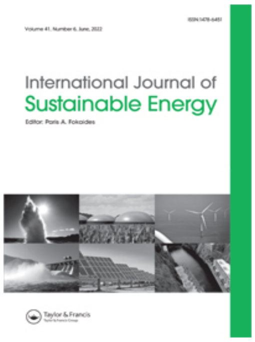

International Journal of Sustainable Energy

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/gsol20

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To cite this article: Frank Adusah-Poku, John Bosco Dramani & Kwame Adjei-Mantey (2022) Determinants of electricity demand in Ghana: the role of power crises, International Journal of Sustainable Energy, 41:6, 699-712, DOI: 10.1080/14786451.2021.1974440

To link to this article: https://doi.org/10.1080/14786451.2021.1974440

INTERNATIONAL JOURNAL OF SUSTAINABLE ENERGY
2022, VOL. 41, NO. 6, 699–712
https://doi.org/10.1080/14786451.2021.1974440

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Determinants of electricity demand in Ghana: the role of power crises

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ABSTRACT

The crucial role of electricity in prosecuting the development agenda of economies is widely known. Yet some key variables are lacking in the assessment of electricity demand determinants. One such variable is power crises. This study re-visits the discussion by investigating the role of power crises on electricity demand. We employ data from 1980 to 2018 to examine how power crises in general and in particular the 2012–2015 severe power crisis in Ghana impacts electricity consumption. Using various econometric techniques, we find that power crises have adverse effects on electricity demand in the long run. The 2012–2015 episode of power crisis in particular, has potentially led to consumers reconsidering their sources of energy by reducing electricity demand in the long term.

ARTICLE HISTORY
Received 10 May 2021
Accepted 24 August 2021

KEYWORDS
Ghana; electricity; demand; power crisis; ARDL Bounds cointegration

1. Introduction

Electricity is described as a life-changing innovation invented by man. Electricity is required for lighting, cooking and heating, transportation and production of goods and services to satisfy human wants. Demand for electricity resource in Ghana more often than not exceeds the supply just like in many developing countries in sub-Sahara Africa. Over the past two decades, the inadequate supply of electricity has been attributed to multiple factors. Erratic supply of gas from Nigeria to Ghana through the West Africa Gas Pipeline combined with insufficient storage facilities to power electricity generation gas plants have not permitted sufficient electricity production to accommodate demand (Mensah, Marbuah, and Amoah 2016). In addition, poor investment commitment in the sector on the part of the utilities and government has over the years, rendered the utilities incapable of upgrading their generation, transmission and distribution networks for efficient provision of electricity services (Adom 2017) as well as growing financial deficit documented by the public utility companies due to low electricity tariff and high electricity theft. However, in recent years, significant strides have been made to raise the generation and dependable capacity to improve supply of electricity. For instance, between 2000 and 2019, installed generation capacity surged from 1652 MW to 5172 MW, denoting a yearly mean growth rate of 6.2% whereas, dependable capacity grew from 1358 MW to 4695 MW in the same period (Energy Commission 2019).

The demand for electricity, however, continues to grow, averaging between 10% and 15% per annum for the past decades. The growing demand for electricity has been attributed to significant population growth leading to increased urbanisation, technology, growing per capita income, structural change of the economy, government policy of providing subsidies to Ghanaians, and rural

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electrification drive of government (Adom, Bekoe, and Akoena 2012; Adom and Bekoe 2012; Dramani, Francis, and Tewari 2012; Mensah, Marbuah, and Amoah 2016; Adom 2017). The consequences are that the gap between electricity supply and demand has grown substantially leading to a significant number of extreme peak load demand in Ghana. Peak electricity demand rose by 50% from 1393 MW to 2087 MW between 2006 and 2016 (Energy Commission 2019). In addition, the system is highly vulnerable to additions of new customers and thus exhibits high frequency of power crisis leading to power failures and shedding of load by utilities. This has put relevant institutions and firms such as hospitals, sewage treatment plants and mining and telecommunication companies at great risk and compelled them to acquire standby generators, leading to increased cost of service delivery and production.

To address the negative consequences that usually emerge due to electricity shortage, government in addition to capacity expansion, has aggressively enacted and modified a number of policies to enhance demand-side management of electricity. For the residential, commercial and industrial end-users, the government put in measures such as giving out free compact florescent lamps, introduction of electricity efficiency rating and labelling system, raising electricity tariff periodically, refrigerator exchange programme, regulations, education on the use of automatic capacitor banks and appliance standardisation. This holistic approach seeks to tackle demand management problems for both short and long terms.

