Does Public Capital Expenditure Reduce Energy Poverty? Evidence from Nigeria (Forthcoming: International Journal of Energy Sector Management)

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Research Department

Does Public Capital Expenditure Reduce Energy Poverty? Evidence from Nigeria

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Abstract

Purpose - Given the ever-growing fiscal commitments of Nigeria and her chequered history of electricity generation and distribution, the fortunes of the energy sector in the country have been affected by the prevalence of energy poverty. Government policies such as public capital expenditure (PCE) present a crucial option for reducing energy poverty in Nigeria, providing the research impetus for this study.

Design/methodology/approach -To investigate the relationship between government capital spending and five distinct energy poverty proxies, this research applies the Bayer-Hanck cointegration system and the Auto-Regressive Distributed Lag (ARDL) bound test.

Findings -The findings indicate that public capital spending in Nigeria worsens energy poverty by reducing access to electricity, urban electrification, renewable energy consumption, and renewable electricity generation, with a positive but insignificant influence on rural electrification.

Originality/value – This inquiry presents a pioneering investigation of the nexus between PCE and energy poverty in Nigeria. Also, aside from the variables of energy poverty adopted by existing studies, this study incorporates renewable energy consumption and renewable electricity output with implications for energy poverty and sustainable development.

Paper type: Research paper

Keywords: Public Capital Expenditure, Energy Poverty, Electricity, Nigeria

1. Introduction

As a result of changing global climate and growing energy costs, energy poverty has recently gained prominence within political, intellectual, and policy-making circles (Chaudhry and Shafiullah, 2021). Nonetheless, among the three essential transformations: energy poverty, energy security and climate change, energy poverty (EP) has gotten relatively less attention (Gonzalez-Eguino, 2015). The deficiency of affordable, dependable, secure and environmentally friendly energy solutions to support human and economic prosperity is referred to as EP (Ozughalu and Ogwumike, 2018). According to Chaudhry and Shafiullah (2021), EP is a concern to both developing and developed nations and it is primarily a problem of proper physical access to clean and modern energy in the former, and a matter of energy efficiency and affordability in the latter (Qurat-ul-Ann and Mirza, 2021).In 2019, about 770 million people were without access to electricity, and above 2.6 billion people worldwide lacked access to efficient cooking facilities, highlighting the global scope of EP (IEA, 2020). The scenario is much worse in budding economies, with the poorest regions being South Asia and Sub-Saharan Africa (Asongu and Odhiambo,2022). According to the International Energy Agency (IEA) (2020), approximately 580 million people in Sub-Saharan Africa (SSA) did not have electric power in 2019, while only about 17% of households utilised eco-friendly cooking in 2018, with these figures projected to worsen due to the adverse consequences of the COVID-19 pandemic (IEA, 2020).

Government policies such as public capital expenditure (PCE) present a crucial option for reducing EP (Nguyen and Su, 2021a). PCE refers to funds set aside for specified long-term capital projects (Azolibe, 2021).Thus, it is an important part of economic policy used as an operative policy instrument to encourage auspicious development outcomes (Azolibe, 2021).Keynes (1936) pioneered the importance of public spending for growing the economy and expanding welfare benefits, observing that government spending boosts general economic activity for development purposes. According to advocates of the Keynesian model, effective use of national wealth may enhance an economy’s productive potential, resulting in economic advancement and improved general welfare. However, opponents of Keynesian theory argue that greater government spending can stifle economic progress by competing away private-sector investment, especially if such expenditure is funded through debt (Amusa and Oyinlola, 2019).

Nigeria serves as an intriguing case study. In the recent two decades, the country's public capital spending has increased considerably. For instance, partly motivated by alleviating poverty (including EP) and attaining sustainable development in general, Nigeria's PCE grew from ₦239.5 billion naira in 2000 to ₦1.6 trillion in 2020 signifying a 574% increase (Central Bank of Nigeria, 2020).In contrast, roughly 62% of Nigerians had electricity access in 2019, with access rates of 91% and 30% in urban and rural areas respectively. As a result, 77 million people in SSA's largest economy lacked access to power (IEA, 2020). Similarly, only 9% of Nigerians had access to clean cooking in 2018, with 142 million Nigerians relying on traditional fuels to meet their domestic needs (IEA, 2019). Statistics from the IEA (2019) further report that 178 million Nigerians do not engage in clean cooking. With electric power consumption per capita of 145 kWh (below the SSA average of 487 kWh and the world average of 3,128 kWh), Nigeria is among the countries with the lowest electricity consumption per capita across the globe (World Bank, 2020). To mitigate the unpredictability of the national grid power supply, many Nigerians acquire and install private gasoline or diesel generators (Nwokoye *et al*., 2017; Omoju *et al*., 2020; Musibau *et al*., 2021; Dimnwobi *et al*., 2022), an expensive and ecologically unfriendly option, costing businesses and households roughly $22 billion yearly in fuel expenditures alone (IEA, 2017). The foregoing highlights that Nigeria is significantly plagued byEP, with repercussions for the environment and socio-economic development. Consequently, our study addresses these research questions: (i) Does PCE influence electricity access in the overall population? (ii) What is the impact ofPCE on urban electrification? (iii) What is the effect of PCE on rural electrification? (iv) Does PCE influence renewable energy consumption (v)What is the implications of PCE on renewable energy electricity output?

This study offers four noteworthy additions to the existing literature stock. First, to our knowledge, this inquiry is the first in Nigeria to explore the effects of PCE on EP. The positioning of the study also differs considerably from a strand of public expenditure literature in Nigeria which have majorly concentrated on inter alia: public expenditure and quality of life (Jeff-Anyeneh *et al*., 2020; Adegboyo, 2020; Jideofor *et al*., 2021); public expenditure and economic growth (Onifade *et al*., 2020; Aluthge *et al*., 2021) and public expenditure and investments (Usman and Abdulsamad, 2017; Azolibe *et al*., 2020; Azolibe, 2021). Second, unlike the only other study in this field (Nguyen and Su, 2021a), which focused on 56 developing nations and employed four energy access indicators as EP proxies, this study looks at

Nigeria with additional EP indicators. EP is an important part of sustainable development (Churchill and Smyth 2020), and sustainable energy utilisation should be incorporated in the advancement of sustainable development (United Nations 2019). Given this, aside from the variables of energy access, we incorporate renewable energy consumption and renewable electricity output to proxy EP. Specifically, five proxies were utilized to proxy EP namely rural electrification, urban electrification, access to electricity, renewable energy consumption, and renewable energy electricity output. This will offer an evidence-based understanding of the effects of government capital spending on EP in the country. Third, this study focuses on Nigeria, an underwhelming region (African nation) which is also one of the energy-poorest countries in the globe, despite huge endowments of natural resources. The findings of this study present useful information on the implications of PCE on EP. Lastly, we utilise recent econometrics procedures in this study, such as the cointegration approach by Bayer and Hanck (2013) considered effective in sidestepping prevalent shortcomings of conventional cointegration approaches. Our research will aid Nigerian policymakers better understand the intricacies of the link involving public capital spending and EP.

The remainder of this study takes the following shape. Section 2 documents the literature review while section 3 contains the methodology. Section 4 reports the main results while the last section concludes the study

2. Literature Review

This section presents literature discourse divided into two parts: the first focuses on the causes of EP, while the second chronicles studies that are relevant to the goal of this study. For the first strand, employing logit model, Ogwumike and Ozughalu (2015) reported that age and gender of household head, educational attainment, family size, and region of residence as the significant EP drivers. Similarly, Ozughalu and Ogwumike (2018) arrived at a similar conclusion. In a recent Nigerian study, Ashagidigbi *et al.*(2020) applied the Tobit regression technique and established that land size, residing in the rural region, and age isEP enhancing variables while access to credit, income, and residing in Southern Nigeria are energy poverty-reducing variables. Likewise, Crentsil *et al.* (2019) assessed the predictors of Ghana's EP and found a strong connection between the socio-demographic variables of the household head, such as age, gender, and educational attainment, as well as spatial locations on the likelihood of the household being energy poor.

