A G D I   Working Paper

WP/20/013

Electricity Consumption, Urbanization and Economic Growth in Nigeria: New Insights from Combined Cointegration amidst Structural Breaks [1]

Forthcoming: Journal of Public Affair

Solomon P. Nathaniel[1*]
University of Lagos, Akoka, Nigeria.
(Corresponding Author)
E-mail: nathaniel_solomon21@yahoo.com
Phone: +2347066471168

Festus V. Bekun[a, b]
[a]Faculty of Economics Administrative and Social sciences,
Istanbul Gelisim University, Istanbul, Turkey.
[b]Department of Accounting, Analysis and Audit
School of Economics and Management.
South Ural State University, 76, Lenin Aven.,
Chelyabinsk, Russia 454080.
E-mail: fbekun@gelisim.edu.tr

[1] This working paper also appears in the Development Bank of Nigeria Working Paper Series.

2020 African Governance and Development Institute WP/20/013

Research Department

Electricity Consumption, Urbanization and Economic Growth in Nigeria: New Insights from Combined Cointegration amidst Structural Breaks

Solomon P. Nathaniel & Festus V. Bekun

January 2020

Abstract

The study explores the link between electricity consumption, urbanization and economic growth in Nigeria from 1971-2014. The bounds test and the Bayer and Hanck (2013) cointegration tests affirm cointegrating relationship. Electricity consumption increases economic growth in both time periods, while the impact of urbanization appears to inhibit growth. The fully modified OLS (FMOLS), dynamic OLS (DOLS) and the canonical cointegrating regression (CCR) confirm the robustness of the findings. The vector error correction model (VECM) Granger causality test supports the neutrality hypothesis in the short run and the feedback hypothesis among the variables in the long run. Therefore, policies to ensure efficient electricity supply, curb rapid urbanization and promote sustainable economic growth were suggested.

Keywords: Electricity Consumption; Urbanization; Economic Growth;ARDL; Nigeria.

1. Introduction

There are plethora of studies on growth and electricity consumption in the literature. The link between both have been clearly established as well. Both variables seem to be highly correlated (EIA, 2013). Electricity is the fulcrum of economic progress. It drives manufacturing, complements capital and labour and a shortage of it precipitate growth (Shahbaz, *et al.* 2017; Jaiyesimi *et al.* 2017; Pinson & Madsen 2014; Lin& Liu 2016) and hampers production (Khan*et al.* 2016; Shahbaz 2015; Costantini & Martini 2010; Abeberese 2017; Sarwar *et al.* 2017). Studies like (Allcott *et al.* 2016; Shahbaz 2015; Fisher-Vanden 2015; Wolfram *et al.* 2012; Baskaran *et al.* 2015; Aklin *et al.* 2016) have attributed shortage in electricity supply in developing countries to either poor infrastructures or low income level. Be that as it may, there are still no consensus on either the magnitude or direction of effect between both variables. Studies have attributed this to institutional factors, policies, time considered for the study, differences in the stages of development and variations in climate (see Payne 2010; Alola 2019a; Alola 2019b; Ozturk 2010). To a large extend, environmental and energy policies design depends on the understanding of this link (Costa-Campi*et al.,* 2018; Mezghani & Haddad 2017).

The importance of electricity is colossal both to the household and the business enterprise alike (Best& Burke 2018; Costa-Campi *et al.* 2018; Alola et al. 2019c; Atems & Hotaling 2018). Electricity is a factor of production (Stern *et al.* 2017a) and a driver of capital formation (Lechthaler, 2017). It has the capacity to mitigate air population emerging from the household (Lim *et al.,* 2012) and increase labour hour (Salmon and Tanguy, 2016). In spite of these importance, access to electricity still remain a huge problem. According to the World Bank (2017a), in developing countries, about one billion people did not have access to electricity in 2014. In the same year, about 40% of Nigerian went without electricity (Best& Burke, 2018). Many factors are responsible for the global increase in electricity demand.

Chief among them are urbanization, population explosion, economic growth, entrepreneurial consideration among others. Energy demand in the world is expected to double in 2050.[1]

The federal government of Nigeria has discovered the importance, especially the backward and forward linkages of electricity in the economy. As a result, various forms of reforms have been introduced in the sector. Whether these reforms have impacted on economic growth is yet to be seen. Also, Nigeria is becoming more urbanized holding to rural poverty and little or no access to basic facilities in the rural areas. The big questions are; is urbanization one of the drivers of electricity consumption in Nigeria? What are the relative impact of urbanization and electricity consumption on growth? Is there a causal link among these variables? It is the urgent need to provide answers to the above questions that the motivation for this study arose. However, the author is not aware of any study that have tried to explore the causal link among these variables in Nigeria, which should be a potential candidate for such investigation. Rather, most studies merely concentrated on the link between electricity consumption and economic growth (see for instance, Essien 2011; Iyke 2015; Akpan & Akpan 2012). This study intends to fill this lacuna. The Bayer and Hanck (2012) combined cointegration test was used to examine the long-run relationship. The FMOLS of Phillips and Hansen (1990), DOLS and Canonical cointegration regression (CCR) were used as sensitivity check and to further scrutinized the findings in order to ensure robust estimates. The joint use of urbanization and electricity consumption in the model will give fresh insights to policy makers and the relevant authorities to come up with comprehensive and well-designed growth and energy policies amidst the impact of urbanization.

The other parts of the study are designed in the following format: Section 2 contains an overview on the electricity sector in Nigeria. Section 3 presents the empirical review of literature. Section 4shows the data source and methodology. Section 5 shows the results and discussion of findings. Section 6 concludes.

2. An Overview on the Electricity Sector in Nigeria

Nigeria is one of the countries that has found extremely difficult to provide adequate electricity for its timing population. Since independent in 1960, the sector has performed below par as about 80million Nigerians do not have access to any form of electricity in their homes, despite the various reforms in the sector (Okafor, 2018). In 2009, only about 47% of Nigerians had access to electricity (UNDP, 2009).

Nigeria started generating its electricity in 1896, and the Nigerian Electricity Supply Company (NESCO), introduced in 1929, was the pioneer utility company. After 22 years of operation, the Electric Corporation of Nigeria (ECN) succeeded NESCO in 1951. ECN acquired both the assets and functions of NESCO. In 1962, the Nigeria Dams Authority (NDA) became a partner to the ECN to assist in the development of hydropower. ECN and NDA later formed a merger in 1972 which led to the emergence of the National Electric Power Authority (NEPA). Probably due to inefficiency and little or no funding, NEPA was later privatized and subsequently called the Power Holding Company of Nigeria (PHCN). With the reform in the sector in 2005, the Nigerian Electricity Regulatory Commission (NERC) became the chief regulator of the sector with eleven distribution companies and 60% of the company's shares were now owned by private investors. The function of electricity transmission was however returned by the government. The sector was further reformed in 2013 but little or no progress was achieved in terms of electricity generation and distribution as the country could only generate about 3500MW which is a far cry from what is expected to meet the demand of about 180 million Nigerians. On December 18, 2017, the sector achieved a peak power generation of 5,222MW which was an all-time national high. This appears to be a tiny speck of good as this trend has hardly been sustained.

3. Literature Review

The most recent of studies on growth and energy has been carried out by Srichaikul *et al.* (2019) with a special consideration on the BRICS countries using Panel Quantile Bayesian regression approach. Findings showed that energy consumption exacts a positive impact on growth. Alola & Alola (2018) discovered feedback causality between economic growth and renewable energy consumption in sixteen Coastline Mediterranean Countries. Saint Akadiri et al. (2019) also discovered the same for EU-28 countries. Alola et al. (2019a) examined the impact of renewable energy, economic growth and migration on GHGs in the United Kingdom, Germany and France. From their findings, there is no causal link between economic growth and renewable energy consumption in these countries.

Bakirtas & Akpolat (2018) investigated the causal link between economic growth, urbanization and energy consumption in a panel of six new emerging-market countries from 1971 to 2014. The bivariate analysis revealed a unidirectional causality from economic growth to energy consumption on one hand, and from urbanization to economic growth and energy consumption on the other. Kumari & Sharma (2018) explored the causal link between GDP and electricity consumption from 1981–2013. Findings revealed that electricity consumption does not only drive economic growth, but also a key determinant of FDI inflow into the country. Elfaki *et al.* (2018) incorporated urban population and trade as control variables while trying to establish a link between growth and energy consumption in Sudan. Contrarily to what is obtained in extant literature, findings showed that energy consumption inhibits growth.

Bilgili *et al.* (2017) examined the link between urbanization and energy intensity for ten countries in Asian from 1990-2014. The impact of urbanization on energy intensity was negative and significant in both time periods. As opposed to previous findings, Osman *et al.*

(2016) confirmed the feedback hypothesis for GCC countries. Maksimović *et al.* (2017) disaggregated energy consumption to ascertain the influence of each of the component on growth in the EU member countries. Energy from renewable sources was found to impact more on growth. Before Bilgili *et al.* (2017), Belloumi & Alshehry (2016) had earlier examined a similar relationship in Saudi Arabia with ARDL, FMOLS, and DOLS. Urbanization added to energy intensity in both time periods. They concluded that sustainable development in Saudi Arabia could only be achieve by reducing energy inefficiency. By using a quarterly data that spans 2005Q1 to 2016Q3, Liu *et al.* (2018) discovered that economic growth causes electricity consumption in Beijing.The finding was consistent in both aggregate and sectoral level.

Shahbaz *et al.* (2017) tried to ascertain if urbanization drives energy consumption in Pakistan by using the STIRPAT model. Findings from the ARDL result suggests that urbanization is the major driver of energy consumption in Pakistan. Similarly, Sbia *et al.* (2017) discovered a U-shaped relationship between electricity consumption and urbanization. It was also the same for electricity consumption and economic growth in the UAE. Tatlı (2017)used the ARDL to predict factors contributing to electricity demand in Turkey. Findings reveal that urbanization and economic growth (proxy by income) negatively and significantly affect residential electricity consumption in both time periods. Lechthaler (2017) explored the impact of electricity consumption on economic growth for various countries. For middle income countries, energy consumption drives economic growth. However, a direct opposite relationship was found for high-income countries. While most studies focused on electricity demand, Atems & Hotaling (2018) were more concerned with electricity generation. As a result, they used a system GMM to estimate data for a panel of one hundred and four countries. Findings revealed that electricity generation drives economic growth among the countries used in the study. By introducing financial development as one of the control variables, Bah & Azam (2017) unlike previous studies in South Africa, discovered no causality between electricity consumption and growth. They however called for investment in the energy sector to boost sustainable development. Iyke (2015) revisited the energy-growth debate for Nigeria with an attempt to ascertain the causal link between both variables. The findings were similar to that of Kumari & Sharma (2018) as causality flow from electricity consumption to economic. The study, however, ignored the influence of urbanization knowing that Nigeria is fast becoming urbanized since the turn of the 21th century owing the poverty in most of its rural areas.

Table1: Studies that supported energy-led growth hypothesis.

Author(s)/year	Region/Country(s)	Methodology	Finding(s)
Baz et al. (2019)	Pakistan	NARDL	A symmetric causality exist between EC and G in Pakistan.
Fotourehchi (2017).	Forty two developing countries	Canning and Pedroni (2008) long-run causality test	EC→ G.
Bayat*et al.* (2017)	BRICS	Emirmahmutoğlu and Kose (2011)panel causality test	EC→ G in Russia
Karanfil and Li (2014)	160 countries	VAR	EL → G. The nexus between both variables is sensitive to urbanization and income level.
Hasanov*et al.* (2017)	10 Eurasian countries.	VECM Granger causality test	EC → G in both time periods.
Shiu& Lam (2004)	China	✓	EL → G. The study called for rural electrification.
Obradović&Lojanica (2017).	South Eastern Europe	✓	EC → G in the long run only.
Dogan (2015)	Turkey	✓	EL → G. Government should invest massively in the energy sector.
Iyke (2015)	Nigeria	✓	EL → G. The unidirectional causality exist in both time periods
Alshehry and Belloumi (2015)	Saudi Arabia	✓	EC → G.

Odhiambo (2014)	4 lower and middle income countries	✓	EC → G in Uruguay and Brazil.
Aslan *et al.* (2014)	USA	Wavelet analysis; Granger causality	EL → G.
Al-mulali and Sab (2012)	Sub-Sahara Africa	Multivariate causality test	EC → G. There is need to introduce energy saving projects in the region.
Narayan (2016)	135 countries	✓	EC → G for lower middle income countries.
Fatai (2014)	18 Sub-Saharan Africa countries	✓	EC → G in Southern and East Africa.

NOTE: ↔ and → denote the bidirectional and unidirectional causalityrespectively. G, EC and EL represent economic growth, energyconsumption and electricity consumption respectively.

Table 2: Studies that supported the growth-led energy consumption hypothesis.

Author(s)/year	Region/Country(s)	Methodology	Finding(s)
Rahman&Velayutham (2020)	South Asia	FMOLS and DOLS.	G → EC.
Chen & Fang (2018)	210 prefecture cities in China	Panel Granger non-causality test	G → EL.
Kirikkaleli et al. (2018)	35 OECD countries	Dumitrescu-Hurlin causality tests	G → EL. Positive link exist among internet, electricity and economic growth.
Nyasha*et al.* (2018)	Ethiopia	VECM Granger causality test	G → EC
Burakov&Freidin (2017)	Russia	✓	G → EC only in the short run period.
Kyophilavong et al. (2017)	Lao PDR	✓	G → EL only in the long run.
Salahuddin and Alam (2015)	Australia	✓	G → EL. Economic growth drives electricity consumption
Hwang &Yoo (2014).	Indonesia	✓	G → EC. EKC exist.
Odhiambo (2014)	Brazil, Cote d'Ivoire, Ghana, and Uruguay	✓	G → EC exist in Cote d'Ivoire and Ghana.
Stern and Enflo (2013)	Sweden	✓	G → EL.
Ouedraogo (2013)	ECOWAS	✓	G → EC exist in the short run.
Iyke&Odhiambo(2014)	Ghana	✓	G → EL in both time periods.
Wolde-Rufael (2009)	17 Africa countries	Multivariate causality test	G → EC was true for eight of the countries (Nigeria

			inclusive).

Table 3: Studies that supported the feedback causality.

Author(s)/year	Region/Country(s)	Methodology	Finding(s)
Zafar et al. (2019)	Asia-Pacific Economic Cooperation countries	Continuously Updated Fully Modified Ordinary Least Square	EC ↔ G.
Lin & Wang (2019)	China	Panel VAR	EL ↔ G.
Ben-Salha et al. (2018)	Iran, Venezuela, USA, Canada, Saudi Arabia, Brazil, China and Australia.	Pooled Mean Group.	EC ↔ G.
Hamdi*et al.* (2014)	Behrain	VECM Granger causality	EL ↔ G
Saad&Taleb (2018)	12 European Union countries	✓	EC ↔ G.
Akpan&Akpan (2012)	Nigeria	✓	EL ↔ G. Findings did not support the EKC.
Solarin*et al.* (2016)	Angola	✓	EL ↔ G. Urbanization also causes EL.
Sarwar*et al.* (2017)	210 countries	✓	EL ↔ G. Developing countries are electricity dependent.
Boukhelkhal&Bengana (2018)	4 North-African countries	✓	EL ↔ G in Tunisia.
Mezghani& Haddad (2017)	Saudi Arabia	✓	EL ↔ G in the short run in Saudi Arabia.
Tang and Tan (2013)	Malaysia	✓	EL ↔ G. Technological innovation also drives electricity consumption.
BazarchehShabestari(2018)	Sweden	✓	EC ↔ G. No causality existed between both in the short run.
Rafindadi (2016)	Nigeria	✓	EC ↔ G. Economic growth reduces energy consumption.
Ajlouni (2015)	Jordan	✓	EC ↔ G. Growth depends on energy consumption.
Solarin& Shahbaz (2013)	Angola	✓	EL ↔ G. Angola will witness growth if electricity supply increase.
Shahbaz *et al.* (2011).	Portugal	✓	EL ↔ G exist for

			Portugal in the long run.
Aslan (2014).	Turkey	✓	EL ↔ G.
Mohammadi&Parvaresh (2014)	14 oil-exporting countries	✓	EC ↔ G. Growth policies may have adverse effect on the environment.
Hasan*et al.* (2017)	Bangladesh	✓	EL ↔ G. Electricity consumption impacts positively on GDP in the long run.
Bayar &Ozel (2014)	Emerging economies	Block Exogeneity Wald Test	EL ↔ G. Electricity drives growth.
Osman *et al.* (2016)	GCC countries	✓	EL ↔ G.

