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Research article

Modelling electricity consumption in Ghana: the role of financial development indicators

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Abstract: Access to electricity is touted as one of the ways of reducing poverty and improving the livelihoods of people. However, an increased consumption may also contribute to higher carbon dioxide emissions. While many studies have therefore assessed the determinants of electricity consumption for developing countries that have a lower electricity consumption and inadequate supply to meet demand, the effect of financial development on electricity consumption has been mixed. Consequently, this study models electricity consumption in Ghana with special attention on the effect of financial development. The results show that price reduces electricity consumption while income and population density increase consumption of electricity. When financial development is represented by domestic credit to private sector, domestic credit to private sector by banks and broad money supply, the effect is negative on electricity consumption. However, the effect is positive when financial development is represented by foreign direct investment. A financial index constructed from the four indicators shows financial development reduces electricity consumption in Ghana. Among other things the policy implication includes the need to formulate appropriate policy based on a specific indicator for financial development.

Keywords: electricity consumption; financial development; income; price; population; Ghana

JEL Codes: K32, N7, O13, P18, P28, Q43

1. Introduction

The importance of electricity to the socio-economic development of emerging economies including Ghana cannot be over-emphasized (Alam et al., 2016; Kwakwa and Solomon, 2014; Onisanwa and Adaji, 2020). This is because, in the last few decades, electricity has become a mainstay for technological development. Without a dependable electricity supply, poor individuals in developing countries will not be able to make ends meet by engaging in income making activities. This will make it difficult for the poor to absolve themselves from poverty and unable to contribute their quota to the economic development of the economy (Kwakwa et al., 2021; Onisanwa and Adaji, 2020). Similarly, governments in countries with scant or low electricity supply cannot fulfill their obligation of providing basic amenities and development to their citizenry (Bhagat, 2011; Kumar, 2015; Meles, 2020; Williams and Porter, 2006). Equally, the quest to industrialize an economy calls for the provision of electricity (Abbasi et al., 2020; Kwakwa, 2012). It is therefore necessary for governments of emerging economies to ensure adequate supply of electricity. However, developing countries and their governments are faced with the problem of inadequate electricity supply for development due to the numerous challenges (such as insufficient investment). This leads to load shedding most of the time (Sichone et al., 2016; Zalengera et al., 2014). In short, it is not out of place to conclude that while the demand for electricity in emerging economies is very high, supply has been low (Ansu-Mensah and Bein, 2019; Kwakwa et al., 2021). With the exception of South Africa which has close to 100% of citizens having access to electricity, several countries in Sub-Saharan Africa (SSA) are yet to achieve electrification rate of 100%.

Ghana currently has an electrification rate of 84% and average electricity consumption has been increasing by 5% annually (World Bank, 2021; Adom, 2016). That notwithstanding, electricity supply constraints in Ghana had led to a recurring power crisis associated with load shedding and power outages (Nduhuura et al., 2021; Boakye et al., 2016). As part of the process of resolving Ghana's electricity problems it will be easier, financially, to manage the demand side than the supply side. With an unreliable power supply, failure to manage the consumption side of electricity in the country may worsen the situation (Burgess et al., 2020; Gore et al., 2018; Nduhuura et al., 2020; Quartey and Ametorwotia, 2017; Amoah et al., 2017). Another reason to manage the country's electricity consumption is that its usage is found to be a contributory factor of carbon dioxide emissions and climate change problems (Churchill et al., 2021; Osobajo et al., 2020; Shahbaz et al., 2013). Empirical studies on Ghana by Kwakwa (2021), Lin and Agyeman (2019), Kwakwa and Alhassan (2018), Asumadu-Sarkodie and Owusu (2017) and elsewhere by Craig et al. (2018), Jiang et al. (2021), Karmellos et al. (2021), Liddle and Sadorsky (2017), Liu et al. (2021) and Rehman et al. (2019) have found that increasing electricity usage increases carbon dioxide emissions. Available data from the World Bank (2021) suggests that a rise in Ghana's carbon emissions follows an upward trend with the country's electricity consumption (Kwakwa, 2021; Liu et al., 2021). In this regard, once electricity consumption is managed, there may be greater chances of reducing carbon dioxide emissions which will help the country attain Sustainable Development Goals seven (affordable and clean energy), twelve (responsible consumption and production) and thirteen (climate action).