Studying six South Asian giants, Abbas *et al.* (2020) reported that household wealth, house size, occupation, education, and household head gender as significant negative drivers of EP while household size, age of the household head, residential location were recognized as the positive determinants of EP. Employing the logit model on Pakistan household-level data, Qurat-ul-Ann and Mirza (2021) discovered that male-headed households are more probably to be energy poor; however, increasing the age and educational background of the household head, remittance-receiving households as well as increasing the latitude of the household location, significantly decreases the likelihood of EP. Gafa and Egbendewe (2021) applied the logit model to assess the drivers of EP in rural Togo and Senegal and the study identified the kind of fuel utilized, fertility, and household income as the major predictors of EP in both countries. In related studies, Koomson and Danquah (2021) and Dogan *et al.* (2021) reported that financial inclusion significantly reduced EP in Ghana and Turkey respectively.

The foregoing studies looked at EP on a micro-level and found that it is mostly driven by household head factors, household characteristics, community characteristics, socio-economic and regional variables. Despite their importance to the existing literature, these micro studies are unable to probe the consequences of national economic conditions on EP (Kwakwa, 2020). As a result, investigating EP from a macro-level viewpoint is critical. There have been few studies that have focused on the influence of macro factors on EP. For example, Nguyen and Su (2021a) explored the implications of public expenditure on EP in selected 56 economies and the study found that government spending decreases EP. Nguyen et al. (2021) investigated the link involving EP and financial development from 2002 to 2015 for 65 nations and found that financial growth lowers EP. Eren *et al.* (2019) highlighted that renewable energy use is promoted by financial development in India. Likewise, for a group of EU nations, Anton and Nucu (2019) reported that financial development encourages the use of renewable energy. Analogously, Ankrah and Lin (2020) established that financial underdevelopment impedes Ghana's renewable energy development. Khan *et al.* (2020) found a positive relationship between financial development and renewable energy use in a panel of 192 countries. Asongu and Odhiambo (2020) reported similar outcomes for selected SSA nations. In a recent study, Dimnwobi *et al.*

(2022) reported that renewable energy consumption is significantly influenced by financial development in Nigeria.

From the foregoing, barring Nguyen and Su (2021a), studies on PCE and EP are rare in the literature. Unlike the only previous study on the subject matter, the current study utilized additional EP indicators to have a comprehensive understanding of the subject matter while focusing on Nigeria, an underwhelming region (African nation) which is also one of the energy-poorest countries in the globe, despite huge endowments of natural resources. Lastly, by concentrating on a single country, we eliminate issues about heterogeneity and data comparability.

3. Methodology

3.1. The Model

Building on the previous works of Nguyen *et al.* (2021) and Nguyen and Su (2021a), we implement EP-PCE model which is specified as:

$$lnEP1 = \alpha_0 + \alpha_1 lnPCE + \alpha_2 lnPCGDP + \alpha_3 lnEPR + \alpha_4 lnFD + \mu_t \quad (1)$$

$$lnEP2 = \beta_0 + \beta_1 lnPCE + \beta_2 lnPCGDP + \beta_3 lnEPR + \beta_4 lnFD + \varepsilon_t \quad (2)$$

$$lnEP3 = b_0 + b_1 lnPCE + b_2 lnPCGDP + b_3 lnEPR + b_4 lnFD + \omega_t \quad (3)$$

$$lnEP4 = a_0 + a_1 lnPCE + a_2 lnPCGDP + a_3 lnEPR + a_4 lnFD + E_t \quad (4)$$

$$lnEP5 = B_0 + B_1 lnPCE + B_2 lnPCGDP + B_3 lnEPR + B_4 lnFD + e_t \quad (5)$$

Equations 1 to 5 indicate the log-linear association between the dependent and explanatory variables. lnEP1 to lnEP5 denote log of five different EP variables as explained in Table I, lnPCE represents the log of PCE, lnPCGDP stands for the log of GDP per capita, lnEPR is the log of energy price and lnFD denotes log of financial development. α0, β0, b0, a0, and B0 are the constants for model 1 to 5 respectively while μt, εt, ω, Et and et are the error terms for model 1 to 5 respectively.

The study employed Pesaran *et al.* (2001) Auto-Regressive Distributed Lag (ARDL) approach to cointegration to analyze equations (model 1 to 5). The ARDL technique provides better and valid results irrespective of the variables' order of integration which may be either I(0) or I(1) or partially and mutually integrated [I(0) and I(1)]. Besides, ARDL bound testing method is more appropriate in dealing with unbiased variable coefficients in small and finite sample sizes. Finally, this approach contains short-term changes and long-term dynamic equilibrium. Hence the ARDL can be stated as follows;

$$\Delta lnEP_{\mathrm{t}} = \beta_0 + \sum_{i=1}^{n} \beta_{1\mathrm{i}}\, \Delta lnEP_{t-i} + \sum_{i=0}^{n} \beta_{2\mathrm{i}}\, \Delta lnPCE_{1t-i} + \sum_{i=0}^{n} \beta_{3\mathrm{i}}\, \Delta lnPCGDP_{2t-i} + \sum_{i=0}^{n} \beta_{4\mathrm{i}}\, \Delta lnEPR_{3t-i} + \sum_{i=0}^{n} \beta_{5\mathrm{i}}\, \Delta \mathrm{lnFD}_{4t-i} + \beta_6 lnEP1_{t-i} + \beta_7 lnPCE_{t-1} + \beta_8 lnPCGDP_{t-1} + \beta_9 lnEPR_{t-1} + \beta_{10} lnFD_{t-1} + \mu\mathrm{t} \qquad (6)$$

Where EP represents energy poverty 1 to 5, μt denotes the error term, Δ represents the difference operator. Every variable stayed the same as earlier defined. As seen below, the estimate of a short-run causal relationship can be described using an error correction term:

$$\Delta lnEP_{\mathrm{t}} = \beta_0 + \sum_{i=1}^{n} \beta_{1\mathrm{i}}\, \Delta lnEP_{t-i} + \sum_{i=0}^{n} \beta_{2\mathrm{i}}\, \Delta lnPCE_{1t-i} + \sum_{i=0}^{n} \beta_{3\mathrm{i}}\, \Delta lnPCGDP_{2t-i} + \sum_{i=0}^{n} \beta_{4\mathrm{i}}\, \Delta lnEPR_{3t-i} + \sum_{i=0}^{n} \beta_{5\mathrm{i}}\, \Delta \mathrm{lnFD}_{4t-i} \delta_1\, \mathrm{ECT}_{t-i} + \mu 2\mathrm{t} \qquad (7)$$

Where ECT_{t-i} stands for the error correction model derived via the cointegration equation and δ_1 denotes the error correction term coefficient. This coefficient is expected by, a priori, to be negative and statistically significant. This suggests that any divergence from the short-run equilibrium will eventually converge to the long-term equilibrium.

3.2. Estimation Technique

3.2.1. Unit root tests with structural break

Before implementing the ARDL model, a unit root test is conducted to determine the data stationarity properties, asany outcome above I(1) makes the regression result invalid. Hence, we adopt the NG-Perron standard unit root test and the Lee and Strazicich (2003, 2004) tests, respectively. The first standard unit root test estimates time-series features of variables without taking structural breaks into account whereas the second considers structural breaks within the series. Also, the Lee and Strazicich (L-S) test which is a minimum Lagrange multiplier (LM) unit root test sidesteps the shortcomings of the traditional unit root tests including the Kwiatkowski, Phillips, Schmidt, and Shin test (KPSS), augmented Dickey-Fuller (ADF) test, and the Phillips-Perron test (PP), by providing details regarding the unknown break dates. It has improved size and power attributes, and it can more correctly predict break dates, and above all, it compares other structural break tests like Lumsdaine and Papell (1997),Zivot-Andrews (1992) and Clemente *et al.* (1998) tests. Thus, the test's implementationhelps in overcoming the issues of spurious results and incorrect break date determination.