According to Adom (2017), significant attention has been given to electricity demand management relative to supply policies due to its low-cost efficiency to ensure stability in electricity systems. Based on this, electricity consumption efficiency measures are central to global energy conservation and climate change agenda. In 2019, an amount of US$250 billion was spent to improve energy efficiency in transportation, industrial sector and buildings in an effort to reduce energy intensity (International Energy Agency [IEA] 2020). In addition, before the onset of the 2012–2015 power crisis, the average end-user tariff of electricity was GHS/kWh 0.232 in the first quarter of 2012 but by the beginning of 2016 the tariff had risen to GHS/kwh 0.817, representing about 71% (Energy Commission 2019). Even though the Public Utility Regulatory Commission justified the hike on the grounds that it will assist government in addressing the power crisis bedeviling the country, it resulted in a strong protest by consumers groups as well as organised labour who pushed for a 50% rise in salary to ameliorate the effects of the hike in electricity tariff. Based on the reaction of the consumer groups, the hike in the average end-user tariff may have had a significant effect on the consumption of electricity. However, most economic agents could not access readily available alternative sources of energy such as solar because the initial up-front costs were more expensive relative to electricity. To make informed decisions on the continuity of electricity demand management measures, empirical evidence on the driving forces of electricity demand is relevant. Provision of empirical evidence on the magnitude of effect of the relevant determinants of electricity demand can induce accurate future prediction of electricity requirements of Ghanaians and introducing appropriate measures to accomplish them.

In parallel, the enormous consideration toward energy efficiency issues has ignited renewed research interest in investigating factors driving electricity demand. Adom, Bekoe, and Akoena (2012), Adom and Bekoe (2012), Dramani, Francis, and Tewari (2012) and Mensah, Marbuah, and Amoah (2016) disclosed that economic activity, urban growth, structural change and income exerted weighty effects on electricity use in Ghana relative to efficiency issues. Similarly, Adom and Bekoe (2013) and Adom (2013) asserted that episodes of policy regime changes and technological adoption after the introduction of reform are positive drivers of electricity use while adoption of technology before a reform has an electricity consumption-reduction effect. Adom (2017), established that the connection between electricity tariff and demand is an inverted U-shape with an indication that end-users can afford electricity tariff hike up to a certain point but beyond which demand will fall to zero. This implies electricity tariff is an important determinant of demand. Kim (2018) detected that the amount of electricity-drawing equipment is a relevant force behind electricity usage while Fuerst et al. (2020) ascribed growing electricity usage to household socioeconomic and dwelling characteristics. However, the prior studies have overlooked the examination of the drivers of electricity demand in the presence of episodes of electricity crisis.

This study endeavours to seal the identified gap in the literature by offering an understanding of the drivers of electricity demand in Ghana. Against this background, we make several contributions to the prior studies. First, we examine the determinants of electricity demand in Ghana taking into consideration the effect of power crises[1] on demand. Second, we investigate the impact of the 2012–2015 power crisis on electricity demand in Ghana. Between 2012 and 2015, Ghana experienced an excruciating and protracted power crisis which led to the introduction of unprecedented power rationing by the utilities. At the peak of the rationing, customers were provided with an average of 12.5 hours of electricity every three days (Abeberese, Ackah, and Asuming 2017). This affected demand for electricity as the unsatisfied portion widened and increased the cost of electricity consumption among households and firms since alternative sources of unclean and expensive energy surged. Though the 2012–2015 power crisis has been pronounced the severest to have hit Ghana in recent times, empirical evidence on its effect on electricity demand is non-existent.

The remainder of the study is planned as follows. Section 2 sets out and reviews the important prior studies. Following the review of important past studies, we select and discuss the empirical model and estimation strategies in Section 3. In addition, we present the results in Section 4 and subsequently make the conclusion and outline the policy implications in Section 5.

2. Literature review

Electricity usage influences households and firms in many ways. Households demand electricity for lighting which enhances educational outcome, setting new businesses and for the production of services such as pumping water and accelerating the pace in cooking healthy food. Electricity usage also helps in reallocating time between the day and night which increases the supply of labour time available for work. Among firms, electricity serves as an important input which accelerates the pace of production.

The literature on the forces driving electricity demand can be categorised into various strands. The first strand of the literature focuses on time series and panel framework data and techniques to estimate the determinants of electricity demand. Adom, Bekoe, and Akoena (2012), Dramani, Francis, and Tewari (2012), Adom (2013), Adom and Bekoe (2013), and Adom (2017) used time-series data and techniques such as partial adjustment model (PAM), Autoregressive Distributed Lag (ARDL) model, Vector Autoregression (VAR) and Vector Error Correction Model (VECM) to estimate the determinants of electricity demand in Ghana. The authors disclosed that changing structure of the economy, output, urban growth, tariff and technology account for the variations in electricity usage in Ghana. Furthermore, the results showed that tariff deregulation promotes electricity usage in a manner that improved electricity conservation. In terms of panel framework, Hung and Huang (2015) studied the variations in residential electricity demand applying a panel data of monthly frequency spanning 2007:month1 to 2013:month12 for 19 provinces in Taiwan. The authors revealed that price elasticity of demand and the coefficient of adjustment for electricity in summer are relatively smaller than those in non-summer periods. This is because high temperatures during summer make consumers relatively irresponsive to changes in electricity price to the non-summer seasons when temperatures are low. In addition, income elasticity was revealed to be less than zero in both short and long run, implying electricity is a necessity for the people in the selected provinces.

Another strand of the literature concentrates on the application of cross-sectional and survey data to examine the determinants of electricity demand. Bedir, Hasselaar, and Itard (2013), Kim (2018) applied household data to analyse factors that affect electricity demand. The authors revealed that the utilisation of appliances, number of times a person stays in a hobby or study room, household size and dwelling type accounted for a weighty amount of electricity demand. Early on, Reiss and White (2005) disclosed that a relatively small proportion of households accounted for a huge variation in electricity demand through price variations. Furthermore, the authors established the presence of varied distributional effects of changes in tariff structure on different households' electricity demand and this has been debated over the years. In addition, Halvorsen and Larsen (2001), found that long-run price elasticity of electricity demand was a little bigger than the short run in the presence of appliance stock. The authors ascribed this minute difference between the short and long-run price elasticity of demand to the lack of electricity substitutes for electrical appliances. Deryugina, MacKay, and Reif (2020) examined the driving forces of residential electricity demand for 250 communities in Illinois using difference-in-difference matching estimator and discovered that price elasticity of demand grew from −0.09 to about −0.27 within a time span of 6 to 24 months. The authors suggested the relevance of capturing changes in electricity consumption in fashioning energy policy.

The literature has also delved into the causal connection between electricity demand and economic growth. However, the findings of these studies are mixed. Mahfoudh and Amar (2014), Bouznit, Pablo-Romero, and Sánchez-Braza (2018) established that changes in GDP had a causal impact on electricity consumption in Africa. Based on this finding, the authors pushed for the adoption of policies that will improve electricity supply to meet demand. However, Altinay and Karagol (2005), Shengfeng (2012), Burke, Stern, and Bruns (2018) and Ali et al. (2020) detected that electricity usage and access Granger causes variations in income and economic development. The authors pushed for policies aimed at increasing the supply of electricity for industrial expansion to engender economic growth.

Finally, the extant studies have explored how power crises have impacted the performance of firms and well-being of households. For instance, Donatos and Mergos (1989) found that electricity utilisation patterns are likely to differ as a result of changes in price and income after the power crisis, however, the parameters driving this demand usually remain the same for households.

Further, Lodhi and Malik (2013), through the application of survey data proved that electricity crises impaired the daily activities of households in Pakistan. Among other things, the authors found ineffective learning, inability to complete responsibilities, insomnia, application of inefficient, and costly electricity substitutes by households as negative consequences of electricity load shedding. In conclusion, the authors indicated that electricity shortage changes the lifestyles of people notwithstanding their occupation. In term of firms, Allcott, Collard-Wexler, and O'Connell (2016) disclosed that power outages reduced the output of manufacturing firms by 5% in India and raised self-generation cost by 0.5%. Alby, Dethier, and Straub (2013) early on, applied the World Bank Enterprise Survey database to assess the effect of power crisis on firm behaviour and output. The authors detected that electricity constraints compelled firms to make a difficult decision of choosing between acquisition of backup generators or efficient electricity-drawing equipment which entails huge initial capital investment. Thus, small-size firms that are unable to access financial resources from the market to acquire such backup generators or efficient technologies are squeezed out of business.

Worthy of stating from the literature review is the absence of empirical studies which explored the effect of power crises on electricity demand. Thus, employing time series techniques such as ARDL bound, fully modified ordinary least squares (FMOLS) and the Partial adjustment model (PAM), we re-analyse the driving forces of electricity demand in Ghana taking into consideration power crises.

3. Data and methodology

3.1. Theoretical and empirical modelling

The theoretical model for this study is based on the traditional theory of demand. We consider electricity demand as a commodity that electricity consumers in a particular country choose from a pool of other forms of energy. Electricity demand is also considered as an indirect form of energy as it is generally demanded for the satisfaction an electricity consumer derives from its use. Following from the traditional theory of demand, electricity demand as a commodity is assumed to be determined mainly by price and income. Mathematically, this is expressed in Equation (1) as:

$$ED_t = \beta_0 + \beta_1 P_t + \beta_2 Y_t \tag{1}$$

where ED_t is electricity demand at time t, P_t is electricity price, Y_t represents income, β_1 represents the coefficient of price and β_2 represents the coefficient of income. Based on the law of demand, electricity price usually has an inverse relationship with electricity demand since the lower price will induce consumers to increase their electricity consumption. However, income has a direct relationship with electricity demand with the assumption that electricity is a normal good. Based on empirical studies on electricity demand (Adom and Bekoe 2013; Adom 2017; Mensah, Marbuah, and Amoah 2016; Ubani 2013), Equation (1) is augmented to include other significant variables such as urbanisation and economic structure. More importantly, in addition to urbanisation and economic structure, the study adds two electricity power crises variables to the model. Consequently, Equation (1) is augmented to reflect the effect of urbanisation, economic structure and power crises on electricity demand in Ghana, expressed in Equations (2) and (3):

$$ED = f(P, Y, URB, ES, \ PC, PC\_2) \tag{2}$$

$$ED_t = f(P_t^{\beta_1}, Y_t^{\beta_2}, URB_t^{\beta_3}, ES_t^{\beta_4}, \ PC_t^{\beta_5}, \ PC\_2_t^{\beta_6}) \tag{3}$$

where ED represents electricity demand, Y represents income, URB represents urbanisation, ES represents economic structure of the economy, t is the time, PC and PC_2 are electricity power crises variables. ED is proxied by total electricity consumption in kilowatts per capita while Y is proxied by real GDP per capita. P is proxied by the average end-user tariff and URB is proxied by the total urban population. ES is measured by the ratio of the industrial sector valued added and the services sector valued added. Power crisis is proxied by two main variables: a binary variable that takes the value of 1 for years the country experienced power crisis and 0 otherwise (PC) and another binary variable that takes the value of 1 for the period 2012–2015 and 0 otherwise (PC_2). We single out the 2012–2015 power crisis as a separate dummy variable because of two main reasons. First, it's the longest power crisis period the country has experienced since her independence in 1957. Second, it is the latest and current electricity crisis in the past 6 years.