4. Data and Methodology

The study made use of data spanning 1971 to 2014. The availability of data informed the time period. Data were derived from the World Development Indicators (2017). The variables used for the study include: electricity consumption (kWh per capita), urbanization (% of total) and real GDP per capita (proxy for economic growth).

4.1 Unit root test

As a precaution to avoid spurious regression, the unit root were first examined with the Augmented Dickey Fuller (1981) and the Phillip & Perron (1988) tests. To make up for the criticism levelled against both tests, in terms of their sensitivity to size, low power and inability to consider break(s) in the series, the variables were further subjected to the Zivot and Andrews (1992), (ZA, hereafter) test to account for structural break

4.2 Cointegration

This test would be achieved using the Bayer& Hanck (2013) combined cointegration test. This test encompasses other individual tests like the Banerjee *et al.,* (1998), Boswijk (1995), Johansen (1991) and Engle & Granger (1987). The Fisher equation is provided as:

$EG - JOH = -2[\ln(\rho_{EG}) + (\rho_{JOH})]$

(1)

$EG - JOH - BO - BDM = -2[\ln((\rho_{EG}) + (\rho_{JOH}) + (\rho_{BO}) + (\rho_{BDM})]$

(2)

$\rho_{BDM}, \rho_{BO}, \rho_{JOH}$ *and* ρ_{EG} are the test probability of individual cointegration tests.

4.3 Estimation Techniques

Apart from the Bayer& Hanck (2013) test, the ARDL bounds test to cointegration of Pesaran *et al.* (2001) was also used. In Eq.3, we state the model in its general form.

$$\Delta Y_t = \vartheta_0 + \sum_{i=1}^{k} \vartheta_1 \Delta y_{t-i} + \sum_{i=0}^{k} \omega_1 \Delta x_{t-i} + \tau_1 y_{t-1} + \tau_2 x_{t-1} + \mu_t \quad (3)$$

Where $\vartheta_1$and ω_1 are the short-run coefficients, $\tau_1$and τ_2 are long-run coefficients. The number of lags and the error term is respectively k and μ_t. The ARDL estimation technique has various advantages over other methods of estimation in that, it is suitable for small sample size, it can be applied regardless of the order of integration with the exception that the series is not integrated at I(2). Also, it can be used for thesimultaneous computation of long-run and short-run results. As earlier mentioned, the FMOLS, DOLS and the CCR were used as sensitivity checks and to further scrutinize the findings in order to ensure robust estimates. Eq. (4) shows the FMOLS equation.

$Y_t = \gamma_0 + \gamma_1 EC_t + \gamma_2 URB_t + \sum_{i=q}^{q} \pi_i \Delta EC_{t-i} + \sum_{i=q}^{q} \pi_i \Delta URB_{t-i} + \mu_t$

(4)

Where Y_t is the dependent variable, EC and URB are the symbols for electricity consumption and urbanization respectively. All variables are in their log-linear form (*ln*); since log-linear models produce efficient results and reduce sharpness in the series (Shahbaz *et al.,* 2013)

4.4 VECM Granger Causality test

This test was picked ahead of other tests because it has the capability to show the direction of causality in both time periods. The test equation, indeterminant form, is given as;

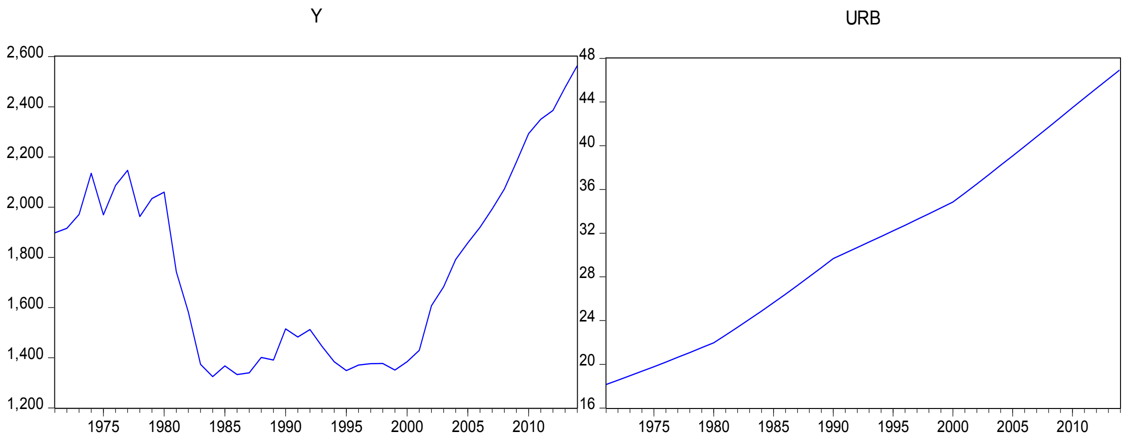
$$(1-L)\begin{bmatrix} Y_t \\ EC_t \\ URB_t \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \end{bmatrix} + \sum_{i=1}^{p}(1-L)\begin{bmatrix} \alpha_{11i}\alpha_{12i}\alpha_{13i} \\ \alpha_{21i}\alpha_{22i}\alpha_{23i} \\ \alpha_{31i}\alpha_{32i}\alpha_{33i} \end{bmatrix} \times \begin{bmatrix} Y_{t-1} \\ EC_{t-1} \\ URB_{t-1} \end{bmatrix} + \begin{bmatrix} \lambda_1 \\ \lambda_2 \\ \lambda_3 \end{bmatrix} ECT_{t-1} + \begin{bmatrix} \varepsilon_{t1} \\ \varepsilon_{t2} \\ \varepsilon_{t3} \end{bmatrix} \quad (5)$$

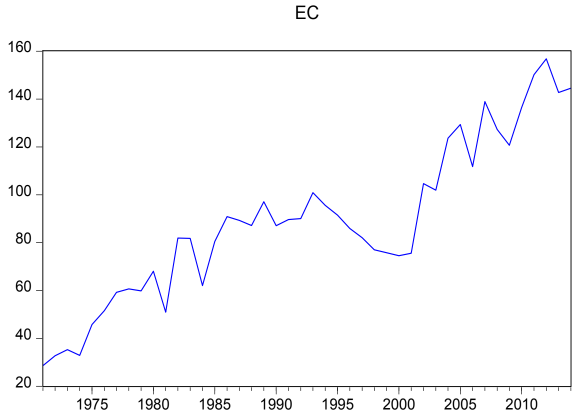
Where $(1-L)$ is the difference operator, ECT_{t-1} represents lagged error term and ε_{it}remains the disturbance term. While the significance of the t-statistic for ECT_{t-1} indicate a long-run causal relationship, short-run causality is confirmed by the significance of F-statistics of the lagged variables.

5. Empirical Results and Discussion of Findings

The graphical representation of the series is required to provide necessary information about the series. See Figure 1 for plots of the series.

Figure 1: Plots of the Series





Sources: Author's compilation, 2019.

From the plots, urbanization exhibits an upward trend. Urbanization maintained a stable increase throughout the time period. Economic growth witnessed a sharp decline in 1980. However, economic growth has witnessed a stable increase from 2002 to 2014. Energy demand to be fluctuating throughout the time period.

A good understanding of the characteristics of time series data is germane for its analysis. From Table 4, the mean of the variables almost equal their median. Urbanization recorded the highest value of 46.98. Urbanization and growth are positively skewed, while electricity consumption is negatively skewed.

Table 4: Descriptive Statistic and Correlation Analysis

Variables*ln*URB*ln*Y*ln*EC			
Mean	30.99	7.4034.407	
Median	30.937.3934.467		
Skewness	0.1870.224-0.724		
Kurtosis	1.8831.6573.091		
Probability	0.2800.1590.145		
*ln*URB	1		
*ln*Y	(0.259)*	1	
*ln*EC	(0.384)**	(0.122)	1

Note: ** and * show significance at 10% and 1% respectively.
Source: Author's computation.

The kurtosis values show that none of the variable is mesokurtic. Electricity consumption is leptokurtic while growth and urbanization are platykurtic. Juxtapose with the Jarque-Bera statistic is the probability values which suggest that the variables are normally distributed. For unit root results, see Table 5.

Table 5: ADF and PP tests (without break) and ZA unit root test (with break)

Variables	ADF	PP	ZA	Break date
	T-statistic	T-statistic	T-statistic	Time break
PANEL A				
AT levels				
EC	-0.980	-1.089	-4.139	1994
URB	-1.006	-0.181	-3.874	1997
Y	-0.372	-0.141	-3.126	1994
PANEL B				
AT first difference				
EC	-8.837*	-9.250*	-5.541**	2002
URB	-3.874*	-3.607*	-5.136**	1997
Y	-5.535*	-5.710*	-7.151*	1988

* and ** show significance at 1% and 5% respectively.
Source: Authors computation.