3.2.2. Co-integration test (Bayer–Hanck Method)

This study employed the Bayer and Hanck (2013) co-integration test to examine the existence of a long-term equilibrium connection among the variables. This test combines the other co-integration tests such as Johansen (1988), Engle and Granger (1987), Banerjee *et al.* (1998) and Boswijk (1994). It also gives a more robust result and overcomes the problems of wrong decision-making when there is inconsistency in the other tests. As a result, the Fisher (1932) method is used in the Bayer-Hanck test to determine the statistical significance of a co-integrating association. For the separate cointegration test, the formula and p-value are as follows:

$$EG - JOH = -2[\ln(PEG) + \ln(PJOH)] \quad (8)$$

$$EG - JOH - BO - BDM = -2[\ln(PEG) + \ln(PJOH) + \ln(PBO) + \ln(pbdm)] \quad (9)$$

Where PEG, PJOH, PBO, and PBDM are the p values of Engle and Granger (1987), Johansen (1988),Boswijk (1994), and Banerjee et al. (1998) tests, respectively. Consequently, if the estimated Fisher statistics is above the Bayer and Hanck (2013) critical levels, the null hypothesis is rejected indicating the absence of co-integration.

3.3 Data Description

This study employed annual data to investigate the impact of PCE on EP in Nigeria. Consistent with recent EP literature (Acheampong *et al.*, 2021; Apergis *et al.*, 2021; Nguyen and Su, 2021a; Nguyen and Su, 2021b), we employed five variables to proxy EP namely access to electricity, urban electrification, rural electrification, renewable electricity output, and renewable energy consumption. In line with related studies (Onifade*et al*., 2020; Azolibe, 2021), the study also utilized PCE. Nigerian policymakers have utilized PCE to support development plans and projects (including the energy sector). Based on the assumption that economic well-being has a significant impact on the utilisation of contemporary energy sources, the study adopts real GDP per capita as a measure of economic progress (Kwakwa, 2020). Analogously, it is assumed that a robust financial sector contributes to the utilization of modern energy because as the financial sector expands, so does the ability to provide credit for sustainable energy sources (Asongu and Odhiambo, 2020). Likewise, energy prices are critical for the utilization of modern energy sources. This study follows in the footsteps of earlier studies (Anton and Nucu, 2019; Kwakwa, 2020) in utilising the consumer price index to proxy energy prices. This research spans the years 1990 to 2020, representing an era of substantial changes in Nigeria's PCE and EP. Table I lists the variables that were employed in this investigation.

Table I. Variables, measurement, and sources

Variable	Measurement	Source	Reference
Energy poverty 1 (EP1)	Access to electricity (% of population)	World Bank (2020)	Nguyen and Su (2021a); Nguyen and Su (2021b)
Energy poverty 2 (EP2)	Access to electricity, urban (% of urban population)	World Bank (2020)	Nguyen and Su (2021a); Nguyen and Su (2021b)
Energy poverty 3 (EP3)	Access to electricity, rural (% of rural population)	World Bank (2020)	Nguyen and Su (2021a); Nguyen and Su (2021b)
Energy poverty 4 (EP4)	Renewable energy consumption (% of total final energy consumption)	World Bank (2020)	Nguyen and Su (2021b)
Energy poverty 5 (EP5)	Renewable electricity output (% of total electricity output)	World Bank (2020)	Nguyen and Su (2021b)
Public Capital expenditure (PCE)	% of the GDP	CBN (2020)	Onifade*et al*. (2020); Azolibe (2021)
Financial development (FD)	Domestic credit to the private sector as a % of GDP	World Bank (2020)	Asongu and Odhiambo (2020); Kwakwa (2020)
Gross Domestic Product Per Capita (PCGDP)	In constant 2010 US$	World Bank (2020)	Kwakwa (2020); Nguyen and Su, (2021b)
Energy price (EP)	Consumer price index (2010 = 100)	World Bank (2020)	Anton andNucu (2019); Kwakwa (2020)

Source: Authors Computation

4. Findings and Discussion

4.1. Descriptive Statistics

The variables of our five models are described in Table II. The insignificance nature of the J-Bera statistics of all the variables indicates normal distribution. Hence, the result indicates that energy price (EPR) has the highest mean value of 0.160 in models 1, 2, 4, and 5 while energy poverty 3 (EP3) has the highest mean value in model 3.

Table II. Data Description

Variables	Mean	Std. dev.	Skewness	Kurtosis	J-B	Prob	Obs
Model 1							
LEP1	0.024	0.074	1.034	5.001	1.358	0.563	30
LPCE	-0.051	0.333	-0.778	3.579	3.453	0.177	30
LPCGDP	0.014	0.037	0.339	3.355	0.734	0.692	30
LEPR	0.160	0.126	1.932	5.551	0.813	0.223	30
LFD	0.029	0.1912	0.471	3.778	1.864	0.393	30
Model 2							
LEP2	-0.047	0.027	5.416	0.702	0.762	0.175	30
LPCE	-0.051	0.333	-0.778	3.579	3.453	0.177	30
LPCGDP	0.014	0.037	0.339	3.355	0.734	0.692	30
LEPR	0.160	0.126	1.932	5.551	0.813	0.223	30
LFD	0.029	0.1912	0.471	3.778	1.864	0.393	30
Model 3							
LEP3	0.660	0.285	2.345	11.567	2.254	0.103	30
LPCE	-0.051	0.333	-0.778	3.579	3.453	0.177	30
LPCGDP	0.014	0.037	0.339	3.355	0.734	0.692	30
LEPR	0.160	0.126	1.932	5.551	0.813	0.223	30
LFD	0.029	0.1912	0.471	3.778	1.864	0.393	30
Model 4							
LEP4	-0.042	0.179	2.007	0.287	1.644	0.439	30
LPCE	-0.051	0.333	-0.778	3.579	3.453	0.177	30
LPCGDP	0.014	0.037	0.339	3.355	0.734	0.692	30
LEPR	0.160	0.126	1.932	5.551	0.813	0.223	30
LFD	0.029	0.1912	0.471	3.778	1.864	0.393	30
Model 5							
LEP5	-0.025	0.079	1.024	6.634	1.514	0.096	30
LPCE	-0.051	0.333	-0.778	3.579	3.453	0.177	30
LPCGDP	0.014	0.037	0.339	3.355	0.734	0.692	30
LEPR	0.160	0.126	1.932	5.551	0.813	0.223	30
LFD	0.029	0.1912	0.471	3.778	1.864	0.393	30

Source: Authors Computation

4.2. Unit Root Tests

The results of the unit root tests with and without a structural break are shown in Tables III and IV, respectively. The Ng and Perron (2001) test determines time series attributes without taking into consideration series fluctuations. The Lee and Strazicich (2003; 2004) test, on the other hand, account for changes in the series to explain time-series features. That is, it accounts for structural breaks in the series.

Table III. Unit root without structural break

At Level					At First Difference				
Variables	Mza	MZt	MSB	MPT	Mza	MZt	MSB	MPT	Remarks
LnEP1	0.223	0.727	0.258	55.883	-10.31**	-3.185	0.877	1 .2517	I(1)
LnEP2	0.689	1.433	0.580	28.988	-11.50**	-6.071	0.110	2.149	I(1)
LnEP3	0.116	0.290	0.498	22.342	-14.9***	-3.934	0.199	1.094	I(1)
LnEP4	-1.371	-2.668	0.486	12.755	-11.23**	-2.369	0.211	2.184	I(1)
LnEP5	-0.974	-0.606	0.622	20.605	-12.77**	-3.552	0.711	2.221	I(1)
LnPCE	-1.200	-2.498	0.400	5.081	-17.6***	-4.899	0.248	1.405	I(1)
LnPCGDP	-4.864	-1.912	0.243	3.372	-12.85**	-2.436	0.190	2.277	I(1)
LnEPR	-3.125	-1.740	0.284	4.031	-8.974	-2.090	0.233	1.138	I(1)
LnFD	-2.644	-1.756	0.314	3.329	-12.96**	-2.539	0.196	1.919	I(1)
Asymptotic critical values									
	1%	-13.8	-2.58	0.174	1.78	-13.8	-2.58	0.174	1.78
	5%	-8.1	-1.98	0.233	3.17	-8.1	-1.98	0.233	3.17
	10%	-5.7	-1.62	0.275	4.45	-5.7	-1.62	0.275	4.45

** and *** denote significance at 5% and 1% levels respectively
Source: Authors Computation

The estimated break-dates lie between 2000 and 2017. This is contingent on the structural changes that have taken place in the Nigerian economy including the transition from a military to a civilian government in 1999 as well as the commencement of the 2005 Reform Act in the power sector.However, both tests show the same order of integration which is I(1). This demonstrates that, regardless of the unit root type employed, the whole variables employed are not stationary at the level but become stationary when differenced once (see Tables III and IV). To establish if the variables have long-run connections, a co-integration test is required.

Table IV. Results of Lee and Strazicich (L-S) unit root test with structural breaks

	L-S Test at Level		L-S Test at First Difference Level	
Variables	LM Statistic	Break Dates	LM Statistic	Break Dates
LnEP1	-2.32047(8)	2010 2015	-6.878408(1)***	2001 2009
LnEP2	-2.807868(8)	2009 2014	-4.777829(8)***	2008 2013
LnEP3	-1.932317(8)	2014 2016	-8.144122(8)***	2009 2016
LnEP4	-3.137144(1)	2008 2017	-5.221931(0)***	2000 2005
LnEP5	-2.039049(7)	2007 2016	-4.122648(3)***	2006 2008
LnPCE	-2.256865(4)	2001 2009	-4.964533(6)***	2009 2014
LnPCGDPP	-3.126693(6)	2000 2005	-5.653065(5)***	2001 2011
LnEPR	-1.748872(8)	2004 2012	-7.157166(5)***	2005 2015
LnFD	-2.72746(2)	2010 2017	-6.082864(2)***	2003 2006
Sig. Level				
1%	-4.073000			
5%	-3.563000			
10%	-3.296000			

Note: Values in bracket are the lag length of variables
***represent the rejection of null hypothesis at the 1% level
Source: Authors Computation

4.3. Co-integration Tests Results

We implemented the Bayer and Hanck (2013) merged co-integration test to ascertain for any co-integration between the series. The combined co-integration tests of EG-JOH-BO-BDM are shown in Table V. The Fisher statistic of EG-JO-BO-BDM for the five models of EP is greater than the critical values at a ($p<0.05$) significant level, according to the results. As a result, the null hypothesis of no co-integration is rejected and we conclude that all the models have a long-run equilibrium connection between the variables.

Table V. Bayer and HanckCointegration test results

	FISHER STATISTICS			
Estimated Models	EG-JOH	EG-JO-BO-BDM	Lag order	Conclusion
LNEP1= F(lnPCE, lnPCGDP, lnEPR, lnFD)	10.860482**	28.122886***	1	Cointegrated
LNEP2= F(lnPCE, lnPCGDP, lnEPR, lnFD)	16.83135****	47.681247***	1	Cointegrated
LNEP3= F(lnPCE, lnPCGDP, lnEPR, lnFD)	13.980753**	48.049525***	1	Cointegrated
LNEP4= F(lnPCE, lnPCGDP, lnEPR, lnFD)	10.872145**	21.722155**	1	Cointegrated
LNEP5= F(lnPCE, lnPCGDP, lnEPR, lnFD)	12.765888**	123.28997***	1	Cointegrated
Significance Level	Critical Values			
1%	15.845	30.774		
5%	10.576	20.143		
10%	8.301	15.938		

Note: ** and ***indicate variables significance at 0.05% and 10% levels respectively
Source: Authors Computation

In addition, as a robustness check, we applied the ARDL bound test for co-integration. Table VI shows the ARDL bound test, which necessitates the employment of a sufficient lag length.

Table VI. Result of ARDL-bounds cointegration test

Specification	ARDL	F-Statistic	Result
1. EP1(lnEP1// lnPCE, lnPCGDP, lnEPR, lnFD)	(1, 1, 1, 1, 1)	14.01120***	Cointegration
2. EP2(lnEP2// lnPCE, lnPCGDP, lnEPR, lnFD)	(1, 1, 0, 0, 0)	15.47255***	Cointegration
3. EP3(lnEP3// lnPCE, lnPCGDP, lnEPR, lnFD)	(1, 0, 1, 0, 1)	20.60338***	Cointegration
4. EP4(lnEP4// lnPCE, lnPCGDP, lnEPR, lnFD)	(1, 0, 0, 0, 1)	4.690465***	Cointegration
5. EP5(lnEP5// lnPCE, lnPCGDP, lnEPR, lnFD)	(1, 0, 2, 2, 0)	5.88738***	Cointegration
Critical Value Bounds	1%	5%	10%
I(0)	3.29	2.56	2.2
I(1)	4.37	3.49	3.09

*** denote rejection of the null hypothesis of no co-integration at a 1% level of significance
Source: Authors Computation

As a result, for lag selection, we utilized the Akaike Information Criteria (AIC), which has better power qualities for small sample sizes, over other criteria (see Table VII). The bound test co-integration (see Table VI) shows that the F-statistics in the entire model are higher than upper limits at a 1% significant level. This also implies that the variables in the five models have a long-term equilibrium association.

Table VII. Lag order criteria

Model 1	EP1					
Lag	LogL	LR	FPE	AIC	SC	HQ
0	113.6641	NA	2.20e-10	-8.049192	-7.809222	-7.977836
1	156.9421	67.32143*	5.89e-11*	-9.403122*	-7.963303*	-8.974989*
2	165.8130	10.51355	2.41e-10	-8.208367	-5.5687	-7.423456
3	204.0536	31.15904	1.71e-10	-9.189155	-5.349639	-8.047466
Model 2	EP2					
0	134.5251	NA	4.69e-11	-9.594454	-9.354484*	-9.523099
1	173.9135	61.27079*	1.68e-11*	-10.66026	-9.22044	-10.23213*
2	188.9130	17.77718	4.35e-11	-9.919481	-7.279813	-9.134569
3	226.3918	30.53826	3.27e-11	-10.84383*	-7.004318	-9.702145
Model 3	EP3					
0	84.73914	NA	1.87e-09	-5.906603	-5.666633	-5.835248
1	130.6317	71.38844*	4.14e-10*	-7.454201	-6.014382*	-7.026067*
2	139.5954	10.62361	1.68e-09	-6.266324	-3.626657	-5.481413
3	181.1465	33.85646	9.34e-10	-7.492333*	-3.652816	-6.350643
Model 4	EP4					
0	152.0768	NA	1.88e-11	-10.50548	-10.26759*	-10.43276
1	186.6539	54.33546*	9.83e-12*	-11.18956*	-9.762201	-10.75320*
2	211.4289	30.08393	1.21e-11	-11.17349	-8.556661	-10.3735
Model 5	EP5					
0	112.9233	NA	2.32e-10	-7.994315	-7.754345*	-7.92296
1	146.4612	52.17010*	1.28e-10*	-8.626754	-7.186935	-8.198620*
2	161.8327	18.21816	3.23e-10	-7.913537	-5.273869	-7.128625
3	206.0067	35.99362	1.48e-10	-9.333832*	-5.494315	-8.192142