Equation (3) can be further expanded after introducing logarithms as:

$$InED_t = \beta_0 + \beta_1 InP_t + \beta_2 InY_t + \beta_3 InURB_t + \beta_4 InES_t + \beta_5 PC_t + \beta_6 PC\_2_t + \varepsilon_t \tag{4}$$

where ε is the independent and identically distributed error term.

Table 1 summarises the variables used in this study with their accompanying definitions.

Table 1. List of variable names and definitions.

Variable name	Definitions
Electricity demand (ED)	Total electricity consumption in kilowatts hours per capita
Income (Y)	Real GDP per capita in constant 2010 $US
Price (P)	Average end-user tariff (Ghana cedis per kilowatt hour)
Urbanisation (URB)	Total urban population
Economic Structure (ES)	Ratio of industrial sector valued added and services sector value added
Power crises (PC)	Power crises (binary taking the value of 1 for years in which Ghana experienced power crisis such as 1984, 1997–1998, 2007–2008 and 2012–2015, and 0, otherwise.
2012–2015 power crisis (PC_2)	Binary taking the value of 1 during the period 2012–2015, and 0, otherwise.

3.2. Sources of data

This study uses data from three main secondary sources. All variables with the exception of the power crises variables and electricity price variable were retrieved from the World Bank's World Development Indicators. Data on electricity price were retrieved from two sources: Electricity price data from 1980 to1990 were sourced from the Volta River Authority while data from 2000 to 2010 were sourced from the Energy Commission of Ghana. Data for this study covers 1980–2018. All nominal prices have been deflated to account for inflation to arrive at real prices using the consumer price index.

3.3. Estimation techniques

In an attempt to assess the impact of electricity power crises on electricity demand in Ghana, the study uses a three-step procedure. First, we ascertain the stationarity properties of our time series variables using two different unit root tests namely: the Augmented Dickey Fuller (ADF) test and the Zivot-Andrews unit root tests. Second, we examine the cointegration relationship to ascertain the long-run relationship between the dependent variable and the independent variables using the ARDL bounds cointegration test proposed by Pesaran, Shin, and Smith (2001). This cointegration test is selected over other traditional cointegration techniques because of several advantages such as its applicability to time series variables with a mixed order of integration. The ARDL Bounds cointegration test estimates the unrestricted error correction model (UECM) using the Ordinary Least Squares (OLS). The UECM which integrates the short run dynamics and the long-run equilibrium is expressed as:

$$
\begin{aligned}
&\Delta InED_t = \\
&\alpha_0 + \sum_{j=1}^{a} \lambda_{1j}\Delta InED_{t-j} + \sum_{j=0}^{b} \lambda_{2j}\Delta InP_{t-j} + \sum_{j=0}^{c} \lambda_{3j}\Delta InY_{t-j} + \sum_{j=0}^{d} \lambda_{4j}\Delta InURB_{t-j} + \\
&\sum_{j=0}^{e} \lambda_{5j}\Delta InES_{t-j} + \sum_{j=0}^{f} \lambda_{6j}\Delta PC_{t-j} + \sum_{j=1}^{g} \lambda_{7j}\Delta PS\_2_{t-j} + \delta_1 InED_{t-1} + \delta_2 InP_{t-1} + \\
&\delta_3 InY_{t-1} + \delta_4 InURB_{t-1} + \delta_5 InES_{t-1} + \delta_6 PC_{t-1} + \delta_7 PC\_2_{t-1} + \alpha_1 T + \mu_t
\end{aligned}
\tag{5}
$$

where *a, b, c, d, e, f* and *g* denote the lag length of the variables selected using the Akaike information criterion (AIC), Δ is the difference operator, μ_t is the normally distributed error term with zero mean and covariance. The short run dynamics are represented by the parameters λ_{1j}, λ_{2j}, λ_{3j}, λ_{4j}, λ_{5j}, λ_{6j}, λ_{7j} and the long-run equilibrium relationships are also represented by the parameters δ_1, δ_2, δ_3, δ_4, δ_5, δ_6 and δ_7. To examine the cointegrating relationship between the dependent variable and the independent variables, the joint significance of the coefficients of the lagged level variables are tested using the F-test as used in Pesaran, Shin, and Smith (2001). Consequently, the null hypothesis of no cointegration given as $H_0 = \delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = \delta_6 = \delta_7 = 0$ is tested against the alternative hypothesis of the existence of cointegration given as $H_1 = \delta_1 \neq \delta_2 \neq \delta_3 \neq \delta_4 \neq \delta_5 \neq \delta_6 \neq \delta_7 \neq 0$.