Studies on the determinants of electricity consumption abound and a number of factors including price, income, urbanization, population and financial development have been identified to influence its consumption by a number of researchers (Ozcan and Ozturk, 2019; Peñalvo-López et al., 2019; Abokyi et al., 2018). However, the argument and the empirical evidence regarding financial development have been mixed. While it is argued by some that through financial development, firms and households get

access to credit at a lower cost which enables them to acquire electricity dependent equipment thereby increasing electricity consumption, it is also argued that the access to cheap credit enables firms and households to buy energy efficient equipment thereby reducing electricity consumption (Mahalik and Mallick, 2014). The empirical works of Matar (2020), Kwakwa (2017), Rafindadi and Ozturk (2016), Sbia et al. (2017), Sekantsi et al. (2016), Shahbaz and Lean (2012) reported the former effect, while Asuamah (2016), Matar (2020), Muibi and Omoju (2016), and Solarin et al. (2021) reported the later effect. A possible reason for the mixed evidence is that different proxies have been used to measure financial development in the empirical studies. Thus, it appears each study has its own measurement for financial development. Such conflicting outcome does not help in policy formulation.

To really appreciate the effect of financial development on electricity consumption, it will be appropriate to estimate the effect of each of the indicators in a study to inform policy direction. Against this background, since Ghana's financial sector has seen some vibrancy over the past few years including recapitalization as argued by the Bank of Ghana, it is important to assess how this has influenced electricity consumption in the country. Therefore, the main purpose of this paper is to model electricity consumption in Ghana, an emerging economy, by investigating the effect of financial development on electricity consumption using various financial sector development indicators.

This study contributes to the literature in the following ways. It is among the few studies to examine the role financial development plays in Ghana's electricity consumption. Ghana's energy situation has been of concern to many researchers (Adusah-Poku et al., 2021; Kwakwa et al., 2018; Kwakwa, 2018; Adom, 2011; Adom and Bekoe, 2013; Adom, 2013; Aboagye, 2017; Dramani and Tewari, 2014; Mensah and Adu, 2015). However, empirical studies on the drivers of electricity consumption (Dramani and Tewari, 2014; Adom and Bekoe, 2013; Adom, 2013) have barely analyzed the effect of financial development. The study's contribution to the literature in general is also seen in the area that it uses more than one proxy for financial development. A financial development index is also constructed to assess the effect of financial development on electricity consumption. This is to ensure the results obtained are robust.

The remainder of this paper is structured as follows. The empirical modeling comes in the next section. The results segment and the analysis of the long and short run regression results follow in section three, while the conclusion and policy recommendations are highlighted in section four.

2. Methods

2.1. Empirical modeling

The theoretical foundation for the study is the theory of demand which indicates that demand for goods and services is influenced by a number of factors key among them are price, income and population pressure. Electricity is a service and its consumption or demand is derived demand since one does not have direct benefit from its consumption but rather through the gadgets that it helps to power. Economic theory argues that the relationship between price and electricity consumption is negative. An increase in the price of electricity will reduce the purchasing power of consumers and as a result, individuals not willing to pay for more will reduce the extent that they use their electrical appliance leading to a reduction in electricity consumption. As a normal commodity, income is posited to positively influence the level of electricity consumption since an increase in income makes it relatively easier for individuals to afford electrical appliances and pay for the charges associated with

its usage (Adom, 2013). The number of population is also argued to have a positive effect on electrical consumption. The reason is that a rise in population means demand for food will increase. Consequently, firms and households will have to use more energy including electricity to meet their food demand. This same idea can be translated to mean that population pressure is likely to increase electricity consumption.

Since financial development has become a force to reckon with in the energy literature and the objective of the study is to assess its effect on electricity consumption in Ghana. It is mentioned in the literature that an increase in financial development may have a positive or negative effect on electricity consumption. Financial development, according to Mahalik and Mallick (2014) promotes, among other things, trade and industrialization which requires electricity thereby leading to higher electricity consumption. Contrarily, financial development makes it easier and cheaper for firms and households to access credit which enables them to acquire energy efficient equipment. The effect is that financial development will reduce electricity consumption (Mahalik and Mallick, 2014). Empirically, the effect has been mixed and this could be attributed to the various ways financial development is measured. Many studies use a single proxy including domestic credit to private sector, domestic credit to private sector by banks, financial development and stock market development (Matar, 2020; Rafindadi and Ozturk, 2016; Sekantsi et al., 2016). Where data is available, it is important to have a single study that will incorporate the various proxies of financial development for effective policy.