The results from the various tests (ADF, PP and ZA) confirm I(1) for the variables. The result of the Bayer& Hanck (2013) cointegration test and the ARDL bounds test results are presented in Table 6.

Table 6: ARDL Bounds Test and Bayer-Hanck Test Results

Estimated models	Optimal lag	Break year	F-stat.	Diagnostic tests Normality	ARCH	Cointegration
Panel A: Bounds Test						
*ln*EC =f(*ln*URB, *ln*Y)	1, 3, 0	2002	4.325*	0.328	0.564	✓
*ln*URB =f(*ln*EC, *ln*Y)	2, 2, 2	1997	2.645	0.453	0.223	✓
*ln*Y =f(*ln*URB, *ln*EC)	2, 1, 2	1986	3.892**	0.154	0.453	**X**

	Critical values bounds	
	Lower Bound	Upper Bound
5% critical value	2.79	3.44
10% critical value	2.54	3.12
1% critical value	2.88	3.98

Panel B: Bayer-Hanck Test

Estimate Models	EG-JOH	EG-JOH-BO-BDM	Cointegration
*ln*EC =f(*ln*URB, *ln*Y)	13.435**	26.487**	Yes
*ln*URB =f(*ln*EC, *ln*Y)	14.645**	25.627**	Yes
*ln*Y =f(*ln*URB, *ln*EC)	16.261**	24.281**	Yes
5% critical value	10.895	21.106	

* and ** indicate significance at 1% and 5% levels respectively.
Source: Author's computation.

The Fisher statistic for EG-JOH and EG-JOH-BO-BDM are greater than the 5% critical values of 10.021 and 20.486 respectively. In this case, we can reject the null hypothesis and conclude that the variables (EC, URB and Y) are cointegrated. The ARDL bounds test further confirmed cointegration among the variables, except when urbanization is being used as a dependent variable. See Table 7 for the ARDL short and long-run results.

Table 7: ARDL Short-run and Long-run Results

Dependent Variable: *ln(Y)*			
Short-run Coefficients			
Independent variables	Coefficient	Standard Error	t-Statistic
Constant	2.3317	0.9128	2.5542
Δ*ln*(Y(-1))	0.0794	0.0658	1.2063
Δ*ln*(EC)	0.1612	0.0673	2.3943
Δ*ln*(URB)	-2.3844	1.2223	-1.9507
ECM_{t-1}	-0.0917	0.0254	-3.6018
Adjusted R^2	0.5182		
Durbin-Watson	2.1087		
Long-run Coefficients			
Independent variables	Coefficient	Standard Error	t-Statistic
ln(EC)	0.1565	0.0341	4.5894
ln(EC(-1))	0.1612	0.0777	2.0746
ln(URB)	-0.2188	0.0815	-2.6846
Diagnostic tests	Probability Values (χ^2)		
Ramsey RESET	0.2361		
Jarque-Bera	0.0743		
ARCH LM test	0.0623		
Breusch-Godfrey LM test	0.5544		

Source: Author's computation.

From the findings in Table 7, a 1% increase in electricity consumption amount to 0.16% increase in growth holding the influence of other variables constant. This finding is intuitive. It suggests that electricity drives growth in Nigeria, in the short run. Nigerians are not among the highest consumers of electricity in Africa, and the world by extension, due to limited supply resulting from little generation of electricity. This could be the reason while the growth in GDP has not been substantial over the years due to little or no attention accorded to the sector. The lack of substantial growth could not be exclusively tied to electricity poverty in the country, there are array of several factors ranging from economic, social, political, religious amongst others. An improvement in electricity consumption has the potential to improve economic growth in the country. However, the same cannot be said for urbanization. Urbanization inhibits growth. It reduces growth by 2.38%. This is a practical revelation of what is obtainable in Nigeria. Few cities like Lagos, Port Harcourt, Kano and Kaduna are becoming increasingly urbanized as a result of a few or no social amenities in the rural areas (electricity inclusive). In the 60's and early 70s, agriculture was the mainstay of the Nigerian economy. Agricultural activities were mainly carried out in the rural areas. The rural areas suffered from inadequate facilities to improve both their yields and preservation of their products. As a result, migration to cities for livelihood was inevitable. These, to a large extend, impacted negatively on the countries growth.

The long run results are consistent with that of the short run in terms of the relationship between the independent variables and the dependent variable. Electricity consumption still exacts a positive impact on economic growth while the impact of urbanization is still negative. The intuition behind this, is that, most people living in the urban areas are unemployed and poor. They contribute very little or nothing to economic growth. This is in line with the Okun's Law which suggests an indirect relationship between economic growth and unemployment. Of little wonder the country became the poverty headquarters of the world in 2018 as reported by the World Poverty Clock with about 86.9million (accounting for about 50%) of its citizen living in extreme poverty. Hydropower has proven not to be sufficient, shifting attention to renewable sources, such as, biofuel, biogas, solar energy, tidal power, wave power, geothermal heat etc. will go a long way to ensure electricity available and by extension, sustain the country's growth. Another added advantage of renewable energy sources is that, they are low in emission and can promote environmental sustainability (Emir & Bekun, 2018).

The study also complied with most of the assumptions of the Ordinary Least Squares (OLS). The study is free from serial correlation, heteroskedasticity, residuals are normally distributed and the model has the right functional form. Impact does not imply causation, Table 8 reports the causality test, and the FMOLS, DOLS, and CCR results.

Table 8: Sensitivity Check and VECM Granger Causality Test

Dependent Variable: *ln(Y)*

Panel A: FMOLS, DOLS, and CCR.

Variables	FMOLS		DOLS		CCR	
	Coefficient	t.Stat.	Coefficient	t.Stat.	Coefficient	t.Stat.
$ln(URB_t)$	-0.1161***	-2.9130	-0.1425***	-3.3504	-0.1111***	-3.2114
$ln(EC_t)$	0.5092***	5.0510	0.5984***	4.8591	0.5254***	4.9767

Panel B: VECM Granger Causality Test

	$Dln(Y_{t-1})$	$Dln(EC_{t-1})$	$Dln(URB_{t-1})$	ECT_{t-1}
$Dln(Y_t)$	---	0.2373	0.0005	-0.0617
		(0.728)	(0.657)	(-2.170)**
$Dln(EC_t)$	0.1578	---	-0.2321	-1.5699
	(1.932)		(1.390)	(2.400)***
$Dln(URB_t)$	1.1777	0.3245	---	-4.0746
	(0.361)	(0.657)		(3.584)***

Note: ** and *** indicate significance at 5% and 1% levels respectively.
Source: Author's computation.

Table 8 affirm the neutrality hypothesis for the variables in the short run. The feedback hypothesis is affirmed in the long run. A bidirectional causality exist between economic growth and electricity consumption. The same direction of causality is found between urbanization and economic growth, similarly for electricity consumption and urbanization.

The message from these findings are clear; electricity conservation policies will cripple growth. This findingscomplements those of Hasan*et al.* (2017) for Bangladesh, Rafindadi (2016) and Akpan & Akpan (2012) for Nigeria, Solarin & Shahbaz (2013) for Angola, Aslan (2014) for Turkey, Hamdi *et al.* (2014) for Behrain, Mezghani & Haddad (2017) for Saudi Arabia, Tang & Tan (2013) for Malaysia and Shahbaz *et al.* (2011) for Portugal.

The FMOLS, DOLS and CCR were used to ascertain the robustness of the ARDL regression results. From the findings, all tests are in harmony. The tests strongly affirm the positive impact of electricity on economic growth, and the negative influence of urbanization on growth.

6. Conclusion and Policy Direction

This study explores the link among economic growth, electricity consumption, and urbanization in Nigeria. The ADF, PP and ZA unit root tests established stationarity of the variables after first difference. The ARDL bounds test and the Bayer and Hanck (2013) cointegration tests confirmed long run relationship among the variables. Findings revealed a positive impact of electricity consumption on economic growth, confirming the energy-growth nexus for Nigeria. This suggests that increasing electricity generation and distribution will improve production, which will in turn trigger growth. Renewable energy sources could be the game changer in this regard especially due to the ubiquitous campaign for clean energy (Alola & Yildirim 2019; Nathaniel & Iheonu 2019; Alola et al. 2019b; Alola et al. 2019c; Balsalobre-Lorente *et al.,* 2018; Bekun*et al.* 2019; Nathaniel et al. 2019; Nathaniel 2019).Renewable energy could be a solution to the country's energy poverty (Nathaniel et al. 2020; Nathaniel & Bekun 2019). This is desirable in Nigeria where most of her youths are unemployed, with a desire to embrace entrepreneurship, but fail due to inadequate power supply. Electricity generation from renewable sources (like geothermal, solar, wind, hydropower, tide, etc.) will help to promote the quality of the environment. The government can also investment in environmentally friendly technologies to curb emissions and enhance growth.

Urbanization arises from discrepancies in development factors such as infrastructural provisions, household income, basic amenities, etc. The negative impact of urbanization on economic growth should be a wake-up call for policymakers to enact relevant policies that will curtail rural-urban migration. The government can also engage in aggressive rural infrastructural development. This will serve as a motivation for rural dwellers to remain in the rural area and contribute meaningfully to economic growth without causing congestion and other urban anomalies. For growth to be sustainable, there must be a commitment to develop infrastructure and the environment (both economic and political) must be conducive for business to thrive.

References

Abeberese, A. B. (2017). Electricity cost and firm performance: Evidence from India. *Review of Economics and Statistics*, *99*(5), 839-852.

Ajlouni, S.A. (2015), Energy consumption and economic growth in Jordan: An ARDL bounds testing approach to co-integration. *Jordan Journal of Economic Sciences, 2*(2), 143-161.

Aklin, M., Cheng, C. Y., Urpelainen, J., Ganesan, K., & Jain, A. (2016). Factors affecting household satisfaction with electricity supply in rural India. *Nature Energy*, *1*(11), 16170.

Akpan, G. E., &Akpan, U. F. (2012). Electricity consumption, carbon emissions and economic growth in Nigeria. *International Journal of Energy Economics and Policy*, *2*(4), 292-306.

Allcott, H., Collard-Wexler, A., & O'Connell, S. D. (2016). How do electricity shortages affect industry? Evidence from India. *American Economic Review*, *106*(3), 587-624.

Al-Mulali, U., & Sab, C. N. B. C. (2012). The impact of energy consumption and CO2 emission on the economic growth and financial development in the Sub Saharan African countries. *Energy*, *39*(1), 180-186.

Alola, A. A. (2019a). The trilemma of trade, monetary and immigration policies in the United States: Accounting for environmental sustainability. *Science of The Total Environment*, *658*, 260-267.

Alola, A. A. (2019b). Carbon emissions and the trilemma of trade policy, migration policy and health care in the US. *Carbon Management*, *10*(2), 209-218.

Alola, A. A., &Alola, U. V. (2018). Agricultural land usage and tourism impact on renewable energy consumption among Coastline Mediterranean Countries. *Energy & Environment*, *29*(8), 1438-1454.

Alola, A. A., &Yildirim, H. (2019). The renewable energy consumption by sectors and household income growth in the United States. *International Journal of Green Energy*, 1-8.

Alola, A. A., Alola, U. V., & Saint Akadiri, S. (2019b). Renewable energy consumption in Coastline Mediterranean Countries: impact of environmental degradation and housing policy. *Environmental Science and Pollution Research*, *26*(25), 25789-25801.

Alola, A. A., Saint Akadiri, S., Akadiri, A. C., Alola, U. V., &Fatigun, A. S. (2019d). Cooling and heating degree days in the US: The role of macroeconomic variables and its impact on environmental sustainability. *Science of The Total Environment*, *695*, 133832.

Alola, A. A., Yalçiner, K., &Alola, U. V. (2019c). Renewables, food (in) security, and inflation regimes in the coastline Mediterranean countries (CMCs): the environmental pros and cons. *Environmental Science and Pollution Research*, 1-11.

Alola, A. A., Yalçiner, K., Alola, U. V., & Saint Akadiri, S. (2019a). The role of renewable energy, immigration and real income in environmental sustainability target. Evidence from Europe largest states. *Science of The Total Environment*, *674*, 307-315.

Alshehry, A. S., &Belloumi, M. (2015). Energy consumption, carbon dioxide emissions and economic growth: The case of Saudi Arabia. *Renewable and Sustainable Energy Reviews*, *41*, 237-247.

Aslan, A. (2014). Causality between electricity consumption and economic growth in Turkey: An ARDL bounds testing approach. *Energy Sources, Part B: Economics, Planning, and Policy*, *9*(1), 25-31.

Aslan, A., Apergis, N., &Yildirim, S. (2014). Causality between energy consumption and GDP in the US: evidence from wavelet analysis. *Frontiers in Energy*, *8*(1), 1-8.

Atems, B., &Hotaling, C. (2018). The effect of renewable and nonrenewable electricity generation on economic growth. *Energy Policy*, *112*, 111-118.

Bah, M. M., &Azam, M. (2017). Investigating the relationship between electricity consumption and economic growth: Evidence from South Africa. *Renewable and Sustainable Energy Reviews*, *80*, 531-537.

Bakirtas, T., &Akpolat, A. G. (2018). The relationship between energy consumption, urbanization, and economic growth in new emerging-market countries. *Energy*, *147*, 110-121.

Balsalobre-Lorente, D., M. Shahbaz, D. Roubaud, and S. Farhani. (2018). How economic growth, renewable electricity and natural resources contribute to CO2 emissions? *Energy Policy* 113: 356-367.

Banerjee, A., Dolado, J., &Mestre, R. (1998). Error-correction mechanism tests for cointegration in a single-equation framework. *Journal of time series analysis, 19*(3), 267-283.

Baskaran, T., Min, B., &Uppal, Y. (2015). Election cycles and electricity provision: Evidence from a quasi-experiment with Indian special elections. *Journal of Public Economics*, *126*, 64-73.

Bayar, Y., &Özel, H. A. (2014). Electricity consumption and economic growth in emerging economies. *Journal of Knowledge Management, Economics and Information Technology*, *4*(2), 1-18.

Bayat, T., Tas, S., &Tasar, I. (2017). Energy Consumption is a Determinant of Economic Growth in BRICS Countries or Not?.*Asian Economic and Financial Review*, *7*(8), 823-835.

Bayer, C., & Hanck, C. (2013). Combining non-cointegration tests. *Journal of Time Series Analysis, 34*(1), 83–95.

Baz, K., Deyi, X., Ampofo, G. M. K., Ali, I., Khan, I., Cheng, J., & Ali, H. (2019). Energy consumption and economic growth nexus: New evidence from Pakistan using asymmetric analysis. *Energy*, 116254.

BazarchehShabestari, N. (2018). Energy Consumption, CO2 Emissions and Economic Growth: Sweden's case.

Bekun, F. V., Emir, F., &Sarkodie, S. A. (2019). Another look at the relationship between energy consumption, carbon dioxide emissions, and economic growth in South Africa. *Science of the Total Environment*, *655*, 759-765.

Belloumi, M., &Alshehry, A. S. (2016). The impact of urbanization on energy intensity in Saudi Arabia. *Sustainability*, *8*(4), 375.

Ben-Salha, O., Dachraoui, H., &Sebri, M. (2018). Natural resource rents and economic growth in the top resource-abundant countries: a PMG estimation. *Resources Policy*.

Best, R., & Burke, P. J. (2018). Electricity availability: A precondition for faster economic growth?.*Energy Economics*.

Bilgili, F., Koçak, E., Bulut, Ü.,&Kuloğlu, A. (2017). The impact of urbanization on energy intensity: Panel data evidence considering cross-sectional dependence and heterogeneity. *Energy*, *133*, 242-256.

Boswijk, H. P. (1995). Efficient inference on cointegration parameters in structural error correction models. *Journal of Econometrics, 69*(1), 133-158.

Boukhelkhal, A., &Bengana, I. (2018). Cointegration and causality among electricity consumption, economic, climatic and environmental factors: Evidence from North-Africa region. *Energy*, *163*, 1193-1206.

Burakov, D., &Freidin, M. (2017). Financial development, economic growth and renewable energy consumption in Russia: A vector error correction approach. *International Journal of Energy Economics and Policy*, *7*(6), 39-47.

Canning, D., &Pedroni, P. (2008). Infrastructure, long-run economic growth and causality tests for cointegrated panels. *The Manchester School*, *76*(5), 504-527.

Chen, Y., & Fang, Z. (2018). Industrial electricity consumption, human capital investment and economic growth in Chinese cities. *Economic Modelling*, *69*, 205-219.

Costa-Campi, M. T., García-Quevedo, J., & Trujillo-Baute, E. (2018). Electricity regulation and economic growth. *Energy Policy*, *113*, 232-238.

Costantini, V., & Martini, C. (2010). The causality between energy consumption and economic growth: A multi-sectoral analysis using non-stationary cointegrated panel data. *Energy Economics*, *32*(3), 591-603.

Dickey, D. A., & Fuller, W. A. (1979). Distribution of the estimators for autoregressive time series with a unit root. *Journal of the American statistical association*, *74*(366a), 427-431.

Dickey, D. A., & Fuller, W. A. (1981). Likelihood ratio statistics for autoregressive time series with a unit root. *Econometrica: Journal of the Econometric Society*, 1057-1072.

Dogan, E. (2015). The relationship between economic growth and electricity consumption from renewable and non-renewable sources: A study of Turkey. *Renewable and Sustainable Energy Reviews*, *52*, 534-546.

EIA, U. (2013). Annual energy outlook 2013. *US Energy Information Administration, Washington, DC*, 60-62.

Elfaki, K. E., Poernomo, A., Anwar, N., & Ahmad, A. A. (2018). Energy Consumption and Economic Growth: Empirical Evidence for Sudan. *International Journal of Energy Economics and Policy*, *8*(5), 35-41.

Emir, F., &Bekun, F. V. (2018). Energy intensity, carbon emissions, renewable energy, and economic growth nexus: New insights from Romania. *Energy & Environment*, 0958305X18793108.

Emirmahmutoğlu, F. and N. Kose, (2011). Testing for Granger causality in heterogeneous mixed panels. *Economic Modelling, 28*(3): 870–876.

Engle, R. F., & Granger, C. W. (1987). Co-integration and error correction: representation, estimation, and testing. *Econometrica: Journal of the Econometric Society*, 251-276.

Essien, A. V. (2011). The Nigeria Energy Sector: Electricity Consumption and the Macroeconomic Performance (1980-2009).

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

Fisher-Vanden, K., Mansur, E. T., & Wang, Q. J. (2015). Electricity shortages and firm productivity: evidence from China's industrial firms. *Journal of Development Economics*, *114*, 172-188.

Fotourehchi, Z. (2017). Clean Energy Consumption and Economic Growth: A Case Study for Developing Countries. *International Journal of Energy Economics and Policy*, *7*(2), 61-64.

Hamdi, H., Sbia, R., & Shahbaz, M. (2014). The nexus between electricity consumption and economic growth in Bahrain. *Economic Modelling*, *38*, 227-237.

Hasan, A., Zaman, A., Sikder, Z. I., &Wadud, A. (2017). The Dynamics of Electricity Consumption, Energy Use and GDP in Bangladesh. *Romanian Economic Journal*, *20*(65).

Hasanov, F., Bulut, C., &Suleymanov, E. (2017). Review of energy-growth nexus: A panel analysis for ten Eurasian oil exporting countries. *Renewable and Sustainable Energy Reviews*, *73*, 369-386.

Hwang, J. H., &Yoo, S. H. (2014). Energy consumption, CO 2 emissions, and economic growth: evidence from Indonesia. *Quality & Quantity*, *48*(1), 63-73.

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

Iyke, B. N., &Odhiambo, N. M. (2014). The Dynamic Causal Relationship between Electricity Consumption and Economic Growth in Ghana: A Trivariate Causality Model. *Managing Global Transitions: International Research Journal*, *12*(2).

Jaiyesimi, M. T., Osinubi, T. S., &Amaghionyeodiwe, L. (2017). Energy Consumption and GGP in the OECD Countries: A Causality Analysis. *Review of Economic and Business Studies*, *10*(1), 55-74.

Johansen, S. (1991). Estimation and hypothesis testing of cointegration vectors in Gaussian vector autoregressive models. *Econometrica, 59*(6), 1551–1580.

Karanfil, F., & Li, Y. (2015). Electricity consumption and economic growth: exploring panel-specific differences. *Energy Policy*, *82*, 264-277.

Khan, M. M., Zaman, K., Irfan, D., Awan, U., Ali, G., Kyophilavong, P., &Naseem, I. (2016). Triangular relationship among energy consumption, air pollution and water resources in Pakistan. *Journal of Cleaner Production*, *112*, 1375-1385.

Kirikkaleli, D., Sokri, A., Candemir, M., &Ertugrul, H. M. (2018). Panel cointegration: Long-run relationship between internet, electricity consumption and economic growth. Evidence from OECD countries. *Investigacióneconómica*, *77*(303), 161-176.

Kumari, A., & Sharma, A. K. (2018). Causal relationships among electricity consumption, foreign direct investment and economic growth in India. *The Electricity Journal*, *31*(7), 33-38.

Kyophilavong, P., Shahbaz, M., Kim, B., & Jeong-Soo, O. H. (2017). A note on the electricity-growth nexus in Lao PDR. *Renewable and Sustainable Energy Reviews*, *77*, 1251-1260.

Lechthaler, F. (2017). Economic growth and energy use during different stages of development: an empirical analysis. *Environment and Development Economics*, *22*(1), 26-50.

Lim, S. S., Vos, T., Flaxman, A. D., Danaei, G., Shibuya, K., Adair-Rohani, H., &Aryee, M. (2012). A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. *The lancet*, *380*(9859), 2224-2260.

Lin, B., & Liu, C. (2016). Why is electricity consumption inconsistent with economic growth in China?.*Energy Policy*, *88*, 310-316.

Lin, B., & Wang, Y. (2019). Inconsistency of economic growth and electricity consumption in China: A panel VAR approach. *Journal of Cleaner Production*, *229*, 144-156.

Liu, D., Ruan, L., Liu, J., Huan, H., Zhang, G., Feng, Y., & Li, Y. (2018). Electricity consumption and economic growth nexus in Beijing: A causal analysis of quarterly sectoral data. *Renewable and Sustainable Energy Reviews*, *82*, 2498-2503.

Maksimović, G., Milosavljević, V., Ćirković, B., Milošević, B., Jović, S., &Alizamir, M. (2017). Analyzing of economic growth based on electricity consumption from different sources. *Physica A: Statistical Mechanics and Its Applications*, *484*, 37-40.

Mezghani, I., & Haddad, H. B. (2017). Energy consumption and economic growth: An empirical study of the electricity consumption in Saudi Arabia. *Renewable and Sustainable Energy Reviews*, *75*, 145-156.

Mohammadi, H., &Parvaresh, S. (2014). Energy consumption and output: Evidence from a panel of 14 oil-exporting countries. *Energy Economics*, *41*, 41-46.

Narayan, S. (2016). Predictability within the energy consumption–economic growth nexus: Some evidence from income and regional groups. *Economic Modelling*, *54*, 515-521.

Nathaniel, S. P. (2019). Modelling urbanization, trade flow, economic growth and energy consumption with regards to the environment in Nigeria. *GeoJournal*, 1-15.

Nathaniel, S. P., &Iheonu, C. I. (2019). Carbon dioxide abatement in Africa: The role of renewable and non-renewable energy consumption. *Science of The Total Environment*, *679,* 337-345.

Nathaniel, S. P., &Bekun, F. V. (2019). Environmental management amidst energy use, urbanization, trade openness, and deforestation: The Nigerian experience. *Journal of Public Affairs*, e2037.

Nathaniel, S., Nwodo, O., Adediran, A., Sharma, G., Shah, M., &Adeleye, N. (2019). Ecological footprint, urbanization, and energy consumption in South Africa: including the excluded. *Environmental Science and Pollution Research*, 1-12.

Nathaniel, S., Anyanwu, O., & Shah, M. (2020). Renewable energy, urbanization, and ecological footprint in the Middle East and North Africa region. *Environmental Science and Pollution Research*, 1-13.

Nyasha, S., Gwenhure, Y., &Odhiambo, N. M. (2018). Energy consumption and economic growth in Ethiopia: A dynamic causal linkage. *Energy & Environment*, *29*(8), 1393-1412.

Obradović, S., &Lojanica, N. (2017). Energy use, CO2 emissions and economic growth–causality on a sample of SEE countries. *Economic research-Ekonomskaistraživanja*, *30*(1), 511-526.

Odhiambo, N. M. (2014). Energy dependence in developing countries: does the level of income matter?.*Atlantic Economic Journal*, *42*(1), 65-77.

Okafor, Chineme (2018, December 18). Nigeria's Power Sector: 58 Years of Falling Behind Expectations. *This Day p.36.*

Osman, M., Gachino, G., &Hoque, A. (2016). Electricity consumption and economic growth in the GCC countries: Panel data analysis. *Energy Policy*, *98*, 318-327.

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*(1), 340-349.

Payne, J. E. (2010). Survey of the international evidence on the causal relationship between energy consumption and growth. *Journal of Economic Studies*, *37*(1), 53-95.

Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of applied econometrics*, *16*(3), 289-326.

Phillips, P. C., & Perron, P. (1988). Testing for a unit root in time series regression. *Biometrika*, *75*(2), 335-346.

Phillips, P.C., & Hansen, B.E. (1990). Statistical inference in instrumental variables regression with I(1) processes. *The Review of Economic Studies, 57*(1), 99–125.

Pinson, P., & Madsen, H. (2014). Benefits and challenges of electrical demand response: A critical review. *Renewable and Sustainable Energy Reviews*, *39*, 686-699.

Rafindadi, A. A. (2016). Does the need for economic growth influence energy consumption and CO2 emissions in Nigeria? Evidence from the innovation accounting test. *Renewable and Sustainable Energy Reviews*, *62*, 1209-1225.

Rahman, M. M., &Velayutham, E. (2020). Renewable and non-renewable energy consumption-economic growth nexus: New evidence from South Asia. *Renewable Energy*, *147*, 399-408.

Saad, W., &Taleb, A. (2018). The causal relationship between renewable energy consumption and economic growth: evidence from Europe. *Clean Technologies and Environmental Policy*, *20*(1), 127-136.

Saint Akadiri, S., Alola, A. A., Akadiri, A. C., &Alola, U. V. (2019). Renewable energy consumption in EU-28 countries: policy toward pollution mitigation and economic sustainability. *Energy Policy*, *132*, 803-810.

Salahuddin, M., &Alam, K. (2015). Internet usage, electricity consumption and economic growth in Australia: A time series evidence. *Telematics and Informatics*, *32*(4), 862-878.

Salmon, C., & Tanguy, J. (2016). Rural electrification and household labour supply: Evidence from Nigeria. *World development*, *82*, 48-68.

Sarwar, S., Chen, W., &Waheed, R. (2017). Electricity consumption, oil price and economic growth: Global perspective. *Renewable and Sustainable Energy Reviews*, *76*, 9-18.

Sbia, R., Shahbaz, M., &Ozturk, I. (2017). Economic growth, financial development, urbanisation and electricity consumption nexus in UAE. *Economic research-Ekonomskaistraživanja*, *30*(1), 527-549.

Shahbaz, M. (2015). *Measuring Economic Cost of Electricity Shortage: Current Challenges and Future Prospects in Pakistan* (No. 67164). University Library of Munich, Germany.

Shahbaz, M., Chaudhary, A. R., &Ozturk, I. (2017). Does urbanization cause increasing energy demand in Pakistan? Empirical evidence from STIRPAT model. *Energy*, *122*, 83-93.

Shahbaz, M., Hye, Q. M. A., Tiwari, A. K., &Leitao, N. C. (2013). Economic growth, energy consumption, financial development, international trade and CO2 emissions in Indonesia. *Renewable and Sustainable Energy Reviews, 25*, 109–121.

Shahbaz, M., Sarwar, S., Chen, W., & Malik, M. N. (2017). Dynamics of electricity consumption, oil price and economic growth: Global perspective. *Energy Policy*, *108*, 256-270.

Shahbaz, M., Tang, C. F., &Shabbir, M. S. (2011). Electricity consumption and economic growth nexus in Portugal using cointegration and causality approaches. *Energy policy*, *39*(6), 3529-3536.

Shiu, A., & Lam, P. L. (2004). Electricity consumption and economic growth in China. *Energy policy*, *32*(1), 47-54.

Solarin, S. A., & Shahbaz, M. (2013). Trivariate causality between economic growth, urbanisation and electricity consumption in Angola: Cointegration and causality analysis. *Energy Policy*, *60*, 876-884.

Solarin, S. A., Shahbaz, M., &Shahzad, S. J. H. (2016). Revisiting the electricity consumption-economic growth nexus in Angola: The role of exports, imports and urbanization. *International Journal of Energy Economics and Policy*, *6*(3), 501-512.

Srichaikul, W., Yamaka, W., &Sriboonchitta, S. (2019, January). The Effect of Energy Consumption on Economic Growth in BRICS Countries: Evidence from Panel Quantile Bayesian Regression. In *International Econometric Conference of Vietnam* (pp. 853-862). Springer, Cham.

Stern, D. I., &Enflo, K. (2013). Causality between energy and output in the long-run. *Energy economics*, *39*, 135-146.

Stern, D., Burke, P., &Bruns, S. (2017, June). The Impact of Electricity on Economic Development: A Macroeconomic Perspective. In *Meeting the Energy Demands of Emerging Economies, 40th IAEE International Conference, June 18-21, 2017.* International Association for Energy Economics.

Tang, C. F., & Tan, E. C. (2013). Exploring the nexus of electricity consumption, economic growth, energy prices and technology innovation in Malaysia. *Applied Energy*, *104*, 297-305.

Tatlı, H. (2017). Short-and long-term determinants of residential electricity demand in Turkey. *International Journal of Economics, Management and Accounting*, *25*(3), 443-464.

UNDP, W., Legros, G., Havet, I., Bruce, N., Bonjour, S., Rijal, K., & Dora, C. (2009). The energy access situation in developing countries. *New York.*

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

Wolfram, C., Shelef, O., &Gertler, P. (2012). How will energy demand develop in the developing world?*Journal of Economic Perspectives*, *26*(1), 119-38.

World Bank (2017a). Overview: State of electricity access report 2017. Washington DC.

Zafar, M. W., Shahbaz, M., Hou, F., & Sinha, A. (2019). From nonrenewable to renewable energy and its impact on economic growth: the role of research & development expenditures in Asia-Pacific Economic Cooperation countries. *Journal of cleaner production*, *212*, 1166-1178.

Zivot, E., & Andrews, D. W. K. (1992).Further evidence on the Great Crash, the oil price shock, and the unit root hypothesis. *Journal of Business and Economic Statistics, 10*(3), 251-270.

End notes

1 https://www.worldenergy.org/wp-content/uploads/2012/10/scenarios_study_es_online.pdf.

APPENDICES

Tables

Table1: Studies that supported energy-led growth hypothesis.

Author(s)/year	Region/Country(s)	Methodology	Finding(s)
Baz et al. (2019)	Pakistan	NARDL	A symmetric causality exist between EC and G in Pakistan.
Fotourehchi (2017).	Forty two developing countries	Canning and Pedroni (2008) long-run causality test	EC→ G.
Bayat*et al.* (2017)	BRICS	Emirmahmutoğlu and Kose (2011)panel causality test	EC→ G in Russia
Karanfil and Li (2014)	160 countries	VAR	EL → G. The nexus between both variables is sensitive to urbanization and income level.
Hasanov*et al.* (2017)	10 Eurasian countries.	VECM Granger causality test	EC → G in both time periods.
Shiu& Lam (2004)	China	✓	EL → G. The study called for rural electrification.
Obradović&Lojanica (2017).	South Eastern Europe	✓	EC → G in the long run only.
Dogan (2015)	Turkey	✓	EL → G. Government should invest massively in the energy sector.
Iyke (2015)	Nigeria	✓	EL → G. The unidirectional causality exist in both time periods
Alshehry and Belloumi (2015)	Saudi Arabia	✓	EC → G.
Odhiambo (2014)	4 lower and middle income countries	✓	EC → G in Uruguay and Brazil.
Aslan *et al.* (2014)	USA	Wavelet analysis; Granger causality	EL → G.
Al-mulali and Sab (2012)	Sub-Sahara Africa	Multivariate causality test	EC → G. There is need to introduce energy saving projects in the region.
Narayan (2016)	135 countries	✓	EC → G for lower middle income countries.
Fatai (2014)	18 Sub-Saharan Africa countries	✓	EC → G in Southern and East Africa.

NOTE: ↔ and → denote the bidirectional and unidirectional causalityrespectively. G, EC and EL represent economic growth, energyconsumption and electricity consumption respectively.

Table 2: Studies that supported the growth-led energy consumption hypothesis.