Third, the short run dynamics and long-run equilibrium relationships are obtained from the Error correction model (ECM) given in Equation (6) as:

$$
\begin{aligned}
&\Delta InED_t = \\
&\gamma_0 + \sum_{j=1}^{h} \gamma_{1j}\Delta InED_{t-j} + \sum_{j=0}^{i} \gamma_{2j}\Delta InP_{t-j} + \sum_{j=0}^{j} \gamma_{3j}\Delta InY_{t-j} + \sum_{j=0}^{k} \gamma_{4j}\Delta InURB_{t-j} + \\
&\sum_{j=0}^{l} \gamma_{5j}\Delta InES_{t-j} + \sum_{j=0}^{m} \gamma_{6j}\Delta PC_{t-j} + \sum_{j=1}^{n} \gamma_{7j}\Delta PS\_2_{t-j} + \rho ecm_{t-1} + \alpha_1 T + \mu_t
\end{aligned}
\tag{6}
$$

where *h, i, j, k, l, m* and *n* denote the lag length of the variables and the parameters γ_1, γ_2, γ_3, γ_4, γ_5, γ_6 and γ_7 are the short run dynamics with the parameter ρ being the speed of adjustment.

We also employ the FMOLS developed by Phillips and Hansen (1990) to support our long-run results from the ARDL framework. The FMOLS is known to perform better in the presence of serial correlation and endogeneity. To confirm our short-run results obtained from the ECM of our ARDL framework, we employ the Partial Adjustment Model (PAM).

4. Results and discussion

This section presents the main estimation results and a discussion of the results. The section is organised as follows: unit root test results; cointegration results, and long and short run analysis by the ARDL approach. Other results from FMOLS and PAM techniques are also presented as robustness checks with some diagnostics discussed at the end of the section.

4.1. Unit root tests

In the presence of non-stationary variables, regression estimates produce results which are spurious thus failing to capture the actual effects of explanatory variables on the explained variable. Additionally, the means and covariances of non-stationary series change overtime and hence shocks to the series could have permanent effects. To avoid this, it is important to test for the stationarity of variables to know their unit root properties before using them in regression estimations. Table 2 shows the results from ADF and the Zivot-Andrew unit root tests.

Under the ADF approach, with the exception of power crises (all periods) which was stationary at levels, all other variables were not stationary at levels. They however are stationary at first difference. In other words, these non-stationary variables have statistical properties which depend on time and the rate of change of the series over time is not constant. This could be due to purely random variations in the series. The stationary series, on the other hand, has time-independent or constant properties and the series tends to revert to its long-run mean even if there are short run deviations. Under the Zivot-Andrew approach, price, urbanisation and economic structure were not stationary at levels. They are stationary at first difference while other variables were stationary at levels. The use of the Zivot-Andrew approach to confirm stationarity properties of our data was due to the fact that the variables have structural breaks with different breakpoints for different series. Structural breaks are said to occur in the series when there is a sudden but permanent change in the underlying processes that produce the series. Otherwise stated, the nature of the relationships among the variables changes at the breakpoints. It is important to account for such changes in the

Table 2. Unit root tests.

Series	ADF	Zivot-Andrews Unit root test				
	Constant	Constant & Trend	Break in trend	Breakpoint	Break in intercept	Breakpoint
lnED	−2.561	−2.893	−4.612**	1992	−5.519***	2002
D(lnED)	−4.855***	−4.875***				
lnY	2.329	−3.622**	−6.564***	2004	−5.846***	2010
D(lnY)	−3.466***	−3.780**				
lnP	1.390	−0.432	−3.913	2010	−2.087	2012
D(lnP)	−4.205***	−4.596***	−4.607**	1997	−4.875**	2010
lnURB	−2.280	0.318	−2.778	2009	−2.297	2012
D(lnURB)	−4.391***	−5.086***	−5.654***	1987	−5.815***	2010
lnES	−0.887	−2.167	−2.419	2012	−3.353	2011
D(lnES)	−3.367**	−3.178*	−4.520*	2016	−5.046*	2013
PC	−4.084***	−4.132***	−4.597**	1990	−5.012**	2007
PC_2	−2.418	−2.593	−4.517**	2008	−8.350***	2012
D(PC_2)	−5.916***	−5.842***				

Note: ***, ** and * denote 1%, 5% and 10% levels of significance respectively.

series in order for inferences made on the basis of the relationship among the variables to be valid and accurate (Hansen 2001). Table 2 reports the points where structural breaks occur in the series. The Zivot-Andrew approach is robust in the presence of structural breakpoints in the series. Overall, we confirm stationarity of all series either at levels or at first difference and hence can be used in estimations without concerns about spurious relationships.

4.2. Cointegration

In this section, we examine whether a linear combination among the series is stationary or not by means of cointegration. Tests of cointegration show whether all the explanatory variables explain variations in the explained variable in the long run. We use the ARDL bounds testing approach due to the fact that the series are integrated of different orders. Results are presented in Table 3.

Under a null hypothesis of no cointegration and an alternative hypothesis of the existence of cointegration, the null hypothesis is rejected if the F-statistic is greater than the critical values of the upper bound, I(1). In both models – one with all years of power crises and the other with the 2012–2015 power crisis – we reject the null hypothesis since F-statistics of 7.63 and 6.83 respectively are greater than the upper bound I(1) critical values at 1% level of significance. Thus, we conclude that there is the existence of cointegration which is an indication that a linear combination among the series is stationary.

4.3. Long and short run estimations

Table 4 reports the results from long-run estimations on the determinants of electricity demand for both models. Our main goal is to examine the effect of power crises in general on electricity demand and particularly the effect of the 2012–2015 episode of power crisis experienced in Ghana. From Table 4, we observe that for power crises years over the period, electricity demand reduced by 31.4% while the effect of the 2012–2015 power crisis was a reduction in electricity demand by 27.6%. Hence, the experience of a power crisis reduces electricity demand by between 27% and 32%.[2] These margins are relatively huge considering the important role of electricity to households and firms and the associated spillover impacts on the economy. It affirms the findings of Donatos and Mergos (1989) which found that the period after energy crisis in Greece saw a structural change in the demand for electricity. Due to the adverse effects that power crisis has on households and firms, successive experiences of power crisis lead them to find long-term alternatives so as to reduce the impact of future power crises. As a result, long-term demand for electricity would tend to fall as economic agents become less and less dependent on electricity and this explains the long-term negative effect of power crises on demand.

A 1% increase in electricity price leads to a 0.11% reduction in electricity demand in the long-term but this effect is weakly significant and disappears when we consider the model with the 2012–2015 power crisis. This shows that demand for electricity is price inelastic contrary to the price elastic case observed in Greece (Donatos and Mergos 1989). While electricity demand tends to have an inverse relationship with price, the significance of this variable in determining electricity demand may be quite unstable. In addition, in years of excessive and continued power crisis, price is not an

Table 3. Results of ARDL Cointegration Test.

Model with all years of power crises F-stat = 7.634			Model with 2012–2015 power crisis F-stat = 6.832	
Significance	I(0) bound	I(1) bound	I(0) bound	I(1) bound
10%	2.26	3.35	2.26	3.35
5%	2.62	3.79	2.62	3.79
1%	3.41	4.68	3.41	4.68

Table 4. Long-run results (ARDL approach).

ARDL (1,1,1,0,1,0) selected based on Akaike Information Criteria				
Dependent variable is electricity consumption (log)				
Regressor	Coefficient	Standard error	Coefficient	Standard error
Income (log)	3.806***	0.217	4.062**	0.734
Price (log)	−0.109*	0.028	−0.020	0.109
Urbanisation (log)	4.996***	0.359	2.950*	1.002
Economic structure (log)	−1.052**	0.206	−0.356***	0.043
Power crises (All)	−0.273***	0.018		
Power crisis (2012–2015)			−0.244**	0.053
Intercept	−49.216**	5.173	36.904	16.219

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

important driver of electricity demand. This could be the case for a few reasons. First, the absence of electricity for a large part of the day (sometimes for up to 24 h as was the case in 2012–2015) means that electricity is available for very limited periods for which reason total electricity expenditure might well remain within households' electricity budget and hence price fails to influence its demand. Another explanation could be the fact that with electricity supply unavailable, reducing or increasing the price will have little or no effect on consumption since there is no supply to meet any changes in demand due to the crisis situation. Finally, in presence of electricity scarcity, demand is completely irresponsive to price because the price is usually set based on an administratively defined value known as the value of lost load (VoLL). This causes consumers to become indifferent between using power at the price set and not using electricity at all (Poletti 2013).

It is seen further, that a 1% increase in per capita income increases electricity consumption by a margin of 3.8%–4.1% in the long run. Economic growth thus is set to increase electricity consumption. This confirms electricity as a normal good with its positive response to income and agrees with the findings of Adom (2017), Mensah, Marbuah, and Amoah (2016), Adom (2013) and Adom, Bekoe, and Akoena (2012) all of whom examined the Ghanaian case but contrasts the findings of Kwakwa (2018) which examined the case for Benin. The findings also show electricity demand to be income elastic and to a large extent agrees with Adom (2017) and Bernstein and Madlener (2015) who found similar results for the industrial sector but income inelasticity was observed to be the case for residential demand (Adom 2017; Hung and Huang 2015). According to the World Bank, Ghana grew by 6.48% in 2019 and though growth in 2020 is expected to be lower due to shocks mostly originating from COVID-19, the overall growth trajectory for Ghana predicts a positive growth over the next couple of years. This implies that electricity demand is set to increase in Ghana and electricity policies must be designed to respond to it.

Similarly, urbanisation has a positive effect on electricity consumption with a 1% increase in urbanisation resulting in an increase in electricity demand of between 3% and 5% in the long run. This is consistent with the findings of Kwakwa (2018), Mensah, Marbuah, and Amoah (2016), Ubani (2013), Adom, Bekoe, and Akoena (2012) and Adom and Bekoe (2012). Urbanised residents tend to possess more household goods which are powered by electricity and hence their electricity demand is often high (Elliott, Sun, and Zhu 2014). Adom and Bekoe (2013), however, find an opposite effect. The authors explain that the period prior to Ghana's economic reform of the 1980s was characterised by severe economic hardships which could be responsible for a reduced demand for electricity.

The economic structure, measured as the ratio of industrial sector value added to the services sector value added has a negative and significant relationship with electricity demand in the long run. This means that as the size of the industrial sector increases relative to the services sector, electricity demand falls and vice versa. This agrees with the findings Adom (2013) who found a similar relationship between electricity demand and the economic structure but disagrees with Mensah, Marbuah, and Amoah (2016) and Adom and Bekoe (2013) who found that an increasing industrial share has a positive relationship with electricity demand. Our findings can be explained as follows:

Industries tend to suffer the most in the presence of power crises due to their heavy reliance on electricity for their activities. Ghana has an unpleasant history of power crises which have forced industries to bear severe negative consequences. Abeberese, Ackah, and Asuming (2017) report, for example, that manufacturing firms in Ghana suffered huge productivity losses of up to 10% due to the 2012–2015 power crisis and the coping mechanisms adopted by these firms were ineffective in mitigating the adverse impacts of the crisis. Such losses under power crises periods have led to industries opting for alternative power sources for their activities and reducing their reliance on the national grid to the extent possible. Industries might be resorting to alternative energy sources for production leading to this result. This adaptation behaviour, however, could have negative environmental implications if the alternative energy sources industries fall on are dirty energy. As such, there is the need to address how the economic structure reacts.

Table 5 presents the short run estimation results. It shows that in the short run, having a power crisis reduces electricity demand by 32.7% while the 2012–2015 power crisis reduced electricity demand by 18% in the short term. The results show that overall, the effect of a power crisis remains relatively consistent from the short term through the long term with a reduced effect on electricity consumption maintained at the 31%–33% threshold. However, focusing on the 2012–2015 power crisis, we note that the reducing effect on electricity demand increases from 18% in the short run to nearly 28% in the long run. The 2012–2015 electricity crisis was so severe and sustained for the longest period in the history of electricity crises to the point that it appears consumers decided to look for more permanent alternative solutions so they will not have to rely on the national grid any longer thus yielding a greater long-term impact. In the short term, a 1% increase in per capita income leads to a 3.7%–4% reduction in electricity demand while a 1% increase in price leads to a 0.15% reduction in electricity demand; an effect whose significance disappears when we consider the model with the 2012–2015 power crisis. Urbanisation increases electricity demand in the short term by between 5.6% and 6.7%. This is greater than the long-term effect suggesting an adjustment of electricity demand over time. This could be linked to the fact that new urban residents might increase electricity demand immediately but with time, high costs of urbanised living would force them to reduce household expenditures where possible and electricity demand could be affected leading to lower long-term impacts. In the short run, the economic structure has no significant effect on electricity demand when we consider the model with general power crisis; consistent with the findings of Adom and Bekoe (2012). This could be linked to consumers' expectation of the system to self-correct and restore electricity supply to normalcy within a short time hence only take stopgap measures to cope in the short term without adjusting their electricity demand structure. However, the model with the 2012–2015 power crisis show a significant short-term effect of the economic structure on electricity demand. A 1% increase in the industry value added to the services value added ratio leads to a 0.34% reduction in electricity demand in the short term. This confirms the peculiar case of the 2012–2015 power crisis and its severe impact on economic agents relative to other episodes of power crisis in history. The error correction term, measuring the short run adjustment to the long-run equilibrium, is estimated at 0.35 and 0.32 for both models

Table 5. Short run results (ARDL approach).

ARDL (1,1,1,0,1,0) selected based on Akaike Information Criteria (power crisis (All))				
Dependent variable is electricity consumption (log)				
Regressor	Coefficient	Standard error	Coefficient	Standard error
Income (log)	3.940***	0.162	3.650**	1.697
Price (log)	−0.150**	0.028	−0.231	0.233
Urbanisation (log)	6.737***	0.276	5.596*	2.911
Economic structure (log)	−0.321	0.126	−0.337***	0.070
Power crises (All)	−0.283***	0.019		
Power crisis (2012–2015)			−0.165*	0.084
ECM_{t-1}	−0.351**	0.136	−0.318***	0.044

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

respectively and this suggests that 32%–35% of every 1% deviation from the long-run electricity demand equilibrium is corrected yearly.

4.4. Robustness and diagnostics tests

Tables 6 and 7 present results by the FMOLS and PAM techniques for the long and short runs respectively. These have been used to test for the robustness of our main results. The FMOLS results confirm the signs and significance of our main results for the long run. The magnitudes of the coefficients are also similar. In the PAM technique for the short run, price is insignificant. This is consistent with our observation that price is not a very stable determinant of electricity demand with our main results finding it insignificant particularly in the model with 2012–2015 power crisis. Another key issue is the speed with which the long-run electricity demand equilibrium is corrected yearly. In the case of the ARDL model, we found that 32%–35% of every 1% deviation from the long-run electricity demand equilibrium is corrected yearly. In the case PAM, however, we find that 83%–87% of every 1% deviation from the long-run electricity demand is corrected yearly.[3] This suggests that the long-run electricity demand adjustment process in the case of PAM is much faster and quicker than in the case of the ARDL model.

