consistent; meaning that, if endogeneity is found in the explanatory variables will be harmless to estimates. the rejection of the null hypothesis (H_0) is a sign that the endogenous explanatory variables impact on the estimations are substantive, and implemental techniques are needed. However, the test of Pagan-Hall is employed to examine the presence of heteroskedasticity. The H_0 of homoscedasticity is accepted, implying that the GMM technique is robust. Then, the robustness of the tools was conducted applying the Hansen test (J-statistics) in which, the H_0 of over identifying limitations is failed to be rejected.

The empirical GMM results are found in table (4), which reveals that energy consumption has a positive and significant effect on GDP on Algeria, Egypt, Morocco, Togo, Tunisia, Democratic Republic of Congo (DR

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Congo), Ghana, Kenya, Mozambique, Congo, Nigeria, Cameroon, Senegal, South Africa, Tanzania, and Zimbabwe, but insignificant on Angola, Botswana, and Sudan. Meanwhile, it has negative and significant effect on Gabon, Côte d'Ivoire, and Benin. This result empirically implies that a unit increase in the consumption of energy per head tends to compress economic growth in Gabon, Côte d'Ivoire, and Benin. In the elasticities, it could be deduced that with a rise in EC (Energy Consumption), growth (GDP) decreases higher in Gabon than in Côte d'Ivoire and Benin with the coefficients of 0.2993 > 0.1545 > 0.0476 respectively. However, this revealed that EC has a positive and significant effect on GDP. The coefficient of EC is 0.4858, specifying that GDP rises by 48.58% when a unit increase in the consumption of energy is recorded. This entails that a rise in EC may boost the growth of the economy. As energy a key to economic growth, policies in energy firms are needed to accomplish sustainable growth, which is parallel to growth hypothesis. Similarly, this result re-affirms the findings of Agboola H. Yusuf (2015), Gbadebo, O., Chinedu, O. (2009), Eggoh, J.C., Bangake, C., and Rault, C. (2011) Apergis and Payne (2010), Sharma, (2010), (Adom (2013) and Adom and Bekoe (2012).

The coefficient of labour is negative for Angola, Côte d'Ivoire, Congo, Rep., DRC, Gabon, Kenya, Morocco, Togo, and Zimbabwe, and positive for Benin, Botswana, Cameroon, Senegal, South Africa, Tanzania, Algeria, Egypt, Ghana, Nigeria, Mozambique, Tunisia, and Sudan. However, the negative effect of labour force on GDP suggesting that most of the GDP is coming from energy intensive capital than labour intensive. This further implies that there was substitution of capital for labour in those countries. This is because the labour force abounds in developing economies and relatively cheaper, (Anis Omeri, 2013). The coefficient of capital is positive and significant for all the countries. This entails that the countries are capital intensive with relation to GDP. This further suggests that capital is a key causal factor to economic growth. The panel results showed that the coefficient of Capital is positive and significant and the coefficient of labour is significantly negative. The findings re-affirms the result of Shahbaz et al. (2012). This mean that GDP rises by 0.269% after a percentage rise in capital. Meanwhile, a percentage rise in labour force decreases GDP by 0.410%.

Table 4: Results of Panel GMM estimation for Eq. (3).

Dependent variable: Economic Growth (GDP)				
Crossid	Intercept	ENC	Labour	Capital
Angola	6.118131**	0.05159***	-0.27214***	0.254908**
Benin	1.298984***	-0.047617***	0.313559**	0.042712***
Botswana	-0.996369**	0.060233***	0.588552**	0.060263**
Cote d'Ivoire	12.76093**	-0.154536***	-0.55678**	0.190921**
Cameroon	-1.389838***	0.311007***	0.225054***	0.140232***
Congo, Dem. Rep.	14.41514**	1.70191**	-1.178605**	0.068641**
Congo, Rep.	8.563773**	0.258168**	-0.193585	0.025918***
Algeria	1.652279***	0.158741**	0.21292***	0.087975**
Egypt	-6.347873**	0.120682***	0.703261**	0.055036**
Gabon	10.78752**	-0.297316**	-0.034341***	0.051349***
Ghana	-11.61000**	0.305865**	0.922311**	0.095797**
Kenya	0.335791***	1.314459**	-0.203055**	0.080055**
Morocco	1.352351***	0.728306***	-0.09111***	0.146489***
Mozambique	-21.5641**	0.897196**	1.299982**	0.057585**
Nigeria	-11.63366**	1.449389**	0.23839***	0.221462***
Sudan	-10.43875**	0.076836***	0.924872**	0.106542**
Senegal	1.704614***	0.182202***	0.092706***	0.138529**
Togo	5.72458**	0.555558***	-0.421328**	0.171919**
Tunisia	-7.407909**	0.809583**	0.626044**	0.030597***
Tanzania	-4.712915**	1.20522**	0.186398***	0.033464***
South Africa	0.079659***	0.112392***	0.258899**	0.143966**
Zimbabwe	3.065259***	1.628023**	-0.524486**	0.058758**
Panel	3.162017**	0.485861**	-0.58079**	0.46284**
Hansen test J-statistic (P-value)	0.0000			
Durbin-wu-Hausman test (P-value)	0.0043			
Pagan-Hall test (p-value)	0.0119			