$$LEC_t = \alpha + \beta_1 LYPC_t + \beta_2 PR_t + \beta_3 LFD_{it} + \beta_4 LPOP_t + \varepsilon_t \quad (1)$$

where EC is the level of electricity consumption, YPC represents income, PR is price of electricity, POP is population density (POPDEN) and FD is financial development. Also, L denotes the natural logarithm form of the variable. Again, α is the intercept, t represents time, ε is the error term and i denotes the various proxies for financial development. Since there is no one proxy for financial development, five different variables were used to ascertain the effect of financial development on electricity consumption. These five variables are mentioned at the data description below.

2.2. *Data source, data description and estimation technique*

It is important to ensure that the variables used for the time series analysis do not contain unit root and thus, they must be stationary to avoid getting spurious results. As a result, the study first of all tests the stationarity property of the variables by using the Augmented-Dicky Fuller, the Phillips-Perron and the Zivot-Andrews tests. After ensuring the variables do not contain unit roots, the autoregressive distributed lag (ARDL) cointegration technique is employed to ascertain the long-run relationship between electricity consumption and the explanatory variables. The long and short run estimation from the autoregressive distributed lag (ARDL) cointegration technique is then estimated. The theoretical details of the ARDL model can be read from Pesaran et al. (2001). The dynamic OLS (DOLS) was also estimated to check for the robustness of the regression results. Once the long-run relationship between the dependent and the explanatory variables have been established, the Granger causality analysis is done to ascertain the direction of causality among the variables. For cointegrated variables as found in this study, the vector error correction model of the granger causality is employed. Details of this approach can be found in Lütkepohl (2005), Toda and Yamamoto (1995), Maddala and Kim (1998).

To get data to meet the objective of the paper, we relied on the World Bank's 2021 World Development Indicators (1971–2019). Price was measured by using consumer price index, income was

measured as GDP per capita (constant US$), population pressure was represented by population density and electricity consumption was measured as Electric power consumption (kWh per capita). Following previous works such as Adu et al. (2013) and Omisakin (2009), financial development was represented by the following five indicators: Domestic credit to private sector (% of GDP) (FD-CP), Domestic credit to private sector by banks (% of GDP) (FD-BP), Broad money (% of GDP) (FD-BRM), Foreign direct investment net inflows (% of GDP) (FD-FDI) and FDINDEX, an index constructed by using principal component analysis method from the four indicators.

Table 1. Descriptive statistics of variables.

	ELEC	YPC	PR	POPDEN	FD-BP	FD-BRM	FD-CP	FD-FDI
Mean	314.2881	991.0308	27.28035	72.89364	8.175558	22.73072	8.056924	2.230983
Median	329.0979	927.4697	3.157668	69.79015	5.873631	22.76131	5.873631	1.226489
Maximum	416.1498	1627.760	150.2096	119.6470	15.88200	34.10823	15.82746	9.466664
Minimum	92.78023	693.9491	0.002245	39.43590	1.542268	11.30499	1.542268	–0.660372
Std. Dev.	70.27512	229.3142	41.32579	24.26149	4.927184	6.176970	4.781816	2.776483

Table 2. Correlation among variables.

Correlation	EC	YPC	PR	POPDEN	FD-BP	FD-BRM	FD-CP	FD-DI
EC	1.000000							
YPC	0.751522	1.000000						
PR	0.789803	0.920052	1.000000					
POPDEN	0.830242	0.722568	0.889844	1.000000				
FD-BP	0.639427	0.780588	0.782874	0.802422	1.000000			
FD-BRM	0.499805	0.554810	0.507090	0.539976	0.761702	1.000000		
FD-CP	0.620848	0.761012	0.762215	0.789998	0.999212	0.764501	1.000000	
FDDI	0.687114	0.779619	0.842959	0.795980	0.760676	0.494113	0.748959	1.000000

Table 3. Results of Principal Component Analysis.

Number	Value	Difference	Proportion	Cumulative Value	Cumulative Proportion
Eigenvalues: (Sum = 4, Average = 1)					
1	3.327067	2.845410	0.8318	3.327067	0.8318
2	0.481657	0.291531	0.1204	3.808724	0.9522
3	0.190126	0.188976	0.0475	3.998850	0.9997
4	0.001150		0.0003	4.000000	1.0000
Eigenvectors (loadings)					
Variable	PC 1	PC 2	PC 3	PC 4	
FDDI	0.463862	–0.680613	0.566439	0.027302	
FD-CP	0.536141	–0.002812	–0.476028	0.697096	
FD-BRM	0.456489	0.731962	0.505808	–0.002732	
FD-BP	0.537591	–0.031464	–0.443511	–0.716453	

The descriptive statistics of the variables and the correlation among the variables are reported in Table 1 and Table 2 respectively. The correlation results indicate that there is no perfect correlation among the explanatory variables that may cause the problem of multicorrelation. The financial development index constructed from the Principal Component Analysis reported in Table 3, shows that foreign direct investment and Domestic credit to private sector (% of GDP) (FD-CP) combined explains 95% of the changes in the original data.

3. Results and discussion

The results of the unit root test, the cointegration test, and the long and short run regression are presented and discussed below.

3.1. Unit root and cointegration tests results

The unit root test results are presented in Table 4 and it is seen that the variables used for the study are stationary at different levels. While ADF unit test result shows that at levels only electricity consumption is stationary and the other variables become stationary at first difference, the PP test shows that price and electricity consumption are stationary at levels with the rest attaining stationarity at first difference. The Zivot-Andrews test results reported in Table 5 also shows that in the presence of structural break, price and electricity are stationary at levels while the remaining variables become stationary at first difference. Thus, it can be concluded from the results that electricity consumption and price are stationary at levels (Integrated on the order 0), while income, financial development and population density are stationary at first difference (Integrated on the order 1). This outcome implies that the variables are suitable for regression analysis.

Table 4. Unit root results.

Variable	At levels		At first difference	
	ADF t-statistic	PP Adj. t-statistic	ADF t-statistic	PP Adj. t-statistic
LYPC	0.8284	1.1016	–4.4539***	–4.4040***
PR	2.2746	9.1033***	5.7165***	N/A
LFD-BP	–1.0676	–1.2112	–5.9375***	–5.8976***
LFD-CP	–1.1323	–1.2715	–5.9408***	–5.9081***
LFD-BRM	–1.6265	–1.6984	–7.1764***	–7.1915***
LFD-FDI	–1.1529	–0.9865	–5.8464***	–5.7782***
LPOPDEN	–2.2645	–1.0734	–4.9169***	–2.0581
LEC	–3.7778**	–2.6049*	N/A	N/A

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

Once the variables are seen to be a mixture of those integrated of order 0 and 1, the ARDL cointegration method is employed to determine the long run relationship among the variables. Since financial development was measured by five different proxies, five different tests were done with electricity consumption as the dependent variable while income, price, population density and the different financial development indicators become the explanatory variables. The reported results in Table 6 show that at a 1% level of significance, there is a confirmation of a cointegeration between

electricity consumption and the explanatory variables irrespective of the financial indicator used. This goes to suggest there is a long run relationship between electricity consumption and income, price, population density and financial development. Previous studies like Abosedra et al. (2015) has found that electricity consumption is cointegrated with price, income, population density and financial development.

Table 5. Zivot Andrews Unit test results.

Series	At levels		At first difference	
	t-statistic	Breakpoint	t-statistic	Breakpoint
LYPC	–3.1396	1979	–5.4752***	1986
PR	5.4788***	2012	N/A	N/A
LFD-BP	–3.9759	1996	–7.7891***	1984
LFD-CP	–3.9168	1996	–7.7923***	1984
LFD-BRM	–3.1942	1979	–8.0045***	1985
LFD-FDI	–3.4657	1989	–6.4344***	1985
LPOPDEN	–2.3295	2012	–4.7251*	1998
LEC	–4.8055*	1983	N/A	N/A

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

Table 6. ARDL Cointegration test results.

Critical values (K=5)	Lower Bounds I (0)	Upper Bounds I (1)
10%	2.45	3.52
5%	2.86	4.01
1%	3.74	5.06
Models	*F-statistic*	*Cointegration status*
LEC LYPC, PR, LPOPDEN, LFD-CB	9.377***	Confirmed
LEC LYPC, PR, LPOPDEN, LFD-BP	6.772***	Confirmed
LEC LYPC, PR, LPOPDEN, LFD-BRM	8.753***	Confirmed
LEC LYPC, PR, LPOPDEN, FDINDEX	5.986***	Confirmed
LEC LYPC, PR, LPOPDEN, LFD- FDI	8.341***	Confirmed

Note: *** denotes 1% level of significance.

3.2. Analysis of the long and short run regression results

From the ARDL cointegration, the long and short run estimates of parameters are generated and reported in tables 7 and 8 respectively. In Table 7 one notices that similar evidence is provided by all the models regarding the effects of income, price and population density. Thus, the results indicate that income and population density have positive effects on electricity consumption while price has negative effect. The positive effect of income suggests that a 1% rise in the per capita income level of Ghanaians is expected to increase the level of electricity consumption by about 2.7–5.0%. This confirms that indeed energy is a normal good that people would want more of it whenever they witness an increase in their income level. The reason is that electricity like many other energy is derived demand. They are indirectly demanded to meet certain needs. As income of people increases and they purchase more

electronic appliances the demand for electricity also rises. This allusion is common among Ghanaians whose appetite for electricity gadgets like television and air conditioner among others increase with income. Previous studies in Ghana including Adom (2013) also obtained positive effect of income on electricity consumption. Elsewhere, Kwakwa (2018) reported similar outcome for Benin, Mukhtarov et al. (2020) for Kazakhstan, Ali et al. (2021) for China, and Bohlmann and Inglesi-Lotz (2021) for South Africa. In the short run, however, income is seen not to exert any significant effect on electricity consumption. This suggests that people do not immediately respond to consume electricity whenever there is an increase in their income level but rather will wait for a longer period of time.

In the long run, price is seen to reduce electricity consumption. This is also in line with economic theory. The law of demand establishes an inverse relationship between price and demand for good/service. The rise in price of goods and service makes things generally expensive for people to afford. It also erodes part of their purchasing power and as such quantity demanded for goods and services reduces. Although the price element used in this study is not the price of electricity but rather CPI, the outcome is generally a reflection of the case in Ghana. Whenever utility charges are increased, citizens are compelled to reduce their consumption. An increase in the general price level which also imposes some hardships on the citizens makes electricity consumption lower. Previous works including Xia and Hu (2012) and Al-Bajjali and Shamayleh (2018) reported of a negative effect of price on electricity consumption. The effect of price in the short run remains negative and significant. Thus, in the short run price reduces electricity consumption. In this case, people hurriedly adjust their consumption level whenever there are price changes.

A rise in a country's population increases the number of people who consume electricity and as a result, it is expected to increase the level of electricity consumption. This is likely to be heightened when there is an increase in population density. Ghana's population has increased from 8 million in 1971 to about 30.42 million at the moment (Ansu-Mensah et al., 2021). The population dynamics in Ghana has seen urban population exceeding rural population since 2010. The effect is that not only has the consuming population of electricity increased but also the demand for electricity in the urban centers has increased. The combined effect is that electricity consumption also increases. This could explain the positive effect of population density on electricity consumption in the long run. In their work, Huang et al., (2018) found that an increase in population pressure increases energy consumption leading to lower energy efficiency in China. The work of Kwakwa (2018) also had similar outcome. In the short run, population density generally increases electricity consumption. It is not surprising since the increase in population will definitely increase the demand for electricity consumption.

On the effect of financial development indicators, the results show that in the long run, domestic credit to private sector (LFD-CP), domestic credit to private sector by banks (LFD-BP) and broad money (LFD-BRM) reduces electricity consumption. Also, while the overall financial development index constructed reduces electricity consumption, foreign direct investment increases electricity consumption. The results tell that domestic credit given to the private sector helps reduce electricity consumption. Access to credit is very essential for firms to expand their production via the acquisition of raw materials, repair or maintenance of their machines and acquisition of new machines. When it is difficult to access credit, firms are compelled to use obsolete equipment for production and this consumes more electricity. The opposite is the case when firms easily access credit. By increasing the credit given to the private sector in Ghana, firms are placed in a position to afford energy efficient equipment for their operations which make the sector more efficient thereby reducing electricity consumption. Similarly, credit by banks to the private sector also helps achieve same outcome. This

suggests that over the years it appears banks in the country have also been concerned with the promotion of efficiency among firms in the private sector. Regarding the effect of broad money supply, it also implies that as money supply increases, citizens and firms easily access funds to afford efficient energy gadgets, hence, the reduction effect of broad money supply on electricity consumption. The above findings are in line with Matar (2020), Rafindadi and Ozturk (2016), Sbia et al. (2017), Sekantsi et al. (2016), Shahbaz and Lean (2012). In the short run, however, the effects of the financial indicators discussed above on electricity consumption is generally insignificant which means an increase in the level of the financial sector does not have immediate effect on electricity consumption.

Table 7. ARDL Long run regression results.

	Model 1 Coefficient [std. error]	Model 2 Coefficient [std. error]	Model 3 Coefficient [std. error]	Model 4 Coefficient [std. error]	Model 5 Coefficient [std. error]
LYPC	2.763***[0.643]	3.445***[0.752]	1.667***[0.822]	4.167***[0.825]	5.087***[1.205]
PR	–0.014***[0.003]	–0.016***[0.003]	–0.007***[0.003]	–0.015***[0.003]	–0.023***[0.005]
LFD-BP	–0.260**[0.118]				
LFD-BRM		–1.115***[0.353]			
LFD-CB			–0.217*[0.124]		
LFD-FDI				0.124*[0.060]	
FDINDEX					–0.217**[0.081]
LPOPDEN	1.797**[0.327]	1.716**[0.299]	1.456**[0.390]	0.498[0.358]	1.483**[0.564]
C	–24.946***[8.649]	–23.856***[7.954]	–12.866***[7.966]	–18.195*[9.651]	–53.285***[16.542]

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

The effect of foreign direct investment as an indicator of financial development is however observed to increase electricity consumption. Electricity is a critical factor that attracts foreign investors. However, there is the argument that foreign direct investment may through the pollution haven effect increases energy consumption in developing countries while through the pollution halo effect it reduces energy consumption. There has been conscious effort by authorities in Ghana to attract foreign investors. However, the finding suggests that the presence of such foreign firms in the country increases electricity consumption in the long run implying that they may not be energy efficient. In the long run, a 1% increase in foreign direct investment is associated with about 0.12% increase in electricity consumption which is similar to the work of Amoako and Insaidoo (2021).

Overall, the financial development index shows that Ghana's financial development in the long run helps to reduce electricity consumption. In the short run, it is rather seen that the overall financial development increases electricity consumption. This gives the impression that the positive effect of the financial development on electricity consumption is short-lived and that in the long run it becomes negative to the benefit of the country.

To ensure that the regression results are robust, the DOLS regression analysis was also employed. The regression results reported in Table 9 confirm what was reported from the ARDL. Thus, it also endorses that income and population density positively affects electricity consumption. Also, the results show that foreign direct investment increases electricity consumption while the other proxies for financial development have the opposite effect confirming what has been reported from the ARDL technique in Table 7.

Table 8. ARDL Short run regression results.

	Model 1 Coefficient [std. error]	Model 2 Coefficient [std. error]	Model 3 Coefficient [std. error]	Model 4 Coefficient [std. error]	Model 5 Coefficient [std. error]
D(LYPC)	0.578[0.767]	0.570[0.673]	–1.489[0.132]	0.377[0.796]	1.169[0.813]
D(PR)	–0.012***[0.003]	–0.011***[0.003]	–0.007***[0.004]	–0.012***[0.003]	–0.017[0.005]
DLFD-BP	–0.221*[0.113]				
DLFD-BRM		0.047[0.221]			
DLFD-CB			–0.225[0.143]		
DLFD-FDI				0.002[0.051]	
DFINDEX					0.124***[0.055]
D(LPOPDEN)	–19.831[12.523]	–3.663[6.820]	5.550**[1.879]	6.344***[1.258]	1.801***[0.587]
Ecm(–1)	–0.853***[0.147]	–0.722***[0.118]	–0.857***[0.147]	–0.858***[0.141]	–0.725***[0.153]

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

Table 9. DOLS regression results.

	Model 1 Coefficient [std. error]	Model 2 Coefficient [std. error]	Model 3 Coefficient [std. error]	Model 4 Coