Analysis of the determinants of electricity consumption in Benin

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Available data indicate that close to two-thirds of the population of the Republic of Benin lacks access to electricity which has dire consequences on the country's development agenda. Although electricity consumption has been increasing, the supply of electricity is not enough to meet the growing demand in the country. Managing electricity consumption in Benin has therefore become critical owing to the expected rise in the future consumption. This will help ensure future electricity security. Accordingly, this paper examines the determinants of electricity consumption for Benin using annual time series data for the period of 1971-2014. Estimation from the Autoregressive Distributed Lag model, the Fully Modified Ordinary Least Squares and the Canonical Co-integrating Regression reveal that population, urbanization, education and industrialisation positively affect electricity consumption for the country while income negatively reduces it. A further analysis using the rolling regression indicates that the effects of the above variables are time-varying with some social, political and economic changes. Among others, the paper recommends the need to increase awareness on environmental-energy issues; and the need for a policy to make new residential and non residential buildings that would be constructed in the urban centres especially, to be energy efficiently designed.

keywords: *Electricity consumption, Benin; time-varying, rolling regression*

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1. INTRODUCTION

Electricity is needed for the attainment of growth and development agenda for all countries as it serves as an input for production of other goods and services. Its global consumption has grown steadily over the years. For instance, according to the Word Development Indicators [1], the global electricity power consumption (kWh per capita) increased from 1199.795 in 1971 to 2152.099 in 1991 and by 2014 the figure had increased to 3126.326. Governments and policy makers recognize the crucial role of electricity in the development process and so strategize towards having adequate supply of electricity. That notwithstanding, many developing countries face the challenges of low electricity accessibility rate and inadequate supply to meet growing demand. Although the number of people in the world that lacks access to electricity saw about 50 million reduction to 1.3 billion in 2010 [2], the situation is no better for many sub-Saharan African countries like the Republic of Benin, where according to the 2018 Economic Freedom Index, close to two-thirds of the population lacks access to electricity [3], and also faces low production capacity amidst increasing electricity consumption. The African Development Fund [4] attributes the growing electricity consumption in Benin to the growth in population and economic activities such that there was over 5% increase in demand for electricity in 2015.

With low electricity production capacity, the Republic of Benin has for many decades depended on fellow West African countries namely Ghana, Nigeria and Ivory Coast for electricity power with 90% of the nation's electric power coming from Ghana [5]. The implication is Benin has always been adversely affected whenever power is curtailed from its external power suppliers. In fact, Kwakwa and Adu [6] have indicated the number of occasions Ghana has been be-deviled with power shortage that cost the nation a great deal. According to Benin's Ministry of Energy, Oil and Mining Research, Water and Development of Renewable Energy [7] the country's electricity consumption has outstripped supply by 50MW with supply of electricity barely reaching 140 MW. The effect is that the country is confronted with unreliable electricity power supply and frequent power outages with its own consequences documented by many studies. For instance, a 2015 World Bank document reveals that firms in Benin lose about 6.2% of value to power outages [8].

This situation poses a serious threat to the country's developmental and growth agenda as spelt out in the Revealing Benin Programme [9]. A key pillar of this developmental and growth agenda is the idea of initiating structural economic change which among other things the "Benin government plans to use ICT (Information and Communication Technologies) as a catalyst for economic dynamism and national modernization in order to quicken the pace of economic growth and social inclusion by 2021. The goal is to establish Benin in the medium term as a digital services hub for the whole of West Africa." It also aims at making agriculture the main driver of economic growth, wealth and job creation by "establishing seven regional hubs of agricultural development, and promote the development of high added-value sectors..." (p.15).

The success of the above pillar will be dependent on reliable power supply since ICT gadgets and factories to add values to agricultural goods require substantial amount of electricity to operate well. Following the arguments presented in Wang and Han [10] and evidence provided by Kwakwa [11] that respectively indicate a relationship between ICT development and energy, as well as manufacturing and electricity, the coming onboard of ICT technologies and factories to transform agricultural products is likely to increase the level of electricity consumption and that may worsen the already vulnerable electricity security in the country. From the ensued facts, two options may be available- a) increase electricity supply, and b) manage electricity consumption (demand-side management). An implementation of the first option that is increasing electricity supply would require substantial resource investment to replace outmoded infrastructure and additional ones that will be a bit difficult for Benin to afford anytime soon [12] considering its low income status. However, the second option which is to manage electricity consumption can be pursued with relatively lower cost. Thus, it is very imperative to give attention to demand-side management options in Benin for the future security of power supply. Managing the electricity consumption also has the tendency to help in the promotion of quality environment [80–82] in the long term which is appropriate as the country seeks to develop. Consequently, it is a prerequisite to identify the influential factors of electricity consumption and quantify their relative effects in order to design the appropriate policy for electricity demand management [49, 53]. However, there is a scarcity of research analyzing the drivers of electricity consumption in Benin. Accordingly, this paper seeks to examine the drivers of electricity consumption in Benin at the national level using time series data.

The paper acknowledges the fact that there is a plethora of empirical studies including Adom et al. [53], Adom and Bekoe [13], Zaman et al. [14], Ekpo et al. [15], Kwakwa [49], Ubani [16], Hasanov et al., [85] and Rafindadi and Ozturk [18] among others [see Table 1] that have investigated the determinants of aggregate electricity consumption for many countries. However, the lack of consensus in the reported findings in such studies, the different explanatory variables whose effects have been examined and the differences in the socio-economic characteristics of the countries make applicability of the results to Benin inappropriate. There is thus the need for further studies on the subject matter with Benin as the focus. In the energy literature, it is realized that Wolde-Rufael [19], Alinsato [20] and Keho [21] remain the few empirical studies on Benin. The present study differs from these studies because Wolde-Rufael [19] and Alinsato [20] examined the causal relationship between electricity and economic growth, while Keho [21] focused on the determinants of aggregate energy consumption in Benin. By focusing on a bivariate analysis, the works of Wolde-Rufael [19] and Alinsato [20] which report of a mixed outcome of a unidirectional causality from electricity to economic growth, and economic growth to electricity respectively, do not capture the potential effect of other variables such as urbanization, population and industrialisation on electricity consumption. Keho [21] on the other hand explored the effects of a number of variables on aggregate energy consumption for Benin with other African countries. However, for effective policy design for specific energy type, it is important to know their respective drivers. In this case, it is not appropriate to also rely on the findings of Keho [21] to design policies to manage electricity consumption for Benin.

In the light of this, the novelty of this paper in the energy literature with respect to Benin is its analysis of the possible drivers of electricity consumption at the macro level. In this regard, the paper does not only help Benin's policy makers to implement lower electricity consumption strategies but also expands the existing literature on the electricity consumption. Generally, there is little known about what drives electricity consumption in least developed and some developing countries. Examining the case of Benin helps bridge this gap. Further, Brohmann et al., [22], and Inglesi-Lotz and Morales [23] among others have revealed the potential effect of education on energy consumption. Brohmann et al., [22] have opined education can reduce energy consumption because it makes people develop positive attitude towards the environment. Also, this is what Inglesi-Lotz and Morales [23] have to say on the possible effect of education on energy consumption:

"By improving education levels, production processes and technology should theoretically become more efficient. This leads to the rationale that education affects energy consumption in the following ways. A priori, it could be seen as increasing energy consumption of relatively poor nations as these nations seek to catch up to their more developed and urbanized counterparts, while making headway in escaping a historically poor or even agrarian economy. On the other hand, education can reduce energy consumption in already developed countries as these countries seek to reduce their energy footprint and develop better, more environmentally friendly production processes. Furthermore, education can also . . . lead to more informed consumers and public planners who will make better energy purchasing, generation, usage and distribution decisions, which may in turn reduce energy consumption levels. It can therefore be argued that education may have different effects on energy." (p: 2)

However, at the macro level, the relationship between energy and education has not caught the attention of researchers [see Table 1] for a summary of related literature since Kwakwa [49] and Inglesi-Lotz and Morales [23] appear to be those to have examined the relationship in their respective studies. To deepen the understanding of the relationship between energy and education at the macro level, this current study explores the potential role of education in Benin's electricity consumption. Benin's education expenditure as share of total expenditure in public institutions has remained quite high over the years ranging between 75.86 and 96.30% for the 2003-2014 period WDI [1] and it is important to ascertain how this has impacted electricity consumption. In addition, although a number of empirical studies [see Table 1] have proven that the drivers of energy consumption may not be time invariant, it is realized that the majority of the previous studies on the determinants of electricity consumption in Africa, with the exception of a few including Adom [24], have not examined the time varying nature of the determinants. Outside the continents, studies like Arisoy and Ozturk [25], and Mikayilov et al., [26] have investigated the time varying effect of the drivers of electricity consumption. By not analysing the time varying effect of the drivers of electricity consumption, the many studies implicitly assume that the parameters are fixed and there is stability within the sample time period. However, major changes in the economic, cultural, social and political environment can cause variation in the effects of the drivers of electricity consumption [24]. It is important to therefore take into consideration the time varying effect of the drivers of electricity consumption. This identified gap of relatively fewer studies that have analyzed time varying nature of the drivers of electricity consumption is also bridged in this study. An analysis of the time varying effects of the variables for Benin is relevant since major national events like the Structural Adjustment Programme between 1989 and 1999, the Educational Reforms in the 1970s, the Poverty Reduction Strategy Support Programme in the early 2000s, as well as international events like the 2008 global financial finance crises could have influenced the level of electricity consumption in the country.

The remainder of the study proceeds as follows: Section 2 reviews relevant empirical literature; Section 3 describes the data and method used; Section 4 explains and discusses the result of the study; and Section 5 concludes and offers policy recommendations.

2. LITERATURE REVIEW

This section reviews the empirical literature under the following sections: a) studies that investigate the drivers of electricity consumption, (b) studies that assess the time-varying nature of the drivers of electricity consumption, (c) a discussion of the parameters and (d) conclusion.

A. Drivers of electricity consumption

Owing to the importance of electricity to the growth and development process, empirical studies on the determinants of electricity consumption at the national level have been investigated by researchers for many countries to help manage level of demand. These studies do cut across both developed and developing countries however, the outcome has not been conclusive. For instance, Bernstein and Madlener [27] relying on panel data for group analysis and time series data for country specific analysis, obtained a positive income effect and a negative price effect for the group analysis and most of the countries for both short-run and long-run periods. Also, Alberini and Filippini [28] examined the residential demand for electricity in the United States and found income effect to be positive and price effect to be negative. Halvorsen and Larsen [29] estimated the effect of price on electricity consumption for Norwegian households and found a small variation in the price elasticity effect in the short-run and the long-run. The work of Holtedahl and Joutz [30] assessed the residential demand for electricity in Taiwan. The results indicated that in the long-run income and urbanisation increase residential electricity consumption while price effect is negative. In the short-run, similar outcome is reported in addition to the fact that cooling degree-day needs positively affects electricity consumption.

Rafindadi and Ozturk [18] examined the effects of financial development, economic growth, exports, imports and capital on electricity consumption in Japan. They established that in the long-run financial development, economic growth, exports and imports increase electricity consumption but capital reduces electricity consumption. Bekhet and Othman [31] examined the short-run and long-run effect of foreign direct investment, export and industrial value added on Malaysia's electricity consumption. The results showed that in the long-run foreign direct investment, export and industrial value added increase electricity consumption but in the short-run, foreign direct investment and industrial value added exert negative effect on electricity consumption. Also, Alawin et al., [33] investigated the drivers of electricity consumption in Jordan. Their application of the Autoregressive Distributed Lag (ARDL) technique revealed that domestic energy price index and improvement in production efficiency in the manufacturing sector reduce electricity consumption while real GDP growth rate and population growth exert positive effect. Ivy-Yap and Bekhet [32] also found that income and population growth positively affect Malaysia's electricity consumption.

From the African continent, Sekantsi et al., [55] found that financial development, industrialization, Lesotho Electricity and Water Authority (LEWA) and urbanisation positively affect the long-run electricity consumption in Lesotho. In the short-run however, they reported that political instability reduces electricity consumption while financial development positively affects electricity consumption. Sekantsi and Timuno [34] modelled electricity consumption for Botswana as a function of economic growth, financial development, industrialisation and urbanization and found that the above variables have positive effects on electricity consumption.

Kwakwa [49] recorded that Egypt's electricity consumption is positively influenced by income, urbanization, financial development, trade and education but negatively affected by industrialization. Furthermore, Khobai and Roux [35] analyzed the impact of urbanisation on electricity consumption in South Africa by incorporating trade openness, capital formation and labour in the estimation process. A positive effect was observed from urbanization, trade openness and labour, but negative effect from capital. Mawia [36] studied electricity consumption in Kenya and the estimation results showed electricity consumption is significantly influenced by industrialisation and price of kerosene. El sahati [37] studied the determinants of electricity demand in Libya and reported that price of electricity reduces electricity consumption while real value of imported electrical appliance and population increase it. Moreover, Ubani [16] found that urbanization, population density, number of manufacturing industry, number of households with electricity, employment rate and distance to nearest power generating station affect electricity consumption in Nigeria. In addition, Adom et al., [53] assessed the drivers of electricity consumption in Ghana and the estimation results indicated that real per capita GDP, industry efficiency, structural changes in the economy and degree of urbanisation influence electricity consumption in the long-run while real per capita GDP, industry efficiency and degree of urbanisation affect short-run electricity consumption.

In the case of Benin, there appears to be no empirical study on the determinants of electricity consumption. However, a closely related study by Keho [21] on the determinants of energy consumption for Benin shows that income, import, foreign direct investment, industrialization, financial development and urbanisation significantly affect energy consumption. Also, Wolde-Rufael [19] and Alinsato [20] examined the energy-growth nexus for Benin and respectively reported of a unidirectional causality from electricity to economic growth, and economic growth to electricity.

Table 1. Summary of related literature

No	Authors	Country/region	Time period	Estimation method	Dependent variable	Explanatory variables	Time varying analysis
1	Adom et al. [53]	Ghana	1975-2005	Autoregressive Distributed Lag (ARDL) model	Electricity consumption	Real per capita GDP, industry efficiency, structural changes in the economy, and degree of urbanisation	NO
2	Adom and Bekoe [13]	Ghana	1971-2008	Fully Modified Ordinary Least Squares (FMOLS)	Electricity consumption	Industry value added as a share of GDP, degree of urbanization, industrial energy efficiency, and real GDP	Yes
3	Zaman et al. [14]	Pakistan	1975-2010	ARDL model	Electricity consumption	economic growth, foreign direct investment and population growth	No
4	Ekpo et al. [15]	Nigeria	1970-2008	ARDL model	Electricity consumption	Price, real GDP per capita, population and industrial output	No
5	Kwakwa [49]	Egypt	1971–2012.	FMOLS and Canonical Co-integrating Regression (CCR)	Electricity consumption	Income, price of Electricity, level of industrialisation, financial development, trade openness, urbanisation, carbon emission and education	No
6	Ubani [16]	Nigeria	1985-2005	Ordinary least squares (OLS)	Electricity consumption	Urbanization, population density, number of manufacturing industry, number of households with electricity, employment rate and distance to nearest power generating station	No
7	Hasanov et al. , [85]	Azerbaijan	1995-2013	ARDL, vector error correction model (VECM), CCR, FMOLS, and Dynamic Ordinary least squares (DOLS)	Total final electricity consumption	Real electricity price, and real Non-oil GDP per capita, and underlying energy demand trend	No
8	Rafindadi and Ozturk [18]	Japan	1970-2010	ARDL model	Electricity consumption	Financial development, economic growth, exports, imports and capital	No
10	Adom [24],	Ghana	1971-2008	FMOLS	Electricity consumption	Income, economic structure and industry efficiency	Yes
11	Arisoy and Ozturk [25]	Turkey	1960–2008	Kalman filter approach	Electricity consumption	Income and price	Yes
12	Mikayilov et al., [26]	Azerbaijan	1990-2014	co-integration approach	Electricity consumption	Income and price	Yes
13	Bernstein and Madlener [27]	OECD Countries	1981–2008	FMOLS and Dynamic Ordinary Least Squares (DOLS)	Electricity consumption	Price and income	No
14	Alberini and Filippini [28]	USA	1997-2007	Kiviet corrected Least Square Dummy Variables (LSDV) and the Blundell-Bond estimators	Electricity consumption	Income and price	No
15	Halvorsen and Larsen [29]	Norway	1975-1994	Discrete-continuous approach for estimating.	Electricity consumption	Price	No

Table 1. continued : Summary of related literature

14	Huang et al [83]	China	1997-2007	Cointegration Analysis and Artificial Intelligence Algorithm	Electricity consumption	total population, GDP, ratio of tertiary sector to GDP, urbanization and price	NO
15	Latif [84]	Canada	983–2010	FMOLS, DOLS and ECM	Electricity consumption	Price and income	No
16	Holtedahl and Joutz [30]	Taiwan	1956-1995	vector autoregressive (VAR) and co-integration analysis	Electricity consumption	Real disposable income, real price of electricity, real world oil price, population and cooling degree-day needs on electricity consumption	No
17	Bekhet and Othman [31]	Malaysia	1971-2011	unrestricted error-correction model	Electricity consumption	Foreign direct investment, export and industrial value	No
18	Ivy-Yap and Bekhet [32]	Malaysia	1978-2011	ARDL model	Electricity consumption	Real disposable income, price of electricity and population	No
19	Alawin et al., [33]	Jordan	1985-2006.	ARDL model	Electricity consumption	Energy price index, improvement in production efficiency in the manufacturing sector, real GDP growth rate and population	No
20	Sekantsi et al., [55]	Lesotho	1973-2012	FMOLS and Error correction method (ECM) and granger causality	Electricity consumption	Financial development, industrialization, Lesotho Electricity and Water Authority (LEWA), political instability and urbanisation	No
21	Sekantsi and Timuno [34]	Botswana	1981-2011	FMOLS and ECM	Electricity consumption	Economic growth, financial development, industrialisation and urbanization	No
22	Khobai and Roux [35]	South Africa	1971-2013	vector error correction model (VECM)	Electricity consumption	Urbanisation, trade openness, capital formation and labour	No
23	Mawia [36]	Kenya	1971 to 2012	OLS and the Error Correction Model	Electricity consumption	Average tariff, Real Gross Domestic Product, Price of Kerosene, Price of LPG, Total and industry value added	NO
24	El sahati [37]	Libya	1980-2010	OLS	Electricity consumption	Price of electricity, real value of imported electrical appliance and population	No
25	Jaunky [57]	16 African countries	1971-2002	FMOLS, DOLS and Granger causality	Electricity consumption	Income	No
26	Chang et al. [38]	Korea	1995-2012 1985-201	error-correction model and Time-Varying Coefficient Models	Residential electricity consumption and industrial and commercial electricity consumption	Income	Yes
27	Ismail et al., [72]	Seven ASEAN countries	1980-2015	vector autoregressive (VAR) and vector error correction (VEC) models	Electricity consumption	Gross domestic product , exports and carbon dioxide emission	No
28	Dhungel [60]	Nepal	1974-2011	ECM	Electricity consumption	Foreign aid and gross domestic product	No
29	Wang and Yan [61]	China	2000-2008	Data Envelopment Analysis (DEA)	Electricity demand	R&D expenditures, the proportion of the second industry in GDP, per capita GDP and raw materials, fuel and power price index	No
30	Xia and Hu [62]	China cities	2009	Finite Mixture Model and Principal component analysis (PCA)	Electricity consumption	urban morphology, industrial structure, regulation context, urbanization degree, price, natural condition, and resource endowment	No

Table 1. continued : Summary of related literature

31	Adom and Kwakwa [63]	Ghana	1975-2011	FMOLS, CCR and DOLS	Energy intensity	manufacturing output; changing technical characteristics of the manufacturing sector; trade openness; changing structure of trade foreign direct investment, and urbanization.	Yes
32	Otsuka (64)	Japan	1990-2010	Stochastic frontier model	Electricity efficiency	real electricity price, real household income, household size, household floor area, population ageing rate and temperature	
33	Adom [65]	South Africa	1970-2011	FMOLS	Energy intensity	economic integration, price, industrial output FDI inflows, and energy intensity	Yes
34	Adom [66]	Nigeria	1971-2011	FMOLD and CCR	Energy intensity	economic integration, price, industrial output FDI inflows, and energy intensity	Yes
35	Adom [67]	Algeria	1971-2010	FMOLS and CCR	Energy intensity	price of firm product/good, output of the firm, composite input, energy use, subsidy withdrawal, value weighted average of crude oil price, dummy for recession, crude oil price, price, foreign direct inflows, industry value added, total factor productivity, income per capita and trade openness.	No
36	Wang and Han [10]	China	2003–2012	Panel error correction model	Energy intensity	Population, GDP per capita, industrial share, coal consumption share, R&D investment intensity and ICT investment intensity	No
37	Inglesi-Lotz and Morales [23]	10 developed and 11 developing countries	1980-2013	OLS model, fixed effects, random effects model and granger causality	Primary energy consumption	Population, urbanization, industrialization, Service Percentage Value Added to GDP, CO2 emissions, income and education	No
38	Aboagye [68]	Ghana	1981–2014	ARDL model	Primary energy consumption and energy intensity	economic growth. Foreign Direct Investment, urbanisation, trade openness, inflation, industrial activities and population	No
39	Kwakwa and Aboagye [69]	Ghana	1971- 2009	ECM	Primary energy consumption	income, urbanization, level of industrialization and trade openness	No
40	Destek [70]	17 emerging Economies	1991–2015	Mean group (MG) and common correlated effect of the mean group (CCE-MG) estimation methods	Primary energy consumption	GDP, energy prices and financial development	No
41	Kwakwa et al., [71]	Ghana	1971-2013	FMOLS	Total energy consumption	Income, trade, natural resource extraction and urbanization	No

Table 1. continued : Summary of related literature

42	Keho [21]	12 African Countries	1996–2009	ARDL model	Total energy consumption and per capita energy consumption	GDP, import, industrialization, foreign direct investment, financial development, urbanization and population	No
43	Ghani [73]	52 developed and developing economies	1970-1999	Fixed effects	average growth of energy consumption	trade liberalization, economic growth and capital per labor	Yes
44	Sadorsky [74]	8 Middle Eastern countries	1980-2007	Vector Error Correction Model	Total energy demand	energy price, income, and trade,	No
45	Chang [75]	53 countries	1999–2008	fixed-effects linear regression	Energy demand	GDP per capita, energy price and financial development	No
46	Liu [76]	China	1978–2008	ARDL model and Factor decomposition model	Total energy consumption	total population, s real GDP and urbanization level.	No
47	Shahbaz and Lean [77]	Tunisia	1971– 008	ARDL model and Granger Causality	Total energy consumption	Domestic credit, real GDP per capita,industrial value added as share of GDP and urban population	No
48	Li and Lin [78]	China	1980-2009	nonlinear threshold cointegration model	energy intensity	industrial structure, technological progress, and energy price	Yes
49	Honjo et al., [79]	Japan	1988- 2016	stepwise regression	Industrial and residential electricity demand	Population, cooling and heating days, industrial activities, real wage, consumer price index and corporate goods price index	Yes
50	Atakhanova and Howie [17]	Kazakhstan	1994–2003	Fixed effects, Random effects, feasible general least-squares, Anderson-Hsiao instrumental variable fixed effects Arellano–Bond GMM, Arellano–Bond system GMM	aggregate demand for electricity, electricity demand in the industrial, service, and residential sectors	Price, income, population, structural changes in the economy, and efficiency improvements	Yes

B. Time-varying analysis of drivers of electricity consumption

All the above studies assumed that the coefficients of the explanatory variables are constant over time. However, major changes in the economic, cultural, social and political environment can cause variation in the effects of the drivers of electricity consumption [24]. Consequently, a few of recent studies have done a time-varying analysis of the drivers of electricity consumption. Adom [24] for instance, examined the time-varying effects of income, economic structure and industry efficiency on aggregate electricity demand for Ghana for the 1971 to 2008 period. The rolling regression technique showed the magnitude of the effects of the explanatory variables of electricity consumption has been changing over the period. Arisoy and Ozturk [25] also applied the Kalman filter approach to investigate the income and price effects of industrial and residential electricity consumption in Turkey over the period 1960–2008. They however found that there is stability in the price and income elasticity of residential and industrial electricity demand over time.

Adom and Bekoe [13] investigated the role of policy regime changes in the electricity consumption pattern for Ghana for the 1971 to 2008 period. The authors examined three different sample periods: pre-economic reform (1971-1983), post-reform (1983-2008), and full-period (1971-2008). The industry efficiency was found to reduce electricity consumption while industry value added, and real per capita GDP increased electricity consumption. The results did not vary much over the three different sample periods apart from the urbanisation effect on electricity consumption which was recorded to be significantly negative for the pre-recovery period. Mikayilov et al., [26] used data from 1990 to 2014 to estimate the effect of economic activities and electricity price on electricity consumption in Azerbaijan using the time-varying coefficient co-integration approach. They concluded that income elasticity and price elasticity of electricity consumption vary over time. Also Chang et al. [38] have found that income effect on the demand for electricity in Korea is time-varying.

C. Discussion of the parameters

The magnitudes of the (significant/efficient) estimated parameters also differ from one study to another since both elastic and inelastic effects of the explanatory variables on electricity consumption have been reported by existing studies. However, the inelastic impacts seem to be the dominant. The differences in the values of the parameters reported by different studies make it more necessary to avoid over generalization of the expected impact a change in a variable may have on electricity consumption. Thus, it becomes important to estimate the parameters for the drivers of electricity consumption for a particular country or region of interest. For instance, Adom et al., [53] reported a long-run coefficient of 0.837 for income, 0.324 for urbanization and 0.156 for industrialization. Kwakwa [49] also reported of a range of 1.503 to 1.6740 for income, 0.4679 to 0.6181 for urbanization, 0.1059 to 1.6100 for education and 0.0233 to 0.0488 trade. In their investigation, Alawin et al., [33] reported of 0.856, 0.25, -0.033 and -0.78 respectively as the coefficients of income, population, price and efficiency of the manufacturing industry. Jaunky [57] found income elasticity to range from 0.089 to 1.18 while Sekantsi and Timuno [34] found the effect of income, financial development, industrialization and urbanization are all inelastic with the value of 0.4016, 0.1026, 0.5860 and 0.2807 respectively.

The study by El sahati [37] also reported inelastic effect of price (-0.1746), income (0.1591) and imported electrical appliances (0.0731) but an elastic effect of population (1.1506). Rafindadi and Ozturk [18] found that the effect of income ranges between 0.2007 and 0.5040; capital effect between -0.1018 to -0.2142; financial development effect between 0.2112 to 0.2429; and trade effect between 0.0921 to 0.2031. Athukorala and Wilson [86] have also indicated that the long-run income and price elasticity effect on electricity consumption are 0.78 and -0.32 respectively. Bernstein and Madlener [27] reported a mixture of both elastic and inelastic effect of income and price for a number of countries. For price effect it ranged from -0.14 to -1.37 while the income effect ranged from 0.38 to 2.04.

D. Conclusion of literature review

The above review has clearly shown that many studies have explored the determinants of electricity consumption at the national level. However, there has been mixed results with some reporting elastic effects and others inelastic effects for different variables. In addition, little to no studies exists for Benin. It appears therefore that although the electricity situation in Benin has become critical, little attention has been paid to examine the drivers of the country's electricity consumption, empirically. Again, limited studies have analyzed the time-varying behaviour of electricity determinants especially in Africa. The current paper therefore aims to bridge these identified gaps.

3. MODEL SPECIFICATION, DATA AND EMPIRICAL STRATEGY

A. The empirical model and Data issues

The mathematical identity called IPAT developed by Ehrlich and Holdren [39] examines the environmental impact of demographic and economic activities. The identity explains that environmental impact (I) is dependent on population (P), affluence (A) and technology (T). Owing to a number of weaknesses associated with the IPAT such as the inability to properly explain the results obtained and the assumption that the elasticities of population, affluence and technology on the environmental impact are one, Dietz and Rosa [40] modified the IPAT identity by introducing a stochastic term to the IPAT equation. The modification led to the Stochastic Impacts on Population, Affluence and Technology (STIRPAT) model which takes the following form:

$$I_t = CP_t^{\beta_1} A_t^{\beta_2} T^{\beta_3} e_t^{\varepsilon_i} \quad (1)$$

Where C is constant term, I is environmental impact, P is population, A is affluence, T represents technology, βs are the parameters to be estimated, e raised to epsilon is the stochastic term and t represents the time period. Since its development, the STIRPAT model has been adopted to study the drivers of carbon dioxide emissions (see Kwakwa [41]) which is a main trigger of climate change. However, since the rising consumption of energy including electricity contributes greatly to carbon dioxide emissions the model is seen applicable to examine the drivers of electricity (energy) consumption. So, researchers including Inglesi-Lotz and Morales [23] and Wang and Han [10] have adopted the STIRPAT model in their studies which examine the determinants of energy consumption. Another plus with the STIRPAT equation is that it allows for the inclusion of relevant control variables to the model. Accordingly, to account for demographic effect on the environment, the paper investigates the impact of population (P) and urbanisation (U) on electricity consumption; and for affluence, we represent it with income. Regarding technology which denotes the efficiency in the transformation of inputs, we represent it with education (E) and industrialisation (N). The decision to use education and industrialization to capture technology is based on the arguments by Brohmann et al., [22], and Inglesi-Lotz and Morales [23], and Adom and Bekoe [87] respectively.

Thus, equation one is modified as:

$$I_t = CP_t^{\alpha} U_t^{\delta} A_t^{\chi} E_t^{\varphi} N_t^{\lambda} e_t^{\varepsilon_i} \tag{2}$$

Letting $I = EC$, $P = POP$, $U = URB$, $A = Y$, $E = EDU$ and $N = IND$ and also taking the natural log of each variable in Equation (2) gives also taking the natural log of each variable in Equation (2) in order to have elasticity interpretation of the estimated parameters gives:

$$\ln EC_t = c + \alpha \ln POP_t + \delta \ln URB_t + \chi \ln Y_t + \varphi \ln EDU_t + \lambda \ln IND_t + \varepsilon_t \tag{3}$$

Where ln is natural logarithm operator and $c = lnC$; $\alpha, \delta, \chi, \varphi$ and λ are the parameters to be estimated. The dependent variable EC is measured using two separate proxies namely the per capita electricity consumption (PEC) and the total electricity consumption (TEC). Estimating the per capita electricity consumption from equation (3) will however exclude population. The reason to estimate for both total and per capita electricity consumption follows Keho [21] argument that the use of per capita energy consumption as the dependent variable implies that population is assumed to have a unitary elasticity with respect to energy consumption which should be avoided. The total electricity consumption was measured as the product of per capita electricity consumption and population. Population is measured as total population, urbanisation is the urban population, income is measured as GDP (constant 2010 US$), education is measured as primary school enrolment while industrialisation is measured as the industrial value added. This study used annual time series data covering 1971-2014 sourced from WDI [1] data base. The selection of this period was influenced by data availability.

Table 2 provides the summary statistics of the variables. While urbanization is negatively skewed, the rest of the variables namely total electricity consumption, per capita electricity consumption, education, population and industrialization are positively skewed. The mean total electricity consumption stands at 330000000kWh with a standard deviation of 292000000kWh and that of per capita electricity consumption stands at 47.50kWh per capita and 26.00kWh respectively. The average school enrolment (primary) is about 74%.2 with a standard deviation of 25.4.

Table 2. Descriptive statistics

Statistics	TEC	PEC	POP	URB	GDP	EDU	IND
Mean	3.30E+08	47.50296	5791250	33.47065	3.94E+09	74.23359	5.87E+08
Median	2.07E+08	39.11794	5331803	35.82700	3.26E+09	65.61971	2.38E+08
Maximum	1.03E+09	100.2264	10286712	43.51400	8.58E+09	125.5612	2.02E+09
Minimum	32000000	10.75062	2976572	17.64700	1.67E+09	34.51070	45170532
Std. Dev.	2.92E+08	26.00545	2209420	7.367675	1.97E+09	25.96341	6.13E+08
Skewness	1.051656	0.631342	0.507484	-0.605230	0.755086	0.574302	1.026123
Kurtosis	2.833418	2.241942	2.037349	2.262464	2.403867	2.231191	2.506185
Jarque-Bera	7.975913	3.886164	3.506036	3.599771	4.722820	3.422721	7.982884
Probability	0.018538	0.143262	0.173250	0.165318	0.094287	0.180620	0.018473
Observations	43	43	43	43	43	43	43

B. Estimation technique

To estimate the impact of population, urbanization, income, education and industrialisation on electricity consumption for Benin, the study set out as follows. In order to avoid generating meaningless results from estimating equation (3), the study first examines the unit root property of the series using the popular Augmented Dickey-Fuller (ADF) and the Phillips-Perron (PP) tests to ascertain whether they are stationary or not. The ADF test tests the null hypothesis that a time series yt is I(1) against the alternative that it is $I(0)$, assuming that the dynamics in the data have an ARMA structure. As outlined in Zivot and Wang [58], the ADF test is based on estimating the test regression:

$$y_t = \beta' D_t + \eta y_{t-1} + \sum_{j=1}^{p} \lambda_j \Delta y_{t-j} + \varepsilon_t \tag{4}$$

where Dt is a vector of deterministic terms. The p lagged difference terms, Δy_{tj}, are used to approximate the ARMA structure of the errors, and the value of p is set so that the error ϵ_t is serially uncorrelated. The error term is also assumed to be homoskedastic and $\eta = \varphi - 1$.The null hypothesis is that Δy_t is $I(0)$ which implies that $\pi = 0$.

The PP unit root tests as outlined in Tomás del Barrio et al., [59] is based on the ordinary least squares (OLS) parameter estimate, from the AR(1) (pseudo) equation

$$x_t = a x_{t-1} + u_t \tag{5}$$

where

$$a = 1 + 2c_0 T^{-1}(1 - cos\varphi) + 0(T^{-2}) \tag{6}$$

Using the estimate $\hat{a}$, the PP unit root statistics are then computed as

$$Z_a := T(\hat{a} - 1) - \frac{1}{2}(\hat{\lambda}^2 - s^2)\left(\frac{1}{T^2}\sum_{t=1}^{T} x_{t-1}^2\right)^{-1} \tag{7}$$

$$Z_t := \frac{s}{\hat{\lambda}} t_{\hat{a}=1} - \frac{1}{2}(\hat{\lambda}^2 - s^2)\left(\frac{\hat{\lambda}^2}{T^2}\sum_{t=1}^{T} x_{t-1}^2\right)^{-1/2} \tag{8}$$

Where $t_{\hat{a}=1} := s^{-1}(a-1)(\sum_{t=1}^{T} x_{t-1}^2)^{1/2}$ and $s^2 := T^{-1}\sum_{t=1}^{T} \hat{u}_t^2$ and $\hat{\lambda}^2$ are estimators of the short and long run variances of u_t; respectively.

Next, co-integration is examined to confirm a long-run relationship among the variables. The study employs the Pesaran et al., [88] Bounds test approach, Engle and Granger [42] and Phillips and Ouliaris [43] tests. After this, the long-run impact of population, urbanization, income, education and industrialisation on electricity consumption for Benin is estimated. This estimation is done using Autoregressive Distributed Lag (ARDL) model due Pesaran et al., [88], which is applicable regardless whether the variables are $I(0)$ or $I(1)$ and also robust to analyzing long-run relationship for with small sample study of this nature. To ensure the stoutness of the estimated results, the Phillip and Hansen [44] Fully Modified Ordinary Least Square (FMOLS) co-integration estimation technique and Park's [45] Canonical Co-integrating Regression (CCR) model are also used to estimate equation (3).

Lastly, the rolling regression analysis is used to ascertain the stability of the parameters overtime. The justification is that the effect of the explanatory variables on electricity consumption may vary in the course of time as a result of major changes in the economic, cultural, social and political environment. Following Adom [24] closely, the rolling linear regression model using a window size of $n < T$, could be expressed as:

$$P_t(n) = A_t(n)\varphi_t(n) + \mathrm{v}_t(n) \quad \textbf{(9)}$$

where $t = n, ..., T; P_t(n)$ is an $(n \times 1)$ vector of observations on the response variable; $A_t(n)$ is $(n \times k)$ matrix of explanatory variables; $\varphi_t(n)$ is $(k \times 1)$ vector of disturbance terms and n is assumed to be greater than the number of parameters (i.e. $n > k$). The n observations in $P_t(n)$ and $A_t(n)$ are the n most recent values from times $t\tilde{}n + 1$ to t. Based on equation (9), the time-varying electricity demand model is specified in equation (10) as:

$$\ln EC_t(n) = c_t(n) + \alpha_t(n) \ln POP_t + \delta_t(n) \ln URB_t + \chi_t(n) \ln Y_t + \varphi_t(n) \ln EDU_t + \lambda_t(n) \ln IND_t + \varepsilon_t(n) \quad \textbf{(10)}$$

The study used the window size n, set to 8 years. The study does the time varying coefficients analysis with the confidence band to see whether the coefficients although they may vary over time, they are within some boundary as used in recent studies [24].

4. EMPIRICAL RESULTS AND DISCUSSIONS

This section presents a discussion of the key findings of the study under the following: stationary and co integration results; long-run estimates for electricity consumption; and time-varying analysis.

A. Unit root and co-integration results

Although the ARDL is applicable to $I(1)$ or $I(0)$ or a mixture of both, it is important to confirm the stationarity properties of the series to ensure none of them is $I(2)$. The results of the Augmented Dickey-Fuller (ADF) and the Phillips-Perron (PP) unit root tests are shown in Table 3. It is observed from the results that all the variables, except population, urbanization, per capita electricity consumption and total electricity consumption, at levels are not stationary. The PP test under the assumption of intercept and trend indicates per capita electricity consumption and total electricity consumption at levels are stationary. The ADF also shows population is stationary at levels. Both tests show urbanisation is also stationary at levels. At first difference however, all the rest of the variables are found to be stationary. Thus, apart from per capita electricity consumption, total electricity consumption, urbanisation and population that are integrated of the order zero, $I(0)$ the other variables are integrated of the order one, $I(1)$. This implies the estimation results from using these variables can be said to be meaningful.

Table 4 and 5 provide the results for the Bounds test, and Engle-Granger and Phillips-Ouliaris tests for co-integration respectively. Results in Table 4 rejects the null hypothesis of no co-integration for each of the models. From Table 5 the tau-statistic and the z-statistic of both tests indicate co-integration exist between per capita electricity consumption, urbanization, education, industrialisation and income. However, only the tau-statistic and the z-statistic of the Phillips-Ouliaris test confirm co-integration exists between total electricity consumption, urbanization, population, education, industrialisation and income.

Table 3. Unit root test results

	PP		ADF	
Variables	Intercept	Intercept and trend	Intercept	Intercept and trend
		At levels		
Lnpec	-1.9267	6.0518***	1.2700	2.7574
Lntec	-1.5229	-6.1737***	-1.0000	-2.5893
Lnpop	1.2710	2.9807	1.0386	3.8729**
Lnurb	-4.8941**	-8.7901***	-1.2771	-3.4785*
Lngdp	2.3220	-1.9795	0.9042	-2.2849
lnedu	1.5262	2.3114	1.4977	2.2609
Lnind	-0.9440	-2.4408	-0.7179	-2.4404
		At first difference		
Lnec	-13.3362***		-5.4766***	-2.9821
Lntec	-15.0177***		-5.5903***	-3.4981*
Lnpop	-2.2521	-1.4597	-2.6054*	
Lnurb			-1.8067	
Lngdp	-6.1194***	-6.8749***	-6.0800***	-6.2707***
lnedu	-6.6995***	-6.7128***	-6.6926***	-6.7102***
Lnind	-7.9114***	-7.8186***	-7.8763***	-7.7872***

***, ** and *denotes 1%, 5% and 10% level of significance respectively.

Table 4. Bounds test for co integration relationship

Series	Test statistic	Value
lnpec I lnpop, lnurb lngdp,lnedu & lnind	F-statisitc	7.1590***
	k	5
lntec I lngdp, lnedu, lnurb & lnind	F-statisitc	7.4626***
	k	4

*** denotes 1% level of significance.

Table 5. Engel-Granger and Phillips-Ouliaris Co-integration Results

	Engel-Granger test		Phillips-Ouliaris test	
Series	tau-statistic	z-statistic	tau-statistic	z-statistic
lnpec I lnpop, lnurb lngdp,lnedu & lnind	-2.0538	-42.8303***	-8.48520**	-46.1237***
lntec I lngdp, lnedu, lnurb & lnind	-4.4224	198.6231	-7.9182***	-47.2855***

*** and ** denotes 1% and 5% level of significance respectively.

One can therefore conclude a long-run equilibrium relationship between electricity consumption, population, urbanization, education, industrialisation and income exists. Thus population, urbanization, education, industrialisation and income can be said to be the long-run forces of electricity consumption in Benin.

B. Long-run estimates of electricity consumption

Tables 6 and 7 provide the results of the long-run estimations of total electricity consumption and per capita electricity consumption in Benin, respectively. The estimated results using the ARDL, FMOLS and CCR models reveal similar outcome in terms of significance of the variables and their direction of the impact on the measurements of electricity consumption. Thus, it is seen that population, urbanization, income, education and industrialisation significantly affect Benin's total electricity consumption level while urbanization, income, education and industrialisation influence per capita electricity consumption. However, the

Table 6. Long run estimates for total electricity consumption

Variables	ARDL		FMOLS		CCR	
	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic
lnPOP	2.3714**	2.4352	2.2334**	2.6483	2.2106**	2.5568
LnURP	0.6471***	3.4418	0.4183*	1.7714	0.4067*	1.9374
lnGDP	-1.5568**	-2.0891	-1.3090**	-2.5304	-1.2472**	-2.1459
lnEDU	0.9883***	3.9129	0.6046***	2.7557	0.5989**	2.2158
lnIND	0.1653**	2.6556	0.2635***	3.2918	0.2537***	2.7841
Constant	-0.6870	-0.1704	-0.4000	-0.1320	-1.0233	-0.3489

***, ** and *denotes 1%, 5% and 10% level of significance respectively.

Table 7. Long run estimates for per capita electricity consumption

Variables	ARDL		FMOLS		CCR	
	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic
LnURP	1.0069***	6.5655	0.5865***	3.5237	0.5903***	3.8073
lnGDP	-0.7384***	-3.1483	-0.5046*	-1.7087	-0.5031*	-2.5789
lnEDU	0.8695***	5.2444	0.5163**	2.0821	0.5230*	2.2158
lnIND	0.1480**	2.4026	0.2600***	2.733	0.2570**	3.5861
Constant	-1.7359	-0.6172	-0.9357	-0.2629	-0.9962	-0.2865

***, ** and *denotes 1%, 5% and 10% level of significance respectively.

elasticities of almost all the explanatory variables are seen to be influenced by the indicator used to measure electricity consumption as well as the estimator.

A critical analysis of the results shows that with the exception of income which negatively affects electricity consumption, all the other variables exert positive effect on Benin's electricity consumption. Specifically, population is seen to have the greatest effect with a coefficient of about 2.3. An increase in the country's population by 1% will lead to about 2.2-2.4% increase in its total electricity consumption.

The positive effect of population on electricity consumption reported in this study can be explained by the fact that people rely on electricity for many domestic activities like cooking, washing and learning, and therefore as the country witnesses population growth, it is rational to expect a rise in electricity usage. Benin's population appears to have increased over the years. For instance, the population of Benin as of 1960 stood at 2,431,622 and in 1971 it was 2,976,572. By 2013 the upward growth trend saw the country's population at over 10million people. The upward trend follows a similar pattern with the level of electricity consumption [1]. One can deduce that since population growth increases demand for the provision of goods and services that rely on electricity there will also be an appreciable increase in the level of electricity usage. In his study on energy consumption, Keho [21] records a positive effect of population on energy consumption for Benin and other countries in Africa. Zaman et al., [14] and Ekpo et al., [15] also report of similar effect of population on Pakistan's and Nigeria's electricity consumption. Thus, the outcome supports Keho [21], Zaman et al., [14] and Ekpo et al., [15].

Urbanisation is also found to increase electricity consumption. The literature indicates there are two opposing thoughts on the effects of urbanisation on energy consumption. One school of thought is that growth in urbanisation implies a concentration of economic activities and also a change in lifestyle and consumption patterns of urban dwellers. This is because they tend to acquire intensive energy products such as air conditioners and refrigerators (see Elliott et al, [47]) and hence an increase in electricity usage. On the other hand, the lack of space, Jones [48] and the high cost of living and production at the urban centre leads to the adaption of innovation and technology that reduces energy consumption. In this study, the effect of urbanisation is in line with the first school of thought that argues an increase in urban population increases electricity consumption. Empirically, the finding from this study is consistent with Holtedahl and Joutz [30] for Taiwan, Khobai and Roux [35] for South Africa, and Adom and Bekoe [13] for Ghana.

Comparing the two demographic variables it is seen that the effect of population is greater that urbanization. This tend to fall in line with the conclusion Kwakwa [41] has drawn that when it comes to the application of STIRPAT model, the population variable is reported to have the greatest effect on environment. The implication is that although both population and urbanisation positively affect electricity consumption, population growth has a greater effect. This can be attributed to the fact that the population growth includes growth in urban population and non-urban population. Therefore, the positive urbanisation effect on electricity consumption may reinforce the positive effect non-urban population will have on electricity consumption.

The estimated results also show that income's effect is negative on electricity consumption irrespective of the measurement used as the dependent variable. Its magnitude implies a 1% increase in the GDP level of Benin will reduce electricity consumption by about 0.5% to 1.5%. This outcome is contrary to the positive relationship between income and normal good and the many energy consumption studies including Kwakwa [49], Alawin et al., [33], Adom [24] and Ekpo et al [15] that have reported of a positive relationship between income and electricity consumption. However, the fact that income reduces electricity consumption for Benin compares favorably with Keho [21] who reports that income reduces energy consumption in Benin. Kwakwa et al., [54] have argued that the unreliable or unpredictable nature of electricity power supply in a country may cause individuals to switch to alternative source of energy as their income increase. However, the finding from this study and Keho [21] seem to invalidate such assertion for Benin. Thus, the outcome therefore can be related to the idea that an increase in income places citizens in a better position to afford energy efficient gadgets (that are relatively expensive) and hence electricity consumption is likely to reduce.

The effect of industrialisation on both aggregate electricity consumption and per capita electricity consumption is recorded to be positive. The results indicate that an increase in the industrial value added by 1% will increase electricity consumption by about 0.16-0.26%. This outcome is expected since the industrial sector relies on electricity as an input to function effectively. In many countries the industrial sector has been badly affected by periods of power fluctuations and load shedding. For instance in Ghana, following the electricity power rationing in 2007 the manufacturing sub-sector of the industrial sector recorded a negative growth rate of 2.3% [56]. Compared to previous studies, Kwakwa [49] records a positive effect of industrialisation on electricity consumption for Egypt, and Adom and Bekoe [13] record similar outcome for Ghana. Keho [21] investigation on energy consumption for Benin also reveals that industrialisation positively affects energy consumption.

Education is also noted to have a positive and significant effect on electricity consumption for Benin. Comparing the coefficients of the variables in the model, education exerts the second greatest impact on electricity consumption for the country. This positive coefficient confirms Inglesi-Lotz and Morales [23] as-

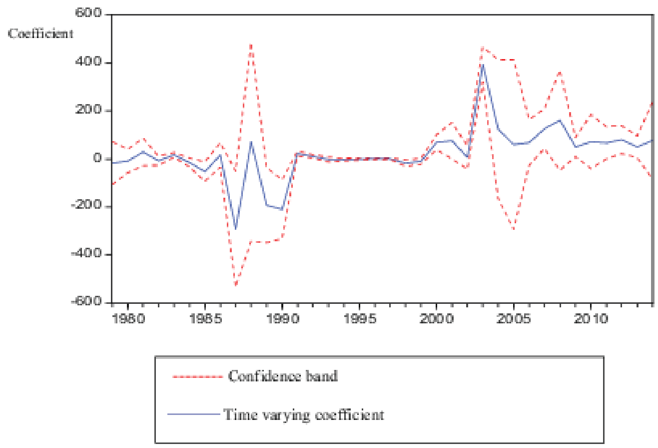

Fig. 1. Time varying coefficient of population for aggregate electricity consumption

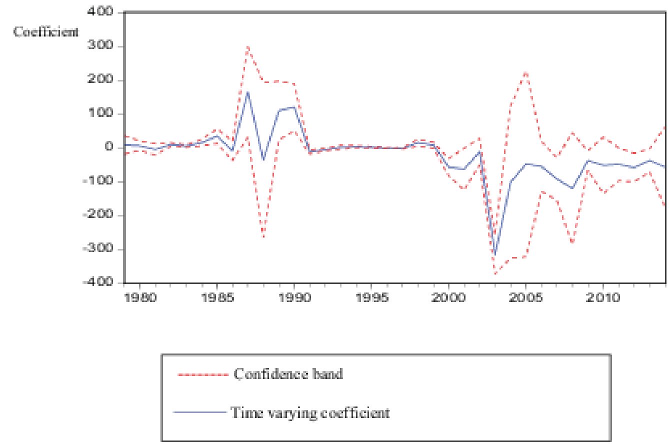

Fig. 2. Time varying coefficient of urbanisation for aggregate electricity consumption

sertion that education increases energy consumption for poor countries. That is, following an improvement in the production process through education, poor countries attempt to produce more and catch up with the advanced countries will lead to more energy usage. Such an experience is similar to the rebound effect of energy consumption after efficient method of production is adapted. The Benin's case can be linked to the above explanation and it is similar to the outcome recorded by Kwakwa [49] for Egypt.

C. Time-varying demand elasticities

In this section, the study examines the time-varying behaviour of electricity demand elasticities for Benin by analyzing the pattern of the coefficients of the explanatory variables used for the regression and relating the coefficients to certain local economic, political and social changes the country has witnessed as well international shocks that might have influenced the level of electricity consumption.

C.1. Time-varying population elasticity

The coefficient for population as seen from Fig. 1 generally portrays an undulating feature within the period for the study. It is seen that it started to increase from 1979 to 1981 after which it fell in 1982 and then picked up the following year and fell again. From 1984 to 1985, and 1988 to 1990 the impact of the population on electricity consumption saw great reductions from positive values to around -300 and -180 respectively. From 2003 to 2005, there was another reduction from around 400 to10. Then from 1987 to 1988 its positive effect increased and although it reduced in 1989, there was an increment in 1990 to 1991. Thereafter, it remained relatively stable between -10 and 10 until 2000 where it increased to reach around 70. The greatest effect is seen from the period 2002-2003 where it rose from around -10 to around 400. From 2009 to 2014 one sees the impact to be relatively stable. All these go to indicate that the coefficient of population's effect on electricity consumption has not been constant but rather it has been shifting poles and these changes can be attributed to some significant changes. For instance, the fall in the coefficient of population between 2002 and 2005 can be linked to the fall in country's population growth from 3.04% to 2.95%. The plot of the evolution of the population coefficients for the 36 rolling periods as shown in Figure 1 are well within the two confidence interval bands.

C.2. Time-varying urbanisation elasticity

The coefficient of urbanisation has not been constant for the study period. The positive effect of urbanisation on total electricity consumption increased to 10 in 1980, but fell slightly to less than 0 in 1981. From 1981 it increased to 20 in 1985, fell the following year but quickly increased to around 180 in 1987. It however fell to -50 the following year. Although it picked up from 1988 to around 100 in 1990 it fell to around -8 after which the effect remained stable till 1998. In the year 2002 to 2003 there was a sharp decline to about -300 but increased gradually till 2005. However, the increment was predominantly less positive and remained less positive from 2009 to 2014 (see Figure 2). With regards to the per capita electricity consumption, the effect gradually increased from 1979 to 1983 where it fell from 9 to around 0 in 1986. From the 1986 to 2003 the effect through a rise and fall declined gradually to around -7. It however increased to around 6 four years later after which its impact was less positive (see Figure 3).

Socio-economic changes can explain some of these fluctuations seen in the coefficient of urbanization. For instance, the positive effect of urbanisation on electricity consumption from 2003 to 2005 can be attributed to a possible rural-urban migration that followed the implementation of a poverty reduction programme which led to a reduction in urban poverty more than rural poverty [50]. The reduction effect from 2007 to 2008 is seen to have coincided with the global financial crises. It seen from Figs 2 and 3 that, the evolutions of the urbanisation coefficients are within the confidence interval bands.

C.3. Time-varying income elasticity

The negative effect of income on electricity consumption was felt most from 1979 to 1981, 1987 to 1990 and from 2004 to 2007 for total electricity consumption (Figure 4). For per capita electricity consumption, the greatest negative impact was from 1983 to 1985, 1986-1988 and 2005 to 2007. Between 1990 and 2001 one can witness that generally there was a gradual increase in the electricity consumption effect of income as the coefficient increases from around -5 to 8 for total electricity consumption and from -1.8 to 3.7 for per capita electricity consumption (Figure 5). This period coincided with the 10 year structural adjustment programme of the country. In their assessment report of the programme, the ADB [50] concludes that the 10 year structural

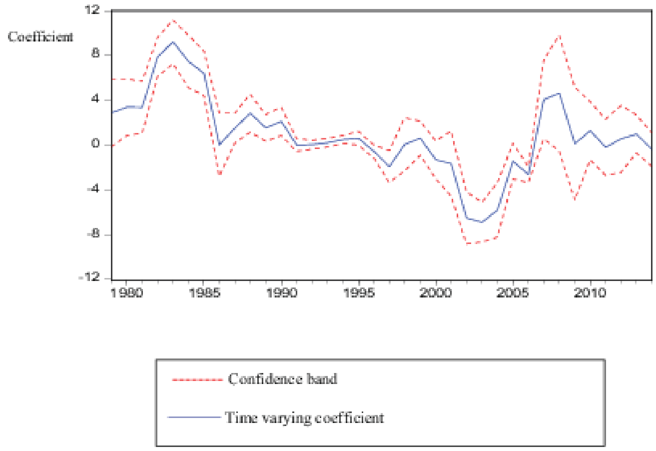

Fig. 3. Time varying coefficient of urbanisation for per capita electricity consumption

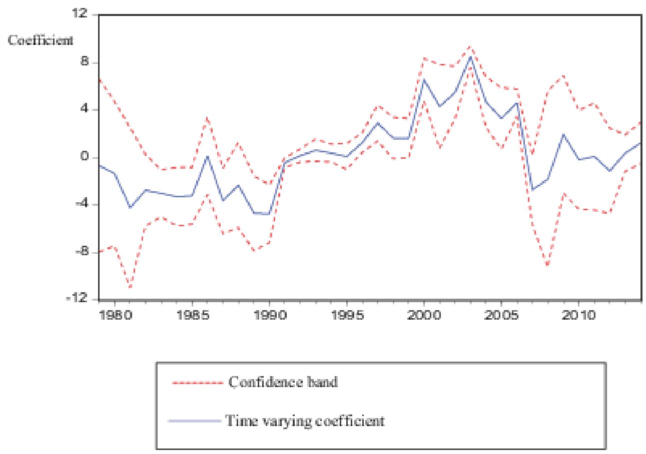

Fig. 4. Time varying coefficient of income for aggregate electricity consumption

adjustment programme led to positive macroeconomic results but that did not translate into better income distribution and led to widespread poverty. Thus, households could not afford energy efficient gadgets. However, from 2004 when the country underwent the Poverty Reduction Strategy Support Programme (PRSSP), poverty level reduced and that helped in the acquisition of energy efficient gadgets hence, a reduction in electricity consumption after 2003. From 2007 to 2009 where income increased electricity consumption can also be attributed to the global financial crises which affected the country's economic growth negatively and hence citizens could not afford efficient electrical gadgets. After the crisis, increases in income led to a fall in electricity consumption. From the Figs 4 and 5 the plot of the evolution of the income coefficients for the rolling periods lies within the two confidence interval bands.

C.4. Time-varying education elasticity

The coefficient of education for total electricity consumption saw a declining trend from 1979 to 1983 where its positive effect later picked up from -14.5 to 3 in 1986. Between 1986 and 1992 there were sharp fluctuations on its positive effect. However its positive effect ranged between around 3 to 0 and thereafter the

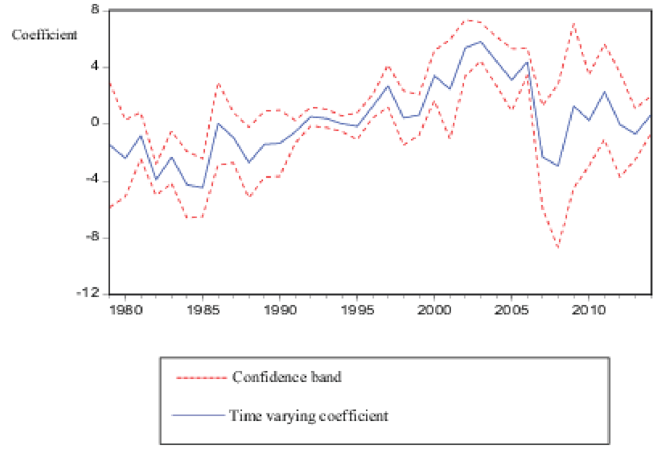

Fig. 5. Time varying coefficient of income for per capita electricity consumption

coefficient remained almost zero till 1997. From the year 2002 to 2014 the effect depicted cyclical variation (Figure 6). For the per capita electricity consumption the coefficient of education fell from -2 in 1979 to around -9.9 in 1983. From 1983 its positive effect was felt as it increased to 2 in 1986. There was a declining effect from 1987 to 1999 after which it also exhibited cyclical variation (Figure 7). The negative effect of education on electricity consumption from 1979 to 1983 could be attributed to the fact that the educational reform in 1975 introduced to among other things adapt to local conditions did help improve the quality of students as the literacy rate increased at this period [51]. However, between 1983 and 1985 the benefit from this educational was marred by the frequent political and social crisis [51] and that could account for the positive effect of education on electricity consumption between the period. The implementation of the structural adjustment programme in the 1990s seems to have caused education exert an insignificant effect on electricity consumption. The fluctuations in the effect of education between 2000 and 2005 can be explained by the frequent strikes actions that characterized the educational sector such that schools had to officially operate on Mondays and Fridays in periods where strike actions where intensive [52]. The plot of the evolution of the education coefficients for the 36 rolling periods as shown in Figs 6 and 7 are well within the confidence interval bands. However, the coefficients have not been constant.

C.5. Time-varying industrialisation elasticity

From Fig. 8, the positive industrial effect on total electricity consumption remained around 0.3 from 1979 to 1980, and fell to almost 0 in 1981 after which it increased to 0.6 in 1983. The period 1983-1986 saw another reduction in its effect as it got to almost -3. From 1986 it picked up sharply and reached 0.4 in 1991 after which one sees a cyclical variation in the coefficient. The behavior of the effect of industrialisation on per capita electricity consumption as seen from Fig. 9 is similar to that of the total consumption except that the positive effect reached as high as 0.6 in 1992 and the declining effect reached as low as -3.2 in 1986. The improvement in industry efficiency in terms of electricity usage from 2003 to 2005 can be linked to the poverty reduction strategy implemented which stimulated economic growth and reduced poverty. The effect was industries' ability to invest in energy efficient technologies. However, from 2007 to 2008

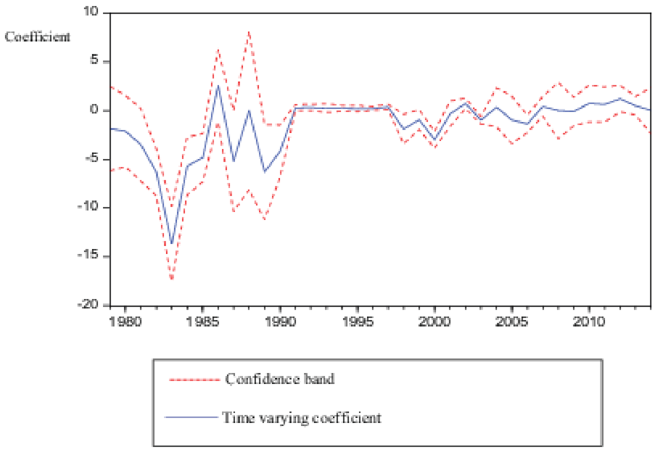

Fig. 6. Time varying coefficient of education for aggregate electricity consumption

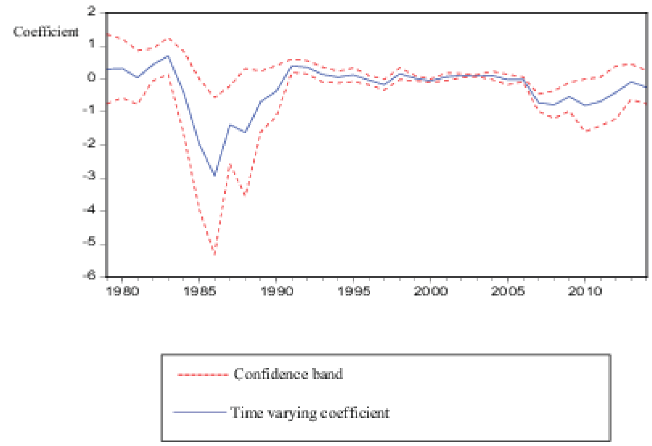

Fig. 8. Time varying coefficient of industrialisation for aggregate electricity consumption

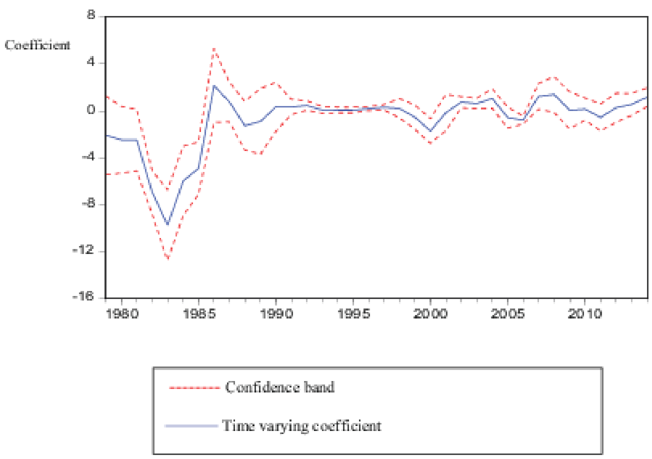

Fig. 7. Time varying coefficient of education for per capita electricity consumption

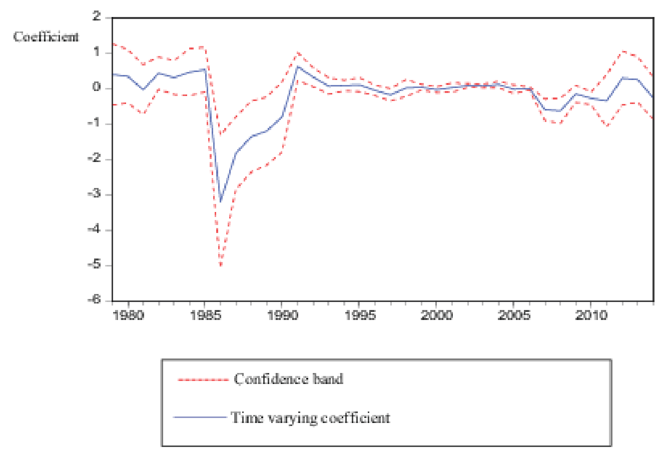

Fig. 9. Time varying coefficient of industrialisation for per capita electricity consumption

when the global financial crises occurred, it badly affected the economy and firms could not sustain their investment in efficient technologies. The evolutions of the industrialisation coefficients for the 36 rolling periods are seen to be within the two confidence interval bands.

5. CONCLUSIONS AND POLICY RECOMMENDATIONS

For many years, the Republic of Benin has relied on electricity supply from Ghana, Nigeria and Ivory Coast to meet its electricity demand. This has made the country very susceptible to the electric power fluctuations in these countries. The current policy to promote economic transformation in Benin will increase the electricity consumption and that is likely to worsen the already shortfall in electricity supply. The above situation calls for the need to manage the level of electricity consumption by identifying the drivers of electricity consumption for the country. Consequently, this study analyzed the determinants of electricity consumption within the STIRPAT framework for Benin using annual time series data for the 1971-2014 period. The ARDL, FMOLS and CCR estimates of the long-run effects reveals that Benin's electricity consumption is positively affected by population, urbanization, education and industrialisation but negatively related to income. Again the demographic variables were found to exert the greatest impact on electricity consumption.

A further analysis using the rolling regression estimates shows that the drivers of electricity consumption are not time-invariant. Thus, there were constant shifting of poles for the 36 rolling periods and those shifts related with major local and/or global political, social, and economic changes. For instance, the coefficient of urbanisation increased from 1979 to 1980 but reduced again the following year. It began to increase again from 1981 to 1985. Although it later fell, there was an increment from 2003 to 2005. Two years later, there was another decline in the coefficient. The positive effect of urbanisation on electricity consumption from 2003 to 2005 can be attributed to a possible rural-urban migration that followed the implementation of a poverty reduction programme which led to a reduction in urban poverty more than rural poverty. Also, the reduction from 2007 to 2008 correlate well with global financial crises at that period.

The income variable is seen to reduce electricity consumption in the 1979-1981, 1987-1990 and 2004-2007 periods but increased electricity consumption from 1990 to 2001 and 2007 to

2009. Between 2003-2007 where income is seen to reduce electricity consumption it can also relate with the period the country embarked upon the Poverty Reduction Strategy Support Programme (PRSSP) that reduced poverty level and helped citizens in the acquisition of energy efficient gadgets. However, from 2007 to 2009 where income increased electricity consumption it can also be attributed to the global financial crises which affected the country's economic growth negatively and hence citizens could not afford efficient electrical gadgets.

Also, from 1979 to 1983 where education reduced electricity consumption it could be attributed to the 1975 educational reform that increased the literacy rate at the period. However, political and social crises between 1983 and 1985 reversed the trend. Again, the fluctuations in the effect of education between 2000 and 2005 can be explained by the frequent strikes actions that characterized the educational sector such that schools had to officially operate on Mondays and Fridays. With regards to industrialization, its effect increased from 1981 to 1983 but fell until 1986. From 2003 to 2005 there was an improvement in industry efficiency in terms of electricity usage which can be linked to the poverty reduction strategy which stimulated economic growth thereby enabling industries to invest in efficient technologies. However, from 2007 to 2008 when the global financial crises occurred it reversed the trend. Based on above findings the paper makes a number of policy recommendations. First, with an expected growth in the country's population in the future it is essential that a stricter ban is imposed on the importation of inefficient electronic goods. For electronic goods that are produced locally for the growing population, high quality standard must be enforced. Second, the results reveal electricity consumption increases with urbanisation and so it is necessary to make energy efficient appliances readily available and relatively affordable for urban households and corporate bodies to access. Because the urban cities are attractive to businesses and corporate bodies that also pull many people to such centres it is necessary that a policy is put in place to ensure that new office buildings and residential buildings to be constructed are designed to be energy-efficient. If the existing buildings can easily be renovated to make them more environmentally friendly then that should be enforced by the state authorities.

Next, education is seen to generally increase electricity consumption for Benin. This suggests that attempts to increase educational levels in the country will increase electricity consumption. The implication is that traditional education may not be enough to help reduce electricity consumption. In this regard, it is expedient to use educational campaign to create awareness on energy-environment issues alongside traditional education as Inglesi-Lotz and Morales [23] have opined. Policies to attain economic growth should be aggressively pursued to help place citizens in a better position to afford efficient electrical goods. Also, efforts to reduce the level of industrial electricity usage should gear towards making the industrial sector more energy efficient. This can be achieved by ensuring firms resort to the usage of efficient electrical technology in their production activities. It is important to note that the implementation of these suggested guidelines should be mindful of certain political, economical and social changes.

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