Author(s)/year	Region/Country(s)	Methodology	Finding(s)
Rahman&Velayutham (2020)	South Asia	FMOLS and DOLS.	G → EC.
Chen & Fang (2018)	210 prefecture cities in China	Panel Granger non-causality test	G → EL.
Kirikkaleli et al. (2018)	35 OECD countries	Dumitrescu-Hurlin causality tests	G → EL. Positive link exist among internet, electricity and economic growth.
Nyasha*et al.* (2018)	Ethiopia	VECM Granger causality test	G → EC
Burakov&Freidin (2017)	Russia	✓	G → EC only in the short run period.
Kyophilavong et al. (2017)	Lao PDR	✓	G → EL only in the long run.
Salahuddin and Alam (2015)	Australia	✓	G → EL. Economic growth drives electricity consumption
Hwang &Yoo (2014).	Indonesia	✓	G → EC. EKC exist.
Odhiambo (2014)	Brazil, Cote d'Ivoire, Ghana, and Uruguay	✓	G → EC exist in Cote d'Ivoire and Ghana.
Stern and Enflo (2013)	Sweden	✓	G → EL.
Ouedraogo (2013)	ECOWAS	✓	G → EC exist in the short run.
Iyke&Odhiambo(2014)	Ghana	✓	G → EL in both time periods.
Wolde-Rufael (2009)	17 Africa countries	Multivariate causality test	G → EC was true for eight of the countries (Nigeria inclusive).

Table 3: Studies that supported the feedback causality.

Author(s)/year	Region/Country(s)	Methodology	Finding(s)
Zafar et al. (2019)	Asia-Pacific Economic Cooperation countries	Continuously Updated Fully Modified Ordinary Least Square	EC ↔ G.
Lin & Wang (2019)	China	Panel VAR	EL ↔ G.
Ben-Salha et al. (2018)	Iran, Venezuela, USA, Canada, Saudi Arabia, Brazil, China and Australia.	Pooled Mean Group.	EC ↔ G.
Hamdi*et al.* (2014)	Behrain	VECM Granger causality	EL ↔ G
Saad&Taleb (2018)	12 European Union countries	✓	EC ↔ G.
Akpan&Akpan (2012)	Nigeria	✓	EL ↔ G. Findings did not support the EKC.
Solarin*et al.* (2016)	Angola	✓	EL ↔ G. Urbanization also causes EL.
Sarwar*et al.* (2017)	210 countries	✓	EL ↔ G. Developing countries are electricity dependent.
Boukhelkhal&Bengana (2018)	4 North-African countries	✓	EL ↔ G in Tunisia.
Mezghani& Haddad (2017)	Saudi Arabia	✓	EL ↔ G in the short run in Saudi Arabia.
Tang and Tan (2013)	Malaysia	✓	EL ↔ G. Technological innovation also drives electricity consumption.
BazarchehShabestari(2018)	Sweden	✓	EC ↔ G. No causality existed between both in the short run.
Rafindadi (2016)	Nigeria	✓	EC ↔ G. Economic growth reduces energy consumption.
Ajlouni (2015)	Jordan	✓	EC ↔ G. Growth depends on energy consumption.
Solarin& Shahbaz (2013)	Angola	✓	EL ↔ G. Angola will witness growth if electricity supply increase.
Shahbaz *et al.* (2011).	Portugal	✓	EL ↔ G exist for Portugal in the long run.
Aslan (2014).	Turkey	✓	EL ↔ G.

Mohammadi&Parvaresh (2014)	14 oil-exporting countries	✓	EC ↔ G. Growth policies may have adverse effect on the environment.
Hasan*et al.* (2017)	Bangladesh	✓	EL ↔ G. Electricity consumption impacts positively on GDP in the long run.
Bayar &Ozel (2014)	Emerging economies	Block Exogeneity Wald Test	EL ↔ G. Electricity drives growth.
Osman *et al.* (2016)	GCC countries	✓	EL ↔ G.

Table 4: Descriptive Statistic and Correlation Analysis

Variables	*ln*URB	*ln*Y	*ln*EC
Mean	30.99	7.4034.407	
Median	30.937.3934.467		
Skewness	0.1870.224-0.724		
Kurtosis	1.8831.6573.091		
Probability	0.2800.1590.145		
*ln*URB	1		
*ln*Y	(0.259)*	1	
*ln*EC	(0.384)**	(0.122)	1

Note: ** and * show significance at 10% and 1% respectively.
Source: Author's computation.

Table 5: ADF and PP tests (without break) and ZA unit root test (with break)

Variables	ADF	PP	ZA	Break date
	T-statistic	T-statistic	T-statistic	Time break
PANEL A				
AT levels				
EC	-0.980	-1.089	-4.139	1994
URB	-1.006	-0.181	-3.874	1997
Y	-0.372	-0.141	-3.126	1994
PANEL B				
AT first difference				
EC	-8.837*	-9.250*	-5.541**	2002
URB	-3.874*	-3.607*	-5.136**	1997
Y	-5.535*	-5.710*	-7.151*	1988

* and ** show significance at 1% and 5% respectively.
Source: Authors computation.

Table 6: ARDL Bounds Test and Bayer-Hanck Test Results

Estimated models	Optimal lag	Break year	F-stat.	Diagnostic tests Normality	ARCH	Cointegration
Panel A: Bounds Test						
*ln*EC =f(*ln*URB, *ln*Y)	1, 3, 0	2002	4.325*	0.328	0.564	✓
*ln*URB =f(*ln*EC, *ln*Y)	2, 2, 2	1997	2.645	0.453	0.223	✓
*ln*Y =f(*ln*URB, *ln*EC)	2, 1, 2	1986	3.892**	0.154	0.453	**X**
	Critical values bounds					
	Lower Bound	Upper Bound				
5% critical value	2.79	3.44				
10% critical value	2.54	3.12				
1% critical value	2.88	3.98				

Panel B: Bayer-Hanck Test

Estimate Models	EG-JOH	EG-JOH-BO-BDM	Cointegration
*ln*EC =f(*ln*URB, *ln*Y)	13.435**	26.487**	Yes
*ln*URB =f(*ln*EC, *ln*Y)	14.645**	25.627**	Yes
*ln*Y =f(*ln*URB, *ln*EC)	16.261**	24.281**	Yes
5% critical value	10.895	21.106	

* and ** indicate significance at 1% and 5% levels respectively.
Source: Author's computation.

Table 7: ARDL Short-run and Long-run Results

Dependent Variable: *ln(Y)*			
Short-run Coefficients			
Independent variables	Coefficient	Standard Error	t-Statistic
Constant	2.3317	0.9128	2.5542
Δln(Y(-1))	0.0794	0.0658	1.2063
Δln(EC)	0.1612	0.0673	2.3943
Δln(URB)	-2.3844	1.2223	-1.9507
ECM_{t-1}	-0.0917	0.0254	-3.6018
Adjusted R^2	0.5182		
Durbin-Watson	2.1087		
Long-run Coefficients			
Independent variables	Coefficient	Standard Error	t-Statistic
ln(EC)	0.1565	0.0341	4.5894
ln(EC(-1))	0.1612	0.0777	2.0746
ln(URB)	-0.2188	0.0815	-2.6846
Diagnostic tests	Probability Values (χ^2)		
Ramsey RESET	0.2361		
Jarque-Bera	0.0743		
ARCH LM test	0.0623		
Breusch-Godfrey LM test	0.5544		

Source: Author’s computation.

Table 8: Sensitivity Check and VECM Granger Causality Test

Dependent Variable: *ln(Y)*

Panel A: FMOLS, DOLS, and CCR.

Variables	FMOLS		DOLS		CCR	
	Coefficient	t.Stat.	Coefficient	t.Stat.	Coefficient	t.Stat.
$ln(URB_t)$	-0.1161***	-2.9130	-0.1425***	-3.3504	-0.1111***	-3.2114
$ln(EC_t)$	0.5092***	5.0510	0.5984***	4.8591	0.5254***	4.9767

Panel B: VECM Granger Causality Test

	$Dln(Y_{t-1})$	$Dln(EC_{t-1})$	$Dln(URB_{t-1})$	ECT_{t-1}
$Dln(Y_t)$	---	0.2373	0.0005	-0.0617
		(0.728)	(0.657)	(-2.170)**
$Dln(EC_t)$	0.1578	---	-0.2321	-1.5699
	(1.932)		(1.390)	(2.400)***
$Dln(URB_t)$	1.1777	0.3245	---	-4.0746
	(0.361)	(0.657)		(3.584)***

Note: ** and *** indicate significance at 5% and 1% levels respectively.

Source: Author's computation.