Notes: All variables are in natural logs
** indicates level of significant @ 5%
*** indicates level of Significant @ 10%

Furthermore, the results of Eq. (4) are provided in Table 5. The result showed that GDP has a positive and significant effect on EC for Algeria, Botswana, Egypt, Morocco, Togo, Tunisia, Democratic Republic of the Congo (DR Congo), Ghana, Kenya, Mozambique, Congo, Rep., Nigeria, Cameroon, Senegal, Tanzania, and Zimbabwe. However, the effect for Angola, Benin, Sudan and South Africa, is insignificant though positive. This mean that, a rise in GDP increased EC in these countries. While, it has a negative and significant effect on Cote d'Ivoire and Gabon. Meaning that a rise in GDP is incline to decline EC in Cote d'Ivoire and Gabon. From these elasticities, it can also be understood that because of the rise in GDP, EC decline more in Gabon than in Cote d'Ivoire (1.5942 > 0.0755). For the panel analysis, it reveals that GDP has an increasing impact on EC. The value is 0.6706, revealing that EC will rise by 67% when GDP rises by a percentage. Meaning that a rise in growth will raise the consumption of energy (Ang, 2008; Shahbaz et al., 2012; Islam et al., 2013; Stern and Enflo, 2013). The outcome re-affirms the results of Altinay and Karagol (2004) for Turkey; Oh and Lee (2004) for Korea; Ang (2008) for Malaysia; Belloumi (2009) for Tunisia; Halicioglu (2009) for Turkey; Odhiambo (2009) for Tanzania; Omeri (2013) for 14 MENA countries.

The coefficient of labour force variable has a positive and significant effect on EC in the case of Morocco, Togo, Cote d'Ivoire, Kenya, Congo Rep., Democratic Republic of Congo (DR Congo), Benin, Senegal, and Zimbabwe. While Egypt, Angola, Ghana, Mozambique, South Africa, and Tanzania shows negative effect. However, capital shows a positive and significant effect on EC for Algeria, Morocco, Gabon, Tunisia, Angola, Côte d'Ivoire, Mozambique, Congo, Rep., South Africa, and Tanzania. This result is parallel to the literature on capital accumulation is anticipated to raise EC (see Lorde et al., 2010). It has a significant negative impact for Botswana, Benin, Egypt, Sudan, Togo, Kenya, Democratic Republic of Congo (DR Congo), Ghana, Nigeria, Cameroon, Senegal, and Zimbabwe. This revealed that a rise in real capital will lead to a decline in EC in these countries. This contradicts postulations in the literature with regards to capital accumulation in relation to energy consumption. In the panel estimation, the effect of real capital is negative on EC. The value is 0.1122, showing that EC declines by 11% if a percentage increase in the real capital is recorded. Therefore, capital play little or zero significant role in EC in Africa. However, findings re-affirms that of Apostolakis (1990), Sari et al. (2008), and Lorde et al. (2010).

Table 5: Results of Panel GMM estimation for Eq. (4).

Dependent variable: Energy Consumption				
Crossid	**Intercept**	**GDP**	**Labour**	**Capital**
Angola	4.991768**	0.003476***	-0.030827***	0.072973***
Benin	-1.042065***	0.003606***	0.513331***	-0.036422***
Botswana	2.440355***	0.762327**	0.094592***	-0.153931***
Cote d'Ivoire	-3.968578***	-0.075524***	0.411165***	0.197313**
Cameroon	8.610322**	0.122218***	0.010119***	-0.168534**
Congo, Dem. Rep.	-4.389197***	0.370958**	0.484315**	-0.007023***
Congo, Rep.	-21.55979**	2.702943**	0.319794***	0.076051***
Algeria	0.26361***	0.281577***	0.007106***	0.175471**
Egypt	4.039915***	1.326962***	-0.410709***	-0.028896***
Gabon	14.05916**	-1.594292**	0.127956***	0.302901**
Ghana	20.97627**	1.144433**	-1.398412**	-0.03888***
Kenya	0.11433***	0.715033**	0.136103**	-0.049831**
Morocco	-8.568061**	0.30335**	0.637657**	0.085684**
Mozambique	13.46393**	0.381797**	-0.610139**	0.004946***
Nigeria	5.127521**	0.209004**	0.018594***	-0.017279***
Sudan	6.289225**	0.071238***	0.003684***	-0.040686**
Senegal	-1.848067***	0.628604***	0.250868***	-0.038313***
Togo	-3.057514**	0.333036***	0.601726**	-0.094076**
Tunisia	0.208695***	0.629317**	0.007538***	0.055515***
Tanzania	3.998114**	0.192151***	-0.053747**	0.07767**
South Africa	5.785766**	0.056295***	-0.018887**	0.077484**
Zimbabwe	2.185397***	0.298332**	0.157622***	-0.001317***
Panel	0.631062**	0.670664**	0.206698**	-0.112254**
Hansen test J-statistic (P-value)	0.0000			
Durbin-wu-Hausman test (P-value)	0.0040			
Pagan-Hall test (p-value)	0.0076			