Source: Authors Computation

4.4. Results of the Short-run and Long-run ARDL models

Table VIII represents the short and long-run estimates of the ARDL models. The upper part contains the long run while the lower part contains the short run and then the diagnostics tests. The long-run estimates reveal that PCE has a significant negative impact on electricity access (EP1), access to electricity in the urban population (EP2), renewable energy consumption (EP4), and renewable electricity output (EP5) but has a positive insignificant impact on access to electricity in the rural population (EP3). Also, income has a positive significant impact on EP1 and EP3 while exerting a negative significant impact on EP2, EP4, and EP5. Similarly, energy price has a positive and significant effect on electricity access, rural electrification, urban electrification, renewable energy generations, and consumption. Financial development is significant and positively related to EP1, EP2, EP4, and EP5 while it has a significant negative effect on EP3

Table VIII. ARDL results of the short-run and long-run estimates

Model	(1)	(2)	(3)	(4)	(5)
Dep.Var	LnEP1	LnEP2	LnEP3	LnEP4	LnEP5
Long Run	Coeff.	Coeff	Coeff	Coeff	Coeff
LnPCE	-0.0151**	-0.04782***	0.10747	-0.0084***	-0.2712**
	[0.0697]	[0.4368]	[0.1996]	[0.2031]	[0.4316]
LnPCGDP	0.2578***	-0.13675**	0.13584**	-0.0274**	-0.8712**
	[0.03225]	[0.0396]	[0.0487]	[0.0516]	[0.3454]
LnEPR	0.1369 **	0.00588**	0.4659*	0.02782*	0.0866***
	[0.1004]	[0.0602]	[0.3095]	[0.2314]	[0.1979]
LnFD	0.0033*	0.02313**	-0.05478***	0.053238*	0.0662**
	[0.1039]	[0.0513]	[0.1055]	[0.0301]	[0.1176]
Constant	-0.0020	-0.00218	-0.043933	-0.01004	0.020669
	[0.0222]	[0.0124]	[0.0671]	[0.0070]	[0.0281]
Short Run					
D(LnPCE)	-0.0255	0.024168	-0.04387	0.0105	0.0043
	[0.0363]	[0.0197]	[0.1055]	[0.0132]	[0.0487]
DLnPCGDP	-0.3540	-0.080268	-0.968289	-0.085157	-0.011916
	[0.4048]	[0.2109]	[0.1088]	[0.1291]	[0.4730]
DLnEPR	0.1563	0.015759	0.764328	-0.033918	-0.031115
	[0.1518]	[0.1015]	[1.1433]	[0.0559]	[0.2127]
DLnFD	0.1111*	0.044396	0.306254	0.011936	0.022709
	[0.0573]	[0.0334]	[0.4971]	[0.0207]	[0.0769]
ECM(-1)	-1.3846***	-1.5505***	-1.3058***	-1.0518***	-1.1511***
	[0.1228]	[0.1452]	[0.1817]	[0.1789]	[0.1713]
R2	0.8627	0.8112	0.880542	0.566233	0.713564
DW*	2.1577	2.4888	2.453585	2.143175	2.420824
Diagnostic test	Statistic				
χ2ARCH	0.0012(0.972)	0.1045(0.749)	0.2244(0.639)	0.1683(0.685)	0.0024(0.961)
χ2SERIAL	1.0459(0.373)	2.2633(0.150)	0.8390(0.449)	2.1712(0.145)	0.704(0.508)
χ2RESET	0.0096(0.923)	2.3713(0.149)	1.5064(0.236)	0.8525(0.368)	0.0656(0.801)
χ2NORMAL	0.7241(0.696)	0.154(0.926)	0.744(0.689)	2.026 (0.363)	2.884(0.236)

Notes: *, ** and *** denote statistical significance at 10%, 5% and 1% levels respectively. The values in [] stands for standard errors while the values in () in the diagnostics test denote P-values

Source: Authors Computation

In the short run, the result showed that apart from financial development which has a positive and significant impact on EP1, the rest have no short-run impact on the EP indicators which is revealed by the insignificant nature of the variables. In the five specifications, the error correction term ECM (−1) is signed negative and statistically significant at a 1% level. This means that the long-run stability after an exogenous shock will be restored.

4.5. Results of the Nonlinear ARDL Model

This section provides the findings of the nonlinear ARDL technique

Table IX. Nonlinear ARDL Result

Variables	EP1	EP2	EP3	EP4	EP5
Long Run Elasticities					
Constant	3.9083***(0.659)	6.04(0.955)	3.9083***(0.659)	1.922(0.977)	2.225(0.131)
LPCE_P	0.0236(0.056)	-0.0619(0.037)	0.0235(0.091)	-0.0366(0.036)	0.0092(0.113)
LPCE_N	-0.0607(0.372)	-0.0206(0.022)	-0.0607(0.056)	-0.0039(0.023)	-0.1498(0.074)
LPCGDP_P	-0.422	-0.0336(0.1490)	-0.4220(0.372)	-0.106394	-0.7060(0.063)
LPCGDP_N	0.995(0.485)	-0.1521(0.610)	0.995(1.485)	0.1317(0.584)	0.916(0.951)
LEPR	0.2176(0.095)	0.022(0.036)	0.2176(0.095)	0.0289(0.034)	0.0272(0.112)
LFD	0.008Z(0.069)	0.016(0.0285)	0.008(0.096)	0.0581(0.028)	0.1369(0.089)
Short Run Elasticities					
ECT(-1)	-0.064***(0.154)	-0.786***(0.258)	-0.277***(0.143)	-0.413***(0.061)	-0.8035***(0.093)
LPCE_P	0.0101(0.104)	0.0163(0.042)	0.0101(0.104)	-0.0498(0.039)	-0.051(0.131)
LPCE_N	-0.0553(0.054)	-0.0095(0.020)	-0.0552(0.054)	0.0292(0.019)	-0.0398(0.062)
LPCGDP_P	-0.3212(0.669)	0.165(0.272)	-0.3212(0.669)	0.0786(0.272)	-0.7187(0.831)
LPCGDP_N	0.0101(0.932)	-0.053(0.344)	0.4549(0.932)	-0.1627(0.326)	0.5581(0.188)
LEPR	-0.055**(0.931)	-0.0071(0.069)	0.181**(0.186)	-0.0025(0.067)	-0.2899(0.022)
LFD	-0.3212(0.932)	0.036(0.022)	0.0702(0.056)	0.0261(0.021)	-0.0021(0.067)
Asymmetric relationship					
Long run Asymmetry					
LPCE	0.4942[0.6196]	2.1541[0.1484]	1.3199[0.2947]	1.1394[0.3446]	0.563[0.5799]
LPCGDP	0.4142[0.6682]	0.3459[0.7127]	0.1702[0.8449]	1.1521[0.3408]	1.1037[0.3556]
Short Run Asymmetry					
LPCE	2.199[0.1453]	0.0182[0.9820]	1.1518[0.3409]	0.3141[0.7348]	1.7135[0.2117]
LPCGDP	1.869[0.1885]	1.558[0.2408]	0.4098[0.6705]	0.3141[0.3972]	2.1997[0.1432]

Notes: ** and *** denote significant at 5% and 1% levels respectively. Values in () represent the standard errors while the values in [] under the asymmetric test stand for the probability values

Source: Authors Computation

Table IX shows that both positive and negative shocks to PCE and PCGDP do not have any significant influence on the energy poverty variables in all the specifications in both the short-run and long run. However, only energy price exerts a short-run significant impact on energy poverty 1 and 3. Also, the asymmetric test result shows that the probability values of both PCE and PCGDP in all models are statistically insignificant. This reveals the acceptance of the null hypothesis which means there is no asymmetric or non-linear association between the variables. This confirms the superiority of linear analysis over non-linear linkage.

