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Financial Development and Energy Consumption in Sub-Saharan Africa: Evidence From Panel Vector Error Correction Model

Chigozie Nelson Nkalu[1], Samuel Chinwero Ugwu[1], Fredrick O. Asogwa[1], Mwuese Patricia Kuma[2], and Queen O. Onyeke[1]

Abstract

This study examines the nexus between financial development and energy consumption/use in Sub-Saharan Africa (SSA) using a panel vector error correction model (VECM), cointegration, and Granger causality tests over the period ranging from 1975 to 2017. The annual panel time-series data generated from the World Bank database were tested for unit-roots processing using both the Levin–Lin–Chu and Im–Pesaran–Shin before proceeding to Johanson cointegration technique, the results of which motivated the choice of adopting the panel VECM rather than panel vector autoregression in the methodology. From the estimation result especially on the variables of interest, there exists a positive and statistically significant relationship between financial development and energy consumption in the long run, but not statistically significant in the short run. Further findings from the panel Granger causality test shows a unidirectional causality running from financial development to energy consumption, gross domestic product per capita, population growth to urbanization with no feedback. Among a series of policy recommendations, the monetary authorities in Sub-Saharan African countries should ensure optimal utilization of financial instruments and technologies available in the system to enhance more robust financial development to boost efficiency in energy consumption in the region in line with the sustainable growth theory.

Keywords

financial development, energy consumption, panel VECM, Granger causality, Sub-Saharan Africa

Introduction

Energy demand and consumption are an integral part of human daily life as it is tied to achieving improved human well-being and making lives worth living. As the annual population growth and urbanization experience rise continuously over the recent years, the level of energy use or consumption tends to triple as it is needed to maintain the quality of human lives and standard of living (Dash, 2013).

Energy consumption in a particular country or economies mainly centers on energy utilization by the household, industrial, and transportation sectors (Dash, 2013). However, energy consumption or use means, "the use of primary energy before transformation to other end-use fuels, which is equal to indigenous production plus imports and stock changes, minus exports and fuels supplied to ships and aircraft engaged in international transport" (World Bank, 2019). At the household level, energy consumption can be affected by the family size, income level of the household, occupation type, gender, education as well as urbanization rate or population density (people per sq. km of land area) and annual population growth at the macro-level (Dash, 2013). In Sub-Saharan Africa (SSA), the level of energy consumption has experienced relative oscillations over the years (World Bank, 2019).

Figure 1 presents interesting trends in energy consumption or use (kg of oil equivalent per capita). It is clear from the trends that energy use in SSA has experienced relative oscillations over the years. For instance, the energy use (kg of oil equivalent per capita) has increased from approximately 678.56 kg of oil equivalent per capita in 1975 to 723.92 kg in

[1]University of Nigeria, Nsukka, Nigeria
[2]Federal University of Agriculture, Makurdi, Nigeria

Corresponding Author:
Samuel Chinwero Ugwu, Department of Public Administration and Local Government, University of Nigeria, Nsukka 410002, Nigeria.
Email: sam.ugwu@unn.edu.ng

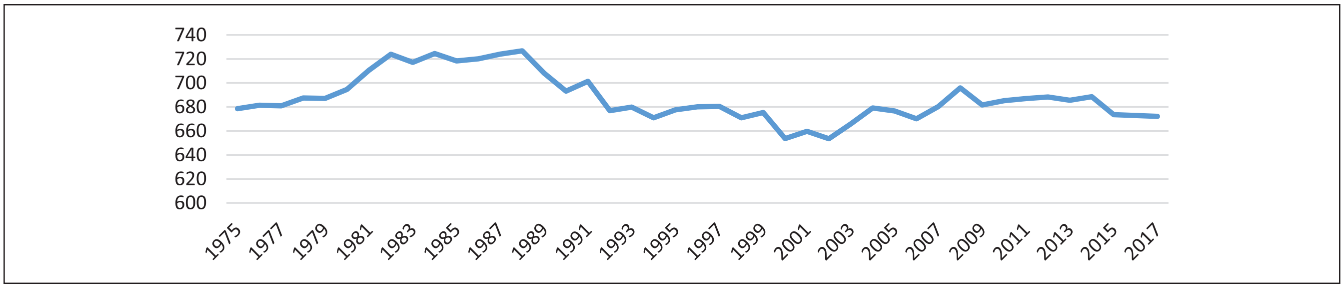

Figure 1. Trends in energy consumption in Sub-Saharan Africa, 1975–2017.
Source. World Development Indicators (2019).

1982, and has continued hovering between 717.14 kg in 1983 and 688.50 kg in 2014, and beyond (World Bank, 2019).

Essentially, the link at which financial development influences energy consumption or use has generated many debates in the literature as many studies have inundated with arguments on establishing the nexus between financial development and energy consumption. For instance, while studies by Sadraoui et al. (2019), Roubaud and Shahbaz (2018), and Destek (2018) found a positive causal relationship between financial development, other studies like Ali et al. (2015), Mahalik and Mallick (2014), and Zeren and Koc (2014) found a negative causality between financial development and energy consumption due to negative shocks in energy prices.

Many studied adopted domestic credit to the private sector by banks as a proxy financial development in a view to calibrate and capture the levels of financial development over the years. However, according to World Bank (2019), domestic credit to the private sector by banks as a percentage of gross domestic product (GDP) means

> financial resources provided to the private sector by other depository corporations (deposit-taking corporations except for central banks), such as through loans, purchases of non-equity securities, and trade credits and other accounts receivable, that establish a claim for repayment. For some countries, these claims include credit to public enterprises (World Bank, 2020).