Notes: All variables are in natural logs
** indicates level of significant @ 5%
*** indicates level of Significant @ 10%

Table: 6 Pairwise Dumitrescu Hurlin Panel Causality Tests

Null Hypothesis:	W-Stat.	Zbar-Stat.	Prob.	Result	Conclusion
ENC→GDP	4.88841	5.18453	0.00000	Yes	Bidirectional causality
GDP→ENC	6.19778	7.70961	0.00000	Yes	between ENC and GDP
L→GDP	12.2070	19.2982	0.00000	Yes	Bidirectional causality
GDP→L	5.76301	6.87118	0.00000	Yes	between L and GDP
K→GDP	5.05337	5.50265	0.00000	Yes	Bidirectional causality
GDP→K	5.14977	5.68855	0.00000	Yes	between K and GDP
L→ENC	6.19681	7.70775	0.00000	Yes	Bidirectional causality
ENC→L	4.99311	5.38644	0.00000	Yes	between L and ENC
K→ENC	6.65460	8.59057	0.00000	Yes	Bidirectional causality
ENC→K	3.63295	2.76340	0.00570	Yes	between K and ENC
K→L	4.19042	3.83848	0.00010	Yes	Bidirectional causality
L→K	6.59840	8.48220	0.00000	Yes	between L and K

Source: Author's computation via Eviews 9

Notes: *ENC→GDP denotes causality runs from energy consumption to income.*
ENC←GDP denotes causality runs from income to energy consumption.
ENC↔GDP denotes bi-directional causality between income and energy consumption.
ENC denotes energy consumption. GDP denotes economic growth.
L denotes Labour. K denotes Capital.

The Dumitrescu Hurlin Panel Causality test (table 6 above) reveal that, the relationship between EC and growth is categorized by bidirectional causality, in both the short and long-run. This insinuates that an increase in GDP could significantly affect EC for two reasons: first, economic growth could raise production activities and infrastructures building, then enhance energy needs, because the latter is an important input in the production process. Second, in as much as production increased, higher revenues will be recorded and that will enhance an even distribution of income among households. In search of ease, households can improve their living by purchasing electronic goods such as, appliances, transport or computers. It further showed that EC and economic growth are interrelated and may very well serve as complements to each other. Hence, an increase in real GDP enhances EC and this in turn can enhance production in real sector. This explains the bidirectional causality obtained between EC and growth.

CONCLUSION AND POLICY IMPLICATIONS

This paper empirically re-examined the causality relationship between EC and growth as well as the impact of GDP and EC on capital stock and labour in 22 African countries over the period of 1990 – 2018 employing the popular production function of Cobb-Douglas in a panel setting. This model was simultaneously estimated by GMM/Dynamic panel data estimation methods. Meanwhile, the studies on the causality connection among energy-growth has risen in recent years, the use of simultaneous equations models to examine this interrelationship seems to be lacking in Africa. Therefore, this study fills in the research gap and add to the depository of existing knowledge. The empirical analysis consists of estimating both the fixed and random effects model, while, the Hausman test was utilized to detect the better panel model, and the random effects model appeared to be the best model for the study at critical level of $p \leq 0.05$.

The estimation of panel GMM/DPD for Eq. (3) shows that EC has a positive and significant effect on GDP. This insinuates that an increase in growth increase EC. However, the value of Capital is positive and significant, while the value of Labour is negative. The panel empirical results of Eq. (4) show that GDP has a positive impact on EC. This means that an increase in growth increase EC. The value of Capital is positive and significant. This implies that the countries are capital intensive with relation to GDP. This further connotes that capital is a significant indicator of growth. The value of Labour is negative and significant, suggesting that most of the GDP is coming from energy intensive capital than labour intensive. This further implies that there was substitution of capital for labour in those countries.

From this discussion, it is ruminated that energy serves as an engine of economic growth, and economic activity will be affected as the result of changes in EC. This insinuates that continuous energy use will stimulate a continuous rise in output. So, the policymakers in African countries can focus a special interest in different sources of energy and invest heavily in the sector, and possibly invite foreign investors to commit their resources in the sector, and design best policies, and provides new alternate and cheap sources of energy. Providing Research and Development departments and rise in their efficiency is also required, so that it provides a multiplier effect on GDP and hence, prosperity will be attained in the economies of African countries therefore energy policy formulations are probably the better policy for a sustained economic growth in African economies.

Causality Tests showed bi-directional relationship exists between GDP and EC as well as between other instrumental variables. However, in terms of country specific, bi-directional causal relationship amongst energy consumption and economic growth was only found in Mozambique. This shows that energy consumption and economic growth and other instrumental variables are interconnected, which also validates the feedback hypothesis showing that the African countries' economies are energy dependent thus energy preservation policies may keep down economic growth and changes in economic performance are reverberated back to energy consumption. The empirical attestation in favour of bi-directional causality amonst energy consumption and economic growth confirms by, Costantini and Martini (2010), Belke et al. (2011), Dobnick (2011), Yıldırım and Aslan (2012), Ozturk and Al-Mulali (2015), Jammazi and Aloui (2015).

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