Finally, Figures 1A to 5B represent stability tests using the cumulative sum of recursive residuals (CUSUM) and cumulative sum of squares (CUSUMSQ) stability test results. The stability test shows that all the graphical plots of the five models fall within the 5% critical bounds. This shows that the specified models are consistent and follow a long-run stable pattern. This also entails that the ARDL bound test is robust, reliable, and adequate for policy decision-making.

Figure 1A. CUSUM for model 1

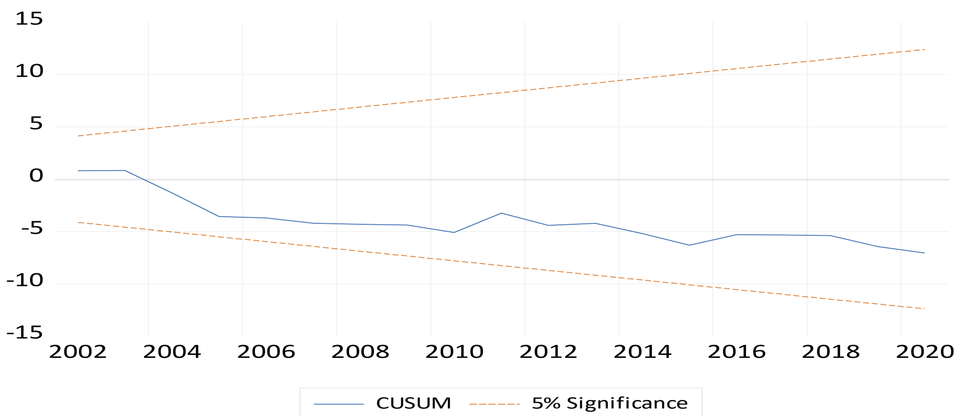


Figure 1B. CUSUMSQ for model 1

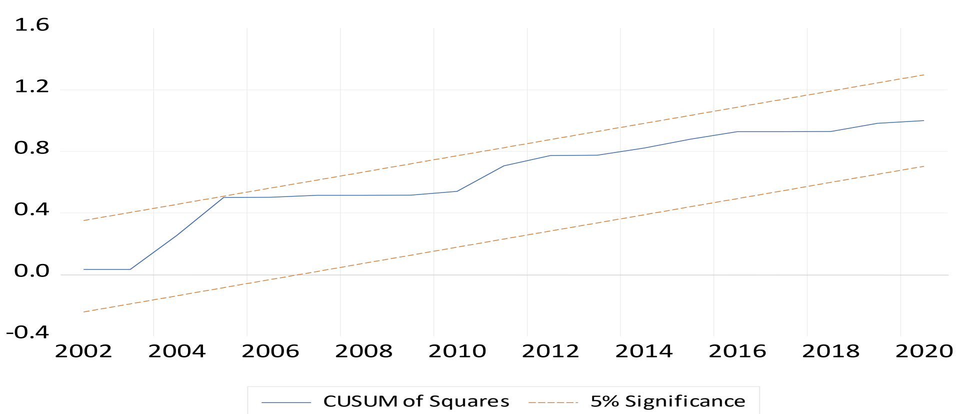


Figure 2A. CUSUM for model 2

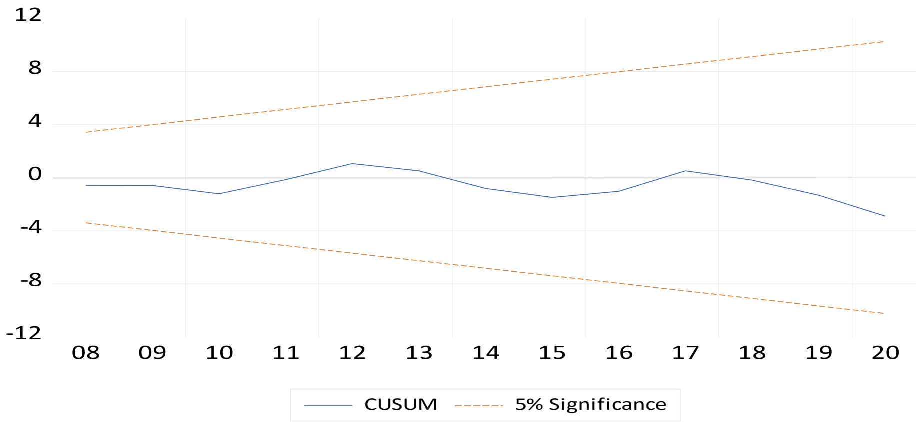


Figure 2B. CUSUMSQ for model 2

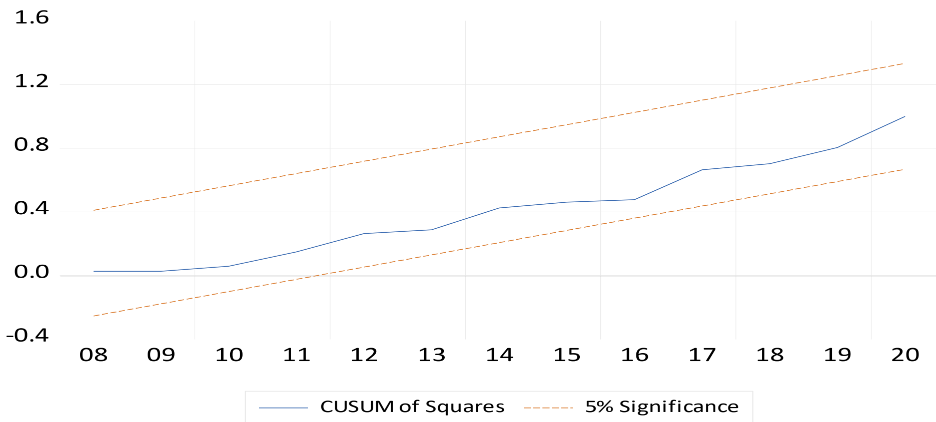


Figure 3A. CUSUM for model 3

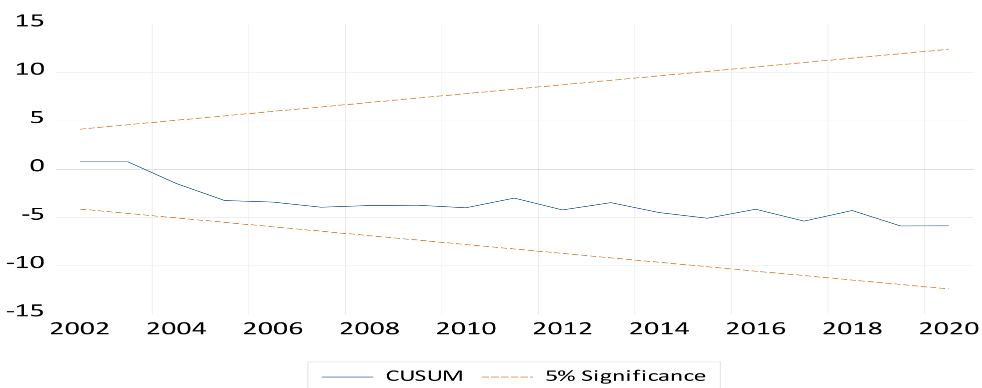


Figure 3B. CUSUMSQ for model 3

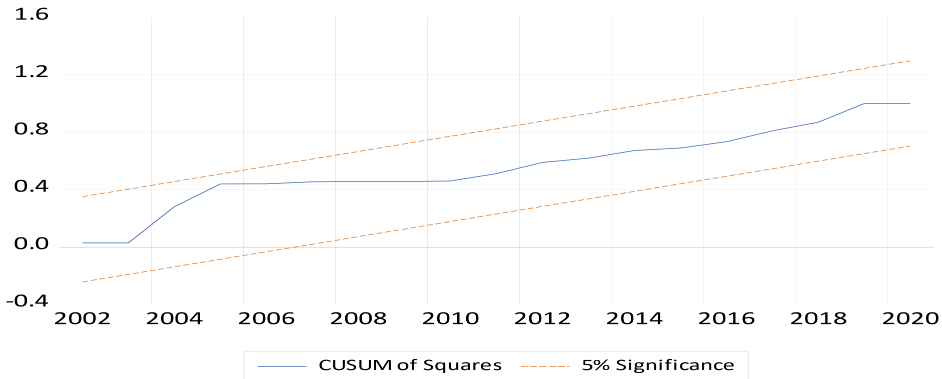


Figure 4A. CUSUM for model 4

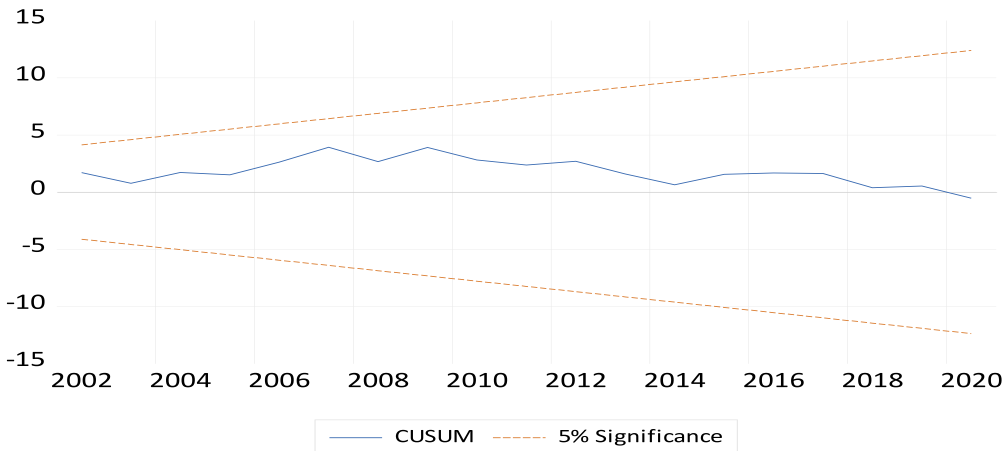


Figure 4B. CUSUMSQ for model 4

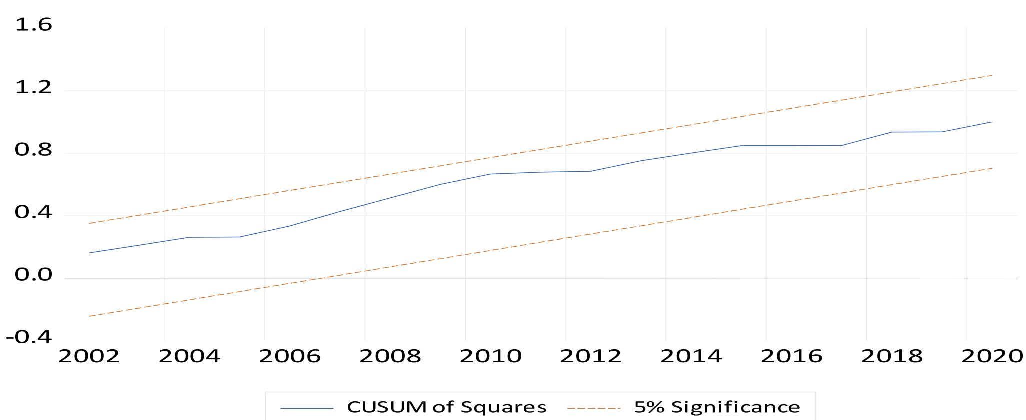


Figure 5A. CUSUM for model 5

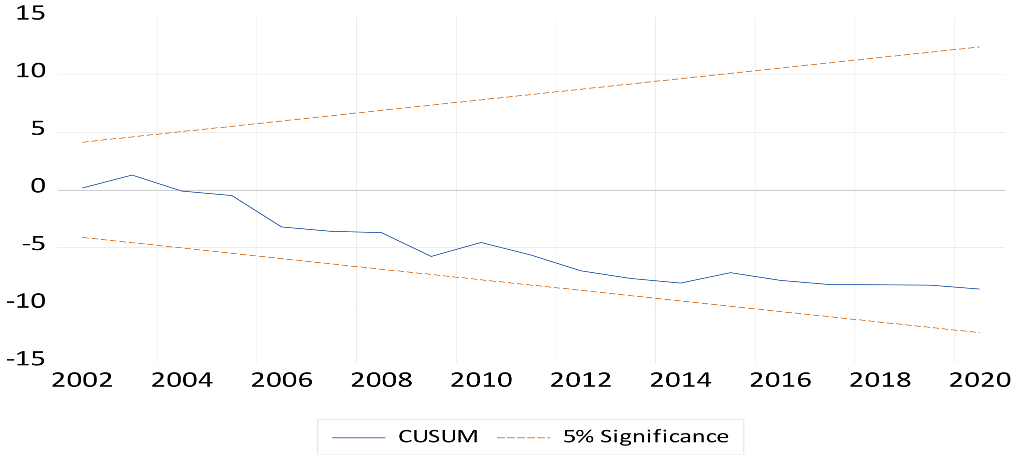
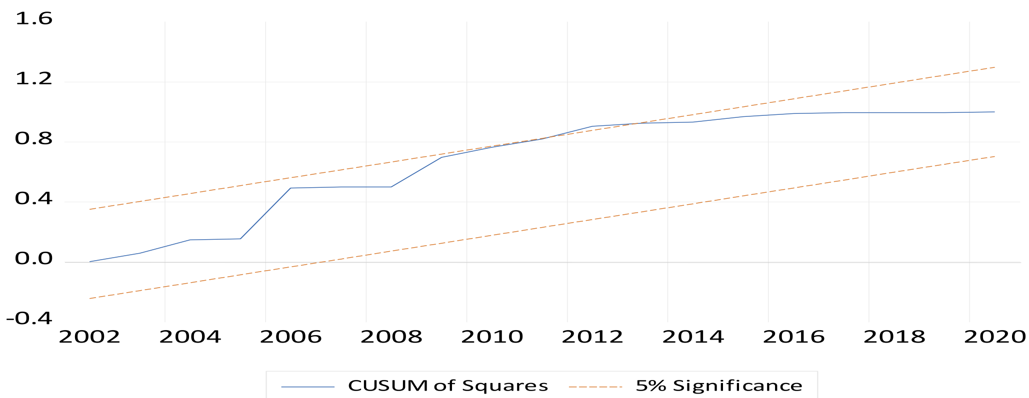


Figure 5B. CUSUMSQ for model 5



4.6. Discussion of Findings

First,the ARDL result of the long-run estimates indicates that PCE has a significant negative influence on electricity access (EP1), electricity access in the urban population (EP2), renewable energy consumption (EP4), and renewable electricity output (EP5) but has a positive insignificant impact on rural electrification (EP3). The result suggests that PCE in Nigeria reduces access to electricity, urban electrification, renewable energy consumption, and renewable electricity output. Although PCE has a positive impact on rural electrification, its effects are however insignificant. This demonstrates that governmental capital investment in Nigeria exacerbates EP. Our findings contradict the Keynesian theory and aligns with related studies (Purokayo and Umaru, 2012; Usman and Abdulsamad, 2017; Adegboyo, 2020; Onifade*et al.*, 2020) that capital expenditure does not stimulate economic and development outcomes. The findings are unsurprising given the long history of corruption and misappropriation of funds in Nigeria, particularly in the energy sector. In an electricity sector 2017 report by the Socio-Economic Rights and Accountability Project, it is estimated that since the comeback of democracy in 1999, Nigeria has lost above eleven trillion naira due to corruption in the power sector.

Second, the result obtained showed that income has a positive significant effect on EP1 and EP3 while exerting a negative significant impact on EP2, EP4, and EP5. This shows that income has an increasing effect on electricity access and rural electrification while reducing electricity access in the urban populations, renewable energy consumption, and renewable energy output. Thus, income supports non-renewable electricity generation and consumption in Nigeria. This is unsurprising given that the existing electricity generation in the country is predominantly fossil-fuel-based (Okwanya *et al*., 2021). Our study agrees with previous studies like Anton and Nucu (2020) and (Kwakwa, 2020) that established that economic growth reduces renewable energy electricity generation and consumption. Despite the fact that Nigeria's economy has grown considerably over the previous decade (Dimnwobi*et al*., 2017; Nwokoye *et al*., 2020; Ekesiobi and Dimnwobi, 2020; Nwokoye *et al*., 2022), renewable energy consumption has been on the decline, while non-renewable energy consumption has soared (Dimnwobi *et al.,* 2022). This indicates that Nigeria's economic performance overtime has been environmentally harmful (Dimnwobi *et al*, 2021), implying that economic progress has not been complemented by considerable investment in renewable energy generation and consumption by businesses, government, and households.

Third, the results indicate that financial sector development is significant and positively connected to EP1, EP2, EP4 and EP5 while it has a significant negative effect on EP3. Financial development increases electricity access, urban electrification, renewable energy generation, and consumption while reducing electricity access in the rural population. This result shows that financial development is indispensable in combating EP in Nigeria and our results agree with Eren*et al* (2019), Anton and Nucu (2019), Asongu and Odhiambo (2020), Khan *et al* (2020), Nguyen *et al* (2021) and Dimnwobi*et al* (2022) while disagreeing with Kwakwa (2020). Our study concurs with the theory on the criticality of financial development in facilitating funds for economic activities.Conversely, the result obtained that financial development reduces rural electrification is plausible given the low rate of financial inclusion in Nigeria's rural regions (Ibrahim and Aliero, 2020).

Fourth, energy price has a positive and significant influence on electricity access, rural electrification, urban electrification, renewable energy generations, and consumption. This agrees with Anton and Nucu (2019) while countering the findings of Kwakwa (2020).This indicates that when energy prices increase, electricity access, rural electrification, urban electrification, renewable energy generation, and consumption will ascend as well.Due to the income and substitution effects of price changes, our findings counters economic theory, which states that a rise in the price of an item produces a drop in the quantity demanded for that commodity, and vice versa (Kwakwa 2020; Okafor *et al*., 2022). The plausible explanation for our results is owing to the unavailability and unreliability of Nigeria's grid power supply and as a result, electricity consumers in the country are probably willing to pay more whenever power is available because it is cheaper and environmentally friendly than off-grid options (Kalu *et al*., 2020; Omoju *et al*., 2020; Dimnwobi *et al*., 2022).

5. Conclusion and policy implications

Given the ever-growing fiscal position of Nigeria and the chequered history of electricity generation and distribution, the fortunes of the energy sector in the country have been affected by the prevalence of energy poverty. Government policies such as PCE present a crucial option for reducing energy poverty in Nigeria, providing a new research impetus for this study. The outcome of the ARDL estimation reveals that public capital spending has a significant negative effect on electricity access (EP1), urban electrification (EP2), renewable energy consumption (EP4), and renewable electricity output (EP5) but has a positive insignificant impact on rural electrification (EP3). Also, income has a positive significant impact on EP1 and EP3 while exerting a negative significant impact on EP2, EP4, and EP5. Similarly, energy price has a positive and significant effect on electricity access, rural electrification, urban electrification, renewable energy generations, and consumption. Financial development is significant and positively related to EP1, EP2, EP4, and EP5 while it has a significant negative effect on EP3

These findings unravel the following implications and policy interventions.PCE hinders the abatement of energy poverty across the majority of indicators adopted (electricity access, urban electrification, renewable energy consumption, and renewable electricity output) except rural electrification. This does not bode well for a country challenged with fiscal and energy issues. To address this, we advocate for the expansion of PCE allocation to the energy sector with the expectation of primary and secondary benefits to the overall economy. This rise in expenditure should be complemented with proper budgetary discipline and improved transparency in the allocation and utilisation of government spending to reap greater rewards. The anti-corruption agencies in the country should awaken to their responsibilities in the fight against corruption and curb further mismanagement of funds earmarked for the development of capital projects. In furtherance of the promotion of the sustainability agenda, the government should key into the global green transition by internalising environmental and climate-change considerations in their budgetary frameworks to grow the much-needed renewable energy infrastructure. While PCE impacts rural electrification positively, traceable to the efforts of the Rural Electrification Agency (REA) of the country, its effects are insignificant. The management of the REA should intensify their endeavours to be more inclusive and effective, in line with their mandate of delivering available, accessible, and affordable electricity to rural dwellers in the country.

The findings related to income and energy poverty illustrate that economic progress increases access to power and access to electricity for rural dwellers while it decreases urban electrification, renewable energy consumption, and production. This demonstrates that, in Nigeria, income encourages non-renewable electricity generation and usage. Consequently, conscious efforts are required to improve the economic growth process inclusively and sustainably. Also, recent national economic plans like the Economic Recovery and Growth Plan and the 2020 post-COVID rebound plan, should be carefully synergised with the National Renewable Energy and Energy Efficiency Policy to foster the switch to green income and renewable energy investments. It is equally essential for policymakers to explore well beyond the volume of renewable energyutilisation and consider the renewable energy percentage share relative to the overall energy consumption in the country. Moreover, deliberate government commitment is required to engage in extensive public awareness on the necessity for individuals to embrace renewable energy with every rise in their income, in conformity with the energy ladder model, and for businesses to choose environmentally friendly technologies in their quest to expand production.

The findings correspondinglyreport that financial development improves access to power, especially in metropolitan areas, as well as renewable energy generation and consumption, while decreasing access to electricity in rural areas. Accordingly, the Central Bank of Nigeria should reform existing financial sector rules, particularly financial institution regulations, to make them more proactive, effective, and responsive to sustainable development funding. Next, increasing efforts towards financial deepening would equally encourage investment and provide enough financial allocation for the construction of essential infrastructure for renewable energy generation. Attracting foreign direct investment (a crucial contributor to financial development) cannot be overemphasised. Since financial development was reported to be significant to renewable energy use in Nigeria, the study advocates for sound, sustained, and dedicated macroeconomic management. This will likely pave the way for improvements in inclusive growth with the rural population in mind, as well as offer opportunities for the Nigerian Investment Promotion Commission to externally project the strong financial sector of the economy to entice more international investors, with a specific focus on increasing the renewable energy share of foreign direct investment and promoting green financing in general.

Our findings assert that a rise in energy prices would result in more people having access to power, more rural and urban electrification, and more renewable energy generation and consumption. While this contradicts the inverse relationship expectation between price and demand in economic theory, it highlights the deficiency in electricity supply in the country which fuels increases in the price of energy. Given the essential nature of electricity to human existence and the insufficient and unreliable grid power supply in Nigeria, consumers opt in favour of more expensive and dirty off-grid sources. The study recommends the full decentralisation of the power sector as enshrined in the Electricity Sector Reform Act to make the sector more competitive. The electricity market in the country also needs to be incentivised to decrease the cost of constructing power grid facilities, attain improved usage, and a drop in transmission and distribution losses. Furthermore, for a long time, power sector operators in the country have unsuccessfully pushed for the implementation of cost-reflective prices. This is required because the utility provider needs income to cover equipment and running costs which the consumers are already paying for via costly and ecologically harmful alternatives.

While energy poverty reduction remains a socioeconomically desirous objective, it would be paramount to assess the role of other fiscal policy instruments (apart from PCE) like public debt, taxation among others in addressing the energy poverty challenge. Also, the interplay between government expenditure, energy poverty, energy security, and environmental quality provides new insights for further studies. Again, this paper limits itself by the choice of variables that can be improved upon by incorporating other variables like governance quality, financial and energy sector reforms among others. Lastly, the study can be extended to other developing countries for comparison insights.

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