In SSA, attention has been given to domestic credit of the private sector by banks as a means of alleviating poverty and thus ensuring improved standard of living. For instance, the domestic credit of the private sector by banks has hovered approximately between the minimum of US$19.57 billion and a maximum of US$34.80 billion between 1975 and 2018 (World Bank, 2019). It is important to note that SSA is made up of a total number of 48 (countries) which include the following (Table 1):

Table 1. List of Countries in Sub-Saharan Africa.

1	Angola
2	Benin
3	Botswana
4	Burkina Faso
5	Burundi
6	Cabo Verde
7	Cameroon
8	The Central African Republic
9	Chad
10	Comoros
11	Congo—Dem. Rep.
12	Congo—Rep.
13	Cote d'Ivoire
14	Equatorial Guinea
15	Eritrea
16	Eswatini
17	Ethiopia
18	Gabon
19	The Gambia
20	Ghana
21	Guinea
22	Guinea-Bissau
23	Kenya
24	Lesotho
25	Liberia
26	Madagascar
27	Malawi
28	Mali
29	Mauritania
30	Mauritius
31	Mozambique
32	Namibia
33	Niger
34	Nigeria
35	Rwanda
36	Sao Tome and Principe
37	Senegal
38	Seychelles
39	Sierra Leone
40	Somalia
41	South Africa
42	South Sudan
43	Sudan
44	Tanzania
45	Togo
46	Uganda
47	Zambia
48	Zimbabwe

Note. Compiled by the Authors using the World Bank Development Indicators.

Therefore, this study is aimed at determining both the short-run and the long-run relationship between financial development and energy consumption, as well as examining the causal relationships between the two core variables in Sub-Saharan African countries. This study is of utmost importance to the economies of SSA given the fact that majority of the economies are still struggling with the challenges associated with financial development, accessing credit from a financial institution, and other issued relating to energy consumption. This study will provide the economies in SSA possible policy options to tackle these challenges as well as achieve more efficiency in energy use and other instruments of financial development. In sum, following an extensive review of the related literature on this subject, this study's objectives can be achieved by adopting either panel vector autoregression (PVAR) or panel vector error correction model (VECM) based on the outcome of cointegration test.

Brief Literature Survey

It is imperative under this brief literature survey to provide both the theoretical literature and the empirical literature to show a holistic insight on the subject matter. This section is classified into two sub-sections as thus: the theoretical literature and the empirical literature.

The Theoretical Literature

In the theoretical front, the centrality of all the debates on energy consumption revolves around energy efficiency. In the literature, energy efficiency as a term is used in different terminologies to reflect energy conservation, energy savings, or even energy consumption (Vasseur et al., 2019). The notable theory of energy consumption or energy efficiency includes the rebound effect theory of 1865, Khazzoom-Brookes theory of 1992, and other modern theories such as the sustainable theory and the green growth theory put forward in 2011 by the Organisation for Economic Cooperation and Development (OECD) and the United Nations Environmental Program (UNEP).

The rebound effect theory of 1865 was postulated by a British economist Williams Stanley Jevons through a book titled *The Coal Question*. He argued that technological development or progress has no negative effect on the dwindling consumption of coal; that the economical consumption of fuel has no reducing effect on its consumption (Blake, 2005). In the late 1980s, two economists, Daniel Khazzoom and Leonard Brookes, criticized the Jevon's Paradox to propound the Khazzoom-Brooks theory even though the theory came into limelight precisely in 1992. According to the Khazzoom-Brooks theory, doubling energy efficiency can triple energy consumption by making energy usage relatively cheaper and thus encouraging greater consumption as well as contributing significantly to economic growth and development (Blake, 2005).

The modern theories of energy consumption such as sustainable theory and green growth theory still hover around energy efficiency. While the sustainable theory centered on providing a possible panacea to excessive carbon dioxide (CO_2) emissions in the environment which could be hazardous to environmental habitats, the green growth theory concentrates on the environmental protection through a reduction in environmental pollutions as well as protecting the natural resources from environmental damage. Just like other theories in the literature, both the sustainable theory and green growth theory of energy efficiency were applauded as well as criticized. It was pointed out that if the theories are properly adopted and utilized, more relative environmental protections could be achieved which will, in turn, lead to sustainable economic growth and development. On the contrary, the theories were criticized in the sense that if the policy options could be channeled to more robust investment and innovations aspect of the economy, more significant positive improvements will be recorded through economic growth and sustainable development by engendering more economic opportunities (Vasseur et al., 2019).

The Empirical Literature

Under the empirical front, Sadraoui et al. (2019) utilized a dynamic panel data model, cointegration, and Granger causality approaches over the time period covering 2000 and 2018 in examining the interconnectivity among financial development, energy consumption, and economic growth in the Middle East and North Africa (MENA) region. The result from the panel analysis showed that financial development has a positive and significant effect on economic growth, while financial development Granger causes energy consumption in the MENA region. In Pakistan, Roubaud and Shahbaz (2018) analyzed the relationship between financial development and electricity consumption using cointegration technique and VECM Granger causality from 1972 to 2014. The study found a feedback bi-directional causality between electricity consumption and financial development in Pakistan economy.

Haider and Adil (2019) utilized the autoregressive distributed lag (ARDL) bounds testing approach in investigating the long-run relationship among financial development, trade openness, and industrial energy use or consumption in India between 1971 and 2016 while applying Johansen and Juselius's (1990) cointegration test and VECM. The results showed the presence of cointegration as well as non-linear/long-run nexus among the variables in the model. In South Africa, Odhiambo (2018) studied the interrelationships among energy consumption, financial development, and economic growth from 1980 to 2013 using both cointegration and ARDL bounds approaches. The study proxied financial development with domestic credit to the private sector, the spread of bank lending deposit, and bank credits. However, the result revealed a long-run unidirectional causality flowing from financial development to energy consumption to economic growth in South Africa.

Destek (2018), using data from seven emerging economies between 1991 and 2015, investigated the relationships among financial development, real income, energy consumption, and energy price. The study viewed financial development under the three categories, namely, stock market, banking sector, and bond market. The study adopted a common correlated effect in determining the objective of the study, and the result revealed that the development of the bond market is the most effective channel of reducing energy consumption in the emerging economies. In an explorative study, Sbia et al. (2017) investigated the links among financial development, economic growth, urbanization, and electricity consumption in the United Arab Emirates (UAE) between 1975 and 2011 using the ARDL bound testing approach. The long-run relationship resulting from the VECM Granger causality estimation outcome is evidenced in financial development and electricity consumption.

In South Africa, Gungor and Simon (2017) studied the interconnectivity among financial development, energy consumption, economic development, urbanization, and industrialization between 1970 and 2015 using Johanson cointegration test, VECM. The empirical result showed energy consumption is positively correlated with urbanization, financial development, and industrialization in the long run. Also, the bi-directional causality identified that the causal effects are between financial development and energy consumption, industrialization and energy consumption, and financial development and industrialization in South Africa. In a related study in India, Shahbaz et al. (2017) incorporated financial development in the study of asymmetric nexus between economic growth and energy consumption using quarterly data spanning from 1960Q1–2015Q4. The nonlinear ARDL bounds approach was adopted in capturing the causal relationship between variables. The study findings showed that negative shocks from energy consumption have devastating consequences on economic growth and financial development in the Indian economy.

Kakar (2016) adopted Pakistan and Malaysia as a case study in determining the dynamic relationships between financial development and energy consumption as well as economic growth over a period ranging from 1980 to 2010 using Granger causality, cointegration, and error correction model (ECM). The result highlighted a unidirectional causality between financial development and energy consumption in both Pakistan and Malaysian economies. In Italy, Magazzino (2016) equally used the ARDL bound test, vector autoregression (VAR) framework, Toda and Yamamoto, and Granger causality test approaches in analyzing the relationship between energy consumption, financial development, and real GDP. The highlighted existence of long-run nexus among the variables is at 1% level of significance. The study also found a positive effect of real GDP on energy consumption in Italy. These findings are similar to the result of Salami et al. (2016) in Nigeria who also examined the interconnectivity among financial development energy consumption and economic growth using the generalized method of single equation model. The empirical findings revealed that financial sector expansion is correlated to influence increase in energy consumption and economic growth in Nigeria.

In re-examining the short-run and long-run causal nexus between financial development and energy consumption in Nigeria, Odusanya et al. (2016) used time-series data from 1971 to 2104 under the methodological framework of ARDL bounds cointegration approach. The estimation output showed existence of both short-run and long-run positive and significant relationship between financial development and energy use in Nigeria which is equally in tandem with theoretical postulations. In related findings, Salman and Atya (2014) utilized ECM as well as Granger causality to examine the effect of energy consumption and financial development on economic growth in selected North African economies which include Tunisia, Egypt, and Algeria between 1980 and 2010. While the empirical result showed a significant positive relationship between financial development and energy consumption in both Algeria and Tunisia, the result of the Egyptian economy was on the negative side.

Abidin et al. (2015) utilized Granger causality and ARDL bound tests in analyzing the connection among energy use, foreign direct investment (FDI), and financial development in some selected ASEAN economies involving Thailand, Singapore, Philippines, Malaysia, and Indonesia. The result from the regression output showed a significant long-run relationship in all the independent variables which include energy consumption, financial development, trade, and FDI. More importantly, the ARDL result further pointed out the existence of a long-run relationship between energy use and financial development, as well as Granger causality running from FDI inflows to energy consumption, and energy consumption to financial development. Equally, Ali et al. (2015) also adopted the same ARDL bound test approach with quarterly data ranging from 1972Q1 to 2011Q4 in investigating the dynamic relationship among financial development, economic growth, energy consumption, and energy price in Nigeria. The study result showed insignificant positive nexus among energy consumption, financial development, and energy price in the short run. In the long-run scenario, energy price is still positive but financial development and economic growth tend toward insignificant negative effects.

Similarly, Çetin et al. (2015) adopted the ARDL bound, VECM, as well as Johansen–Juselius approaches in investigating the Granger causality and cointegration analysis between financial development and energy use in Turkey between 1960 and 2011. The estimation output revealed a positive and statistically significant relationship between financial development and energy consumption in Turkey in the long run with unidirectional causal effect from financial development to energy use in both long and short run. Mahalik and Mallick (2014) employed ARDL model with cointegration in studying the interrelationship among energy consumption, financial development, and economic growth in India using time-series data between 1971 and 2009. The estimation result revealed a significant and negative effect of energy consumption on financial development and economic growth.

Alam et al. (2015) studied the contribution of financial development to the South Asian Association for Regional Cooperation (SAARC) energy demand between 1975 and 2011 using panel fixed-effect model after conducting a Hausman test. The SAARC countries are made up of Sri Lanka, Pakistan, Nepal, India, and Bangladesh. However, many indicators were adopted in measuring financial development which is not limited to broad money, domestic credit to the private sector by banks, and liquidity liability. The empirical findings from the panel fixed-effect analysis revealed significant positive relationship among financial development, economic growth, FDI, and energy consumption in the SAARC countries. Also, utilizing the time-series data spanning from 1971 to 2010 generated from the seven newly industrialized economies, Zeren and Koc (2014) studied the nexus between financial development and energy while adopting Hatemi-J asymmetric causality test to control for both the negative and positive shocks. Essentially, the newly industrialized economies include Turkey, Thailand, Philippines, South Africa, Mexico, Malaysia, and India. The study used three variables in capturing the financial development, namely, share of deposit money bank assets to GDP, the share of financial system deposits to GDP, and the share of private credit to GDP. The result showed causality running from energy use to financial developments in negative shocks only for the Philippines

Çoban and Topcu (2013) applied system generalized method of moments (GMM) in investigating the nexus between financial development and energy utilization in 27 countries of the European Union (EU) between 1990 and 2011. The result showed that irrespective of the angle of the financial development—whether bank or stock markets—financial development's impact on consumption of energy is more significant in the old member countries of the EU. On the contrary, the level of the impact of financial development on energy use largely depends on the unit of measuring the development. Adopting the stock index measurement of the financial development indicated no significant relationship, while the bank index highlighted significant nexus between the core variables. Xu (2012) used a panel dataset of 29 provinces in China between 1999 and 2009 to investigate the dynamic effects of financial development on energy consumption with the system GMM. The study captured financial development with the ratio of FDI to GDP, and the ratio of loans to GDP in financial institutions. However, the result revealed a significant positive relationship between financial development and energy consumption in China. The study equally found a short-run impact of financial development in the development of financial institutions loan scale, and long-run impact in FDI development.

In a related study, Kakar et al. (2011) investigated the nexus between energy use and economic growth through financial development in Pakistan between 1980 and 2009 using annual time-series data. The study utilized ECM, cointegration, and Granger causality tests to ascertain the direction of the causal relationship between energy consumption and financial development. The findings of the study showed a causality running from financial development to energy consumption in Pakistan economy. Sadorsky (2010) also utilized panel data of 22 emerging economies between 1990 and 2006 to study the effect of financial development on energy consumption using the system GMM approach. The study adopted stock market indices such as the share of the market capitalization of GDP, market turnover, and traded market value to GDP as proxies for financial development. The result revealed a statistical and positive nexus between financial development and energy consumption in the 22 emerging countries.

Essentially, having presented the overview of both the theoretical and the empirical literature, it is important to note that a huge gap exists in the literature which this study tends to achieve. The significant contributions of this study to the literature are seen from the angle of providing empirical insights on the relationships between financial development and energy consumption in the 48 developing economies in SSA especially from the aspect of domestic credit to the private sector by banks. Given the underdeveloped nature of financial institutions in most countries in SSA, accessing domestic credit by the private sector from banks is one of the major challenges facing the private sector, especially the small and medium enterprises (SMEs) in the region. When properly harnessed, efficient and smooth credit accessibility by the private sector from banks as well as achieving efficiency in energy consumption, while holding constant urbanization and population growth, the economies in SSA will certainly record significant improvement in economic growth and development.

Model Specification and Description of Data

This study adopts a panel VAR/VEC model and Granger causality approach to investigate the relationship between financial development and energy consumption in SSA over the time spanning from 1975 to 2017. The annual time-series for the analysis is generated from the World Bank database (World Development Indicators [WDIs]) which of course has been subjected to pre-test of stationarity before actual estimation process. However, the justification for adopting panel VAR/VEC model is subject of cointegration test result as well as given that VAR/VEC treats all the variables in both dynamic and static model as a priori endogenous and thus control for interactions between endogenous and exogenous variables (Luetkepohl, 2011). On certain occasions, exogenous variables could be incorporated in the VAR/VEC model (Canova & Ciccarelli, 2013); therefore, the panel VAR specification for cross-section i follows non-stationary VAR process:

$$\begin{aligned} y_{it} &= \beta_i + \mathbf{A}_{i1} y_{it-1} + \cdots + \mathbf{A}_{ip} y_{it-p} \\ &\quad + \mathbf{B}_{i1} y_{-i,t-1} + \mathbf{B}_{i1} y_{-i,t-p} + \varepsilon_{it}, \end{aligned} \tag{1}$$

where β_i is an M-dimensional intercept vector and $\mathbf{A}_{ij}\,(j = 1,\ldots,p)$ refers to a set of $M \times N$-dimensional coefficient matrices related to P lags of y_{it}. The effect of other economies' lagged endogenous variables $y_{-i,\,t-p}$ is quantified via the matrices $\mathbf{B}ij$ with dimension $M \times (N-1)M$, while $\varepsilon_{it} \sim N(0_M, £_{it})$ is a Gaussian vector error term process with covariance matrix Σ_{it}. Equation 1 can be transformed into a conventional estimation equation as follows:

$$y_{it} = C_i x_{it} + \mathbf{B}_i x_{-i,t} + \varepsilon_{it}. \tag{2}$$

In essence, the variables of interest for the panel analysis include ENC = energy consumption/use (kg of oil equivalent per capita), FD = financial development proxied by domestic credit to the private sector by banks (% of GDP), GDPk = gross domestic product per capita, URB = urbanization proxied by population density (people per sq. km of land area), and POPg = population growth (annual %). Essentially, y_{it} in Equation 2 can be equivalently and more compactly represented as a VECM as thus:

$$\Delta y_{it} = \beta_0 + \sum_{i=1}^{n} \beta_1 \Delta y_{i,t-i} + \sum_{i=0}^{k} \beta_2 \Delta X_{i,t-i} + \beta_3 Z_{i,t-1} + \varepsilon_{it}, \tag{3}$$

where t indicates time period covered (t = 1, 2, . . ., T); i denotes the countries covered (i = 1, 2, . . ., N). The error correction term (ECT) is Z and Δ is basically the difference operator. The error correction coefficient measures the speed of adjustment to equilibrium. β_3 is the coefficient of error term which ought to be significant and negative otherwise there will be difficulties in inferring the long-run causality. Consequently, error correction is a term which relates to the last period deviation from long-run equilibrium that influences the short-run dynamics of the dependent variable (Obi et al., 2015). From Equation 3, the VECM equation can be elaborated to suit the empirical objective of the study as thus:

$$\begin{aligned}
\Delta \mathrm{ENC}_{it} &= \alpha + \sum_{i=1}^{k-1} \beta_i \Delta \mathrm{FD}_{i,t-i} + \sum_{j=1}^{k-1} \Phi_j \Delta \mathrm{ENC}_{i,t-j} + \sum_{i=m}^{k-1} \varphi_m \Delta \mathrm{GDPk}_{i,t-m} + \sum_{i=n}^{k-1} \Upsilon_n \Delta \mathrm{POPg}_{i,t-n} + \sum_{i=q}^{k-1} \Psi_q \Delta \mathrm{URB}_{i,t-q} + \lambda_1 \mathrm{ECT}_{i,t-1} + \varepsilon_{1it} \\
\Delta \mathrm{FD}_{it} &= \sigma + \sum_{i=1}^{k-1} \beta_i \Delta \mathrm{FD}_{i,t-i} + \sum_{j=1}^{k-1} \Phi_j \Delta \mathrm{ENC}_{i,t-j} + \sum_{i=m}^{k-1} \varphi_m \Delta \mathrm{GDPk}_{i,t-m} + \sum_{i=n}^{k-1} \Upsilon_n \Delta \mathrm{POPg}_{i,t-n} + \sum_{i=q}^{k-1} \Psi_q \Delta \mathrm{URB}_{i,t-q} + \lambda_2 \mathrm{ECT}_{i,t-1} + \varepsilon_{2it} \\
\Delta \mathrm{URB}_{it} &= \delta + \sum_{i=1}^{k-1} \beta_i \Delta \mathrm{FD}_{i,t-i} + \sum_{j=1}^{k-1} \Phi_j \Delta \mathrm{ENC}_{i,t-j} + \sum_{i=m}^{k-1} \varphi_m \Delta \mathrm{GDPk}_{i,t-m} + \sum_{i=n}^{k-1} \Upsilon_n \Delta \mathrm{POPg}_{i,t-n} + \sum_{i=q}^{k-1} \Psi_q \Delta \mathrm{URB}_{i,t-q} + \lambda_3 \mathrm{ECT}_{i,t-1} + \varepsilon_{3it} \\
\Delta \mathrm{POPg}_{it} &= \vartheta + \sum_{i=1}^{k-1} \beta_i \Delta \mathrm{FD}_{i,t-i} + \sum_{j=1}^{k-1} \Phi_j \Delta \mathrm{ENC}_{i,t-j} + \sum_{i=m}^{k-1} \varphi_m \Delta \mathrm{GDPk}_{i,t-m} + \sum_{i=n}^{k-1} \Upsilon_n \Delta \mathrm{POPg}_{i,t-n} + \sum_{i=q}^{k-1} \Psi_q \Delta \mathrm{URB}_{i,t-q} + \lambda_4 \mathrm{ECT}_{i,t-1} + \varepsilon_{4it} \\
\Delta \mathrm{GDPk}_{it} &= \ell + \sum_{i=1}^{k-1} \beta_i \Delta \mathrm{FD}_{i,t-i} + \sum_{j=1}^{k-1} \Phi_j \Delta \mathrm{ENC}_{i,t-j} + \sum_{i=m}^{k-1} \varphi_m \Delta \mathrm{GDPk}_{i,t-m} + \sum_{i=n}^{k-1} \Upsilon_n \Delta \mathrm{POPg}_{i,t-n} + \sum_{i=q}^{k-1} \Psi_q \Delta \mathrm{URB}_{i,t-q} + \lambda_5 \mathrm{ECT}_{i,t-1} + \varepsilon_{5it},
\end{aligned} \tag{4}$$

where $k-1$ is the lag length as reduced by 1, λ_1 is the speed of adjustment parameter, $\mathrm{ECT}_{i,t-1}$ is the panel ECT as the lagged value of the residuals generated from the cointegrating regression, and ε_{it} is the residuals (stochastic error terms also refer to innovations, impulses, or shocks), while other variables and parameters have been already defined.

Panel Granger Causality

Basically, the panel Granger causality tests the specific relationship between financial development (FD) and energy consumption (ENC) and this can be stated as follows:

$$\mathrm{FD}_{i,t} = \alpha_0 + \sum_{i=1}^{m} \alpha_{1,i} \mathrm{FD}_{i,t-1} + \sum_{i=1}^{m} \alpha_{2,i} \mathrm{ENC}_{i,t-1} + \mu_{it}, \tag{5}$$

$$\mathrm{ENC}_{i,t} = \beta_0 + \sum_{i=1}^{m} \beta_{1,i} \mathrm{ENC}_{i,t-1} + \sum_{i=1}^{m} \beta_{2,i} \mathrm{FD}_{i,t-1} + \varepsilon_{it}, \tag{6}$$

where i (= 1, 2, . . ., N) refers to the country, t (= 1, 2, . . ., T) refers to the time period, and m stands for the lag number. $\mu_{i,t}$ and ε_{it} stand for stochastic error terms.

Furthermore, the adoption of the panel VEC approach will be motivated by the outcome of the cointegration test of long-run relationships among the variables in the system;

Table 2. Summary Descriptive Statistics of the Data in the Model.

	FD	ENC	GDPk	POPg	URB
Mean	28.15394	687.4537	903.2542	2.776229	29.64593
Median	28.40369	681.4429	668.5108	2.759570	28.20285
Maximum	34.80035	726.7979	1,885.509	2.906780	49.43677
Minimum	19.56821	653.4976	408.5765	2.649595	15.65733
Std. Dev.	3.649791	19.38943	453.9363	0.089463	9.976565
Skewness	−0.364426	0.607092	0.980892	0.160134	0.376689
Kurtosis	2.395604	2.607797	2.432520	1.619038	1.974775
Jarque-Bera	1.606267	2.916949	7.472385	3.600582	2.900111
Probability	0.447923	0.232591	0.023845	0.165251	0.234557
Sum	1,210.619	29,560.51	38,839.93	119.3779	1,274.775
Sum square deviation	559.4811	15,789.90	8,654,444.	0.336155	4,180.337
Observations	43	43	43	43	43

Note. Computed by the Authors using EViews 8.0 Statistical Software. FD = financial development, ENC = energy consumption, GDPk = gross domestic product per capita, POPg = population growth, and URB = urbanization.

however, it is easy to analyze the causal effects of the variables in the model as well as examine the nexus between the specific variables—financial development and energy consumption. On that note, Granger (1988) highlighted the causal effect of one variable to another and termed it *Granger causality*, and it exists when variable ENC current and past information is enough and helps to enhance the prediction of FD (Luetkepohl, 2011).

Therefore, in the hypothesis testing, the null hypothesis (H0) states that,

H0: Financial development does not cause energy consumption in SSA.

This is given in order of the corresponding objective as follows:

$$H0: \alpha_{2,1} = \alpha_{2,2} = \cdots = \alpha_{2,m} = 0.$$

Equally, testing whether the $\Delta(\text{FD})$ is said to have predictive power for $\Delta(\text{ENC})$, the corresponding null hypothesis is given as thus:

$$H0: \beta_{2,1} = \beta_{2,2} = \cdots = \beta_{2,m} = 0.$$

In sum, this study will utilize panel Granger causality technique in examining the causal relationship between financial development and energy consumption in SSA.

Presentation/Interpretation of Results and Discussions

Before estimating the panel VAR/VEC model as specified in the previous section, it is pertinent to test if the panel time-series data are stationary by verifying if their variances and means are constant over time (Stock & Watson, 2001). Therefore, the presentation of the descriptive statistics is followed by the panel unit root process to ascertain the stationarity of the time-series data before the actual estimation of the panel VAR/VEC model.

Table 2 presents the descriptive statistics on all the variables in the model. Even though the variables have been defined under the model specification and description of the data section, it is still pertinent to note that FD = financial development, ENC = energy consumption, GDPk = gross domestic product per capita, POPg = population growth, and URB = urbanization. However, these descriptive statistics, the variables in the model, show the characteristics information with respect to the mean values, median values, maximum values, standard deviation, skewness, kurtosis, Jarque–Bera, probability values, sum, sum of square deviation, and observations. All these statistics show the behavioral pattern of the variables in the model. From the available descriptive statistics, the evidence is bound that the variables depict good behavioral pattern; therefore, testing for the panel stationarity (unit-roots) is necessary to identify if the time-series data are stationary overtime for the effective policy-making process.

Table 3 presents the stationarity test results in both Levin–Lin–Chu (LLC) and Im–Pesaran–Shin (IPS). The LLC follows a homogeneous (common) panel unit root process in determining the stationarity of variables in econometrics empirical models, while the IPS follows the heterogeneous (individual) panel unit root process (Greene, 2008). The justification for adopting both the LLC and IPS is to ensure robustness in the panel unit root test result.

Under the LLC panel unit root test result, FD variable is not stationary in level form but stationary in first difference I(1); while other variables such as ENC, GDPk, POPg, and URB are all stationary in level I(0). Put succinctly, all the variables under the LLC test result are stationary in level form except FD variable that is stationary in first difference. Again, under the IPS test result, FD, POPg, and URB are stationary

Table 3. Presentation of Panel Stationarity (Unit Root) Tests Results.

	Levin–Lin–Chu (LLC)			Im–Pesaran–Shin (IPS)		
Variables	In level	First difference	Status	At level	First difference	Status
FD	−2.597	7.360**	I(1)	−1.009	−2.127***	I(1)
ENC	−2.827**	−23.53***	I(0)	−2.158***	−4.928***	I(0)
GDPk	−13.36***	−29.28***	I(0)	−3.048***	−3.850***	I(0)
POPg	15.62**	−8.086***	I(0)	4.211	−2.004***	I(1)
URB	−8.189***	−19.31***	I(0)	−1.423	−3.428***	I(1)

Note. Computed by the Authors using World Bank data of various years. FD = financial development, ENC = energy consumption, GDPk = gross domestic product per capita, POPg = population growth, and URB = urbanization.
***, **, * mean significant at 1%, 5%, and 10% respectively.

Table 4. Lag Order Selection Criteria—Endogenous Variables: ENC, FD, GDPk, POPg, and URB.

Lag	LogL	LR	FPE	AIC	SC	HQ
0	−570.8473	NA	4.598781	29.53063	29.74391	29.60715
1	−138.0524	732.4221	0.003853	8.618072	9.897735	9.077204
2	−4.863059	191.2462	1.60e–05	3.069900	5.415949a	3.911642
3	40.32392	53.29747[a]	6.80e–06	2.034671	5.447105	3.259023
4	72.83912	30.01403	6.76e–06[a]	1.649276[a]	6.128096	3.256238[a]

Note. FD = financial development, ENC = energy consumption, GDPk = gross domestic product per capita, POPg = population growth, and URB = urbanization; LR = sequential modified LR test statistic (each test at 5% level). FPE = final prediction error; AIC = Akaike information criterion; SC = Schwarz information criterion; HQ = Hannan–Quinn information criterion.
[a]Indicates lag order selected by the criterion.

in first difference I(1), while the ENC and GDPk variables are both stationary in the level form I(0). However, these divergent results go a long way in rejecting the null hypothesis of no unit-roots for all panel time series in the model as the panel unit root tests' statistic values are greater than the probability values at different percentage levels (1%, 5%, and 10%) of significances. Therefore, given that the variables are all stationary and integrated at different orders—in level forms I(0) and in first difference I(1)—there is need to test for cointegration among the variables to ascertain if long-run relationships exist after the lag length selection/determination.

Lags Selection and Determination

In determining the appropriate lag order selection criteria, the analysis follows the work of Kaleem et al. (2009) who proposed the lowest Schwarz information criterion (SC)/value as the main concern. The rationale behind the appropriate selection of optimal lag will go a long way in avoiding the problem of multicollinearity. Table 4 presents the lag order selection statistics/criteria of which the study adopted Lag 2 as the optimal lag selection based on the SC statistics.

Cointegration Test

The result from the cointegration test will determine the existence of long-run relationships among the variables in the model. On that note, this test follows Johansen methodology in examining the level of cointegrating vectors. The Johanson cointegration test adopts two likelihood estimators for the cointegration rank, which involve a maximum Eigenvalue test and a trace test. Table 5 presents the output of the cointegration test from the Johansen approach.

In the above Johanson cointegration test result, both Trace statistic and Eigenvalue are used to evaluate the number of the cointegrating equation in relation to the 5% (.05) critical value. The result, however, shows that there exist three cointegrating equations under Trace statistic and two cointegrating equations under Eigenvalue at 5% level of significance. Here * denotes rejection of the null hypothesis at 5% level of significance, therefore, at most, the cointegrating equations exist which reveal the presence of long-run relationships among the variables in the system. Put succinctly, the null hypothesis of no cointegration is rejected against the alternative of cointegrating relationships in the model. However, given that the prevailing result revealed the existence of long-run relationships among the variables in the system, this necessitates the VECM rather than the VAR model estimation. A VECM is a short-run dynamic model which links the movement of a variable to the lag effect or the previous year gap of the long-run equilibrium association (Ssekuma, 2011). Thus, the short-run adjustment is crucial in this panel analysis, and this can be examined using the VECM.

Presentation of the VECM Result and Discussions

It is pertinent to ensure the stability of panel data of the variables of interest and ascertaining the cointegrating status

Table 5. Johanson Cointegration Test Result—Series: ENC, FD, GDPk, POPg, and URB.

Unrestricted Cointegration Rank Test (Trace)

Hypothesized no. of CE(s)	Eigenvalue	Trace statistic	0.05 critical value	Prob.**
None*	0.807182	134.6236	69.81889	0.0000
At most 1*	0.557996	67.13720	47.85613	0.0003
At most 2*	0.394745	33.66331	29.79707	0.0171
At most 3	0.253006	13.07696	15.49471	0.1120
At most 4	0.026885	1.117353	3.841466	0.2905

Trace test indicates three cointegrating equations at the .05 level.
*Denotes rejection of the hypothesis at the .05 level.
**MacKinnon–Haug–Michelis (1999) *p* values.

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized no. of CE(s)	Eigenvalue	Max-Eigen statistic	0.05 critical value	Prob.**
None*	0.807182	67.48644	33.87687	0.0000
At most 1*	0.557996	33.47389	27.58434	0.0078
At most 2	0.394745	20.58635	21.13162	0.0594
At most 3	0.253006	11.95961	14.26460	0.1122
At most 4	0.026885	1.117353	3.841466	0.2905

Max-eigenvalue test indicates two cointegrating equations at the .05 level.
*Denotes rejection of the hypothesis at the .05 level.
**MacKinnon–Haug–Michelis (1999) *p* values.

Note. Computed by the Authors using EViews 8.0 Statistical Software. FD = financial development, ENC = energy consumption, GDPk = gross domestic product per capita, POPg = population growth, CE = cointegrating equations, and URB = urbanization.

before proceeding to VAR/VEC estimation (Canova & Ciccarelli, 2013). Based on the usual pre-testing of the variables of interest, the result from the Johansen cointegration test highlighted the existence of cointegrating equation in the model which goes a long way in establishing the existence of long-run relationships among the variables in the model. Also, result from the lag order selection criteria showed that Lag 2 is the appropriate or optimal lag selection according to the SC. Accordingly, the VECM estimation is the most suitable model for analyzing the short-run speed of adjustment from equilibrium; hence the result is presented and consequently discussed as thus:

Table 6 presents the estimation result from the panel VECM. The manifestation of the cointegrating relationship from the Johanson approach corroborated the existence of long-run relationships among the variables of interest (financial development and energy consumption) in the study. However, the cointegrating result from the Johanson result formed the basis for estimating the VECM to ascertain the speed of adjustment from the long-run equilibrium to the short run.

Under the long-run scenario, specifically, FD, URB, and POPg have positive influences on energy consumption. Comparatively, while FD and POPg are statistically significant, URB is statistically insignificant in influencing energy consumption in SSA. In addition, GDPk exerts a negative influence on energy consumption in SSA with statistically significant result.

Under the short-run situation, the VECM estimation output from the cointegrating equation reveals that the previous year's deviation from long-run equilibrium is corrected in the current period at an adjustment speed of about 7%. For financial development, a percentage change in FD is associated with about 23% increase in energy consumption on the average ceteris paribus in the short run. For the urbanization coefficient, a percentage change in URB is associated with about 260% increase in energy consumption on the average ceteris paribus in the short run. For the population growth, a percentage increase in POPg is associated with about 199% increase in energy consumption on the average ceteris paribus in the short run. Moreover, a percentage increase in GDPk is associated with about 3% increase in energy consumption on the average ceteris paribus, in the short run. In sum, all the variables have positive influences on energy consumption in the short run but not statistically significant enough to cause a robust adjust to the equilibrium.

Furthermore, the results from other diagnostic tests such as VEC residual serial correlation shows no serial correlation in the model, and that of the VEC residual normality test shows that all the variables in the model are normally distributed except FD. In conclusion, a further test of VEC residual heteroscedasticity shows that the model is not heteroscedastic. Also, result from Granger causality/Block Erogeneity Wald tests reveals a unidirectional causality between financial development and energy consumption but

Table 6. Panel VECM Estimation Result/Output—The Target Variable: ENC.

Variable (in logarithms form)	Coefficient	*SE*	*t* statistic	Probability
Long-run scenario				
FD	353.1103	87.9474	4.01502	.000
URB	1,372.651	1,993.74	0.68848	.002
POPg	45,988.49	18,545.5	2.47976	.000
GDPk	−3.231293	1.29040	−2.50410	.006
Short-run scenario (error correction)				
Cointegrating equation	−0.007500	0.00096	−0.77905	.001
FD	0.229154	0.72316	0.31688	.002
URB	26.04395	40.3805	0.64496	.001
POPg	199.2954	101.580	1.96196	.000
GDPk	0.030226	0.01786	1.69255	.006
Constant (C)	−21.31776	32.0399	−0.66535	.000
Included observations = 41 after adjustment, R^2: .26				

Note. Computed by the Authors using EViews 8.0 Statistical Software. VECM = vector error correction model; FD = financial development, ENC = energy consumption, GDPk = gross domestic product per capita, POPg = population growth, and URB = urbanization.

running from financial development to energy consumption without feedback with the probability value of below 0.05%. The findings are in line with the sustainable growth theory of energy efficiency which pointed out that efficiency in energy consumption can lead to economic growth.

Conclusion and Policy Recommendations

This study conducted an empirical enquiry into the relationship between financial development and energy consumption in SSA while incorporating other controlling variables such as population growth, GDP per capita, and Urbanization. The study adopted panel time-series data sourced from the World Bank database (i.e., WDIs) under the time period spanning from 1975 to 2017. Given the objective of the study, the study utilized the Johanson cointegration approach with a panel VECM as well as a Granger causality test in analyzing the study. However, the result from the Johanson cointegration approach revealed the existence of long-run relationship among the variables in the model especially between financial development and energy consumption in SSA. This result was further established under the long-run scenario of the VECM estimation output (see the upper part of Table 5). On the contrary, the VECM result under the short-run scenario revealed positive relationships among energy consumption, financial development, urbanization, population growth, and GDP per capita in SSA; effects are not statistically significant enough to cause a desired change in the short run. Also, the Granger causality test result revealed a unidirectional causality running from financial development to energy consumption, GDP per capita to population growth to urbanization with no feedback. Based on the findings of the empirical study, the following policy recommendations are necessary to achieve the development questions in Sub-Saharan African economies especially in financial and energy sectors:

- The government of Sub-Saharan African economies should ensure fiscal discipline to control for leakages in the system which could be negatively affecting growth in the real GDP, especially in the long run.
- The monetary authorities in the economies of SSA should ensure optimal utilization of financial instruments and technologies available in the system to boost financial development and optimal energy use in the region.
- The government of Sub-Saharan African economies should ensure an adequate supply of available energy to reach the diverse population in the economies to ensure optimal energy use or consumption both in rural and urban areas.
- The government of Sub-Saharan African countries should take appropriate measure to engender efficient financial development policies and institutional framework to robust technological change that can drive the effective energy production and desired economic growth.
- It is also necessary to ensure adequate investments in research and development (R&D) to boost human resources capital to drive the needed expertise in the economies in SSA toward ensuring efficiency in both energy and financial sectors.

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ORCID iD

Chigozie Nelson Nkalu https://orcid.org/0000-0002-7861-8527

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