Tables 8 and 9 present the diagnostic tests results for the ARDL and FMOLS models respectively. Our results have been subjected to the tests of serial correlation, normality, heteroscedasticity and stability to affirm the reliability of the results. From Table 8, the probability values of 0.511, 0.455, 0.546 and 0.391 for serial correlation, normality, heteroscedasticity and stability respectively for the model with all power crisis, imply that we do not reject the respective null hypotheses and conclude that errors are free from the problems of serial correlation, non-normality, heteroscedasticity and non-stability. We arrive at the same conclusions for the model with the 2012–2015 power crisis with probability values of 0.607, 0.826, 0.441 and 0.302, respectively. The test of normality in Table 9 confirms the normality test results in Table 8. We are therefore confident that our estimations are reliable and robust.

5. Conclusion and policy implications

This study examined the determinants of electricity demand in Ghana with focus on the impact of power crises on electricity consumption. The study examined the drivers of electricity demand under two power crises situations: (1) power crisis or otherwise over the entire duration of the study period, and (2) the 2012–2015 power crisis. The 2012–2015 power crisis is especially important for examination because it remains the most intense, protracted, severe episode of power crisis experienced in Ghana. We found that overall power crisis tends to reduce electricity demand in the long run by 27%–32%. We found that particularly in the case of the 2012–2015 power crisis, short run effects were smaller than long-run effects suggesting that the adverse impact of the crisis was so severe that economic agents did not respond only in the short term but also in the long term thus reducing their long-term reliance on electricity supply and resorting to alternatives. In the case of

Table 6. Long results using the FMOLS Approach.

	Dependent variable is electricity consumption (log)			
Regressor	Coefficient	Standard error	Coefficient	Standard error
Income (log)	2.953**	0.695	4.477***	0.690
Price (log)	−0.158**	0.011	−0.178**	0.084
Urbanisation (log)	4.197***	1.070	2.137***	0.536
Economic structure (log)	−0.643**	0.048	−0.845**	0.318
Power crises (All)	−0.297***	0.054		
Power crisis (2012–2015)			−0.277***	0.046
Intercept	−19.262	15.270	7.468	7.8894

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

Table 7. Short run results using the Partial Adjustment Model (PAM).

Dependent variable is electricity consumption (log)				
Regressor	Coefficient	Standard error	Coefficient	Standard error
Lag of elec. consumption (log)	0.130***	0.002	0.167***	0.008
Income (log)	3.095***	1.007	4.815**	1.543
Price (log)	−0.167	0.210	−0.178	0.185
Urbanisation (log)	1.670**	0.480	2.383*	1.007
Economic structure (log)	−0.692*	0.045	−0.858**	0.103
Power crises (All)	−0.154**	0.018		
Power crisis (2012–2015)			−0.287**	0.095

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

Table 8. Diagnostic test from the ARDL estimation.

Diagnostic	Test	Model with power crisis (All)	Model with power crisis (2012–2015)
Serial correlation	Breusch-Godfrey (F-stat)	0.487 (0.511)	0.290 (0.607)
Normality	Jarque-Bera	1.576 (0.455)	0.381 (0.826)
Heteroscedasticity	ARCH (chi-square test)	1.212 (0.546)	1.638 (0.441)
Stability	Ramsey RESET (F-stat)	1.290 (0.391)	1.590 (0.302)

Note: Probability in parenthesis.

Table 9. Diagnostic test from FMOLS estimation.

Diagnostic	Test	Model with power crisis (All)	Model with power crisis (2012–2015)
Normality	Jarque-Bera	3.982 (0.137)	0.615 (0.735)

Note: Probability values in parenthesis.

power crisis over the entire period, however, we found short-term and long-term effects on demand to be similar. We also found that income and urbanisation had positive effects on electricity demand. A key finding was that the share of industry value added negatively affected electricity demand. This finding suggests that industries may be reducing their reliance on electricity in favour of alternative fuels to insulate themselves from the negative consequences of potential power crisis in the future. The sources of their alternative fuels, however, remain a question to be explored as resorting to dirty energy which may be cheaper options will likely have negative implications for environmental health. We recommend that since Ghana is on a positive growth trajectory, policy should plan a sustained and consistent electricity supply to meet the certain increase in demand over the next couple of years due to result from growth in income and rising urbanisation. In addition, we recommend that all efforts to eliminate power crisis should be made so that households, businesses and industries will have the confidence to rely on electric power while firming up policies and incentives for other sustainable sources of power such as renewable energy. That said, should the undesirable situation of a power crisis occur, electricity rationing should be made strategically to reduce the impact that industries might have to face. Finally, since a very strong price effect was not observed, it suggests that availability of electricity supply and incomes are more important than prices in the analysis of the drivers of electricity consumption and hence electricity price subsidies should rather be channelled into improving the power generation and distribution infrastructure in order to regularise electricity supply.

Notes

1. Ghana has been hit by about five episodes of power crises, occurring in 1983, 1994, 1997–1998, 2006–2007 and 2012–2015. The economic, social and psychological costs increase with the length and severity of each crisis.
2. The magnitudes of the coefficients of power crisis (all) and power crisis (2012–2015) can be explained as: $\exp(0.273) - 1 = 0.314$ and $\exp(0.244) - 1 = 0.276$, respectively

3. This is achieved by subtracting the coefficient of the lagged dependent variable from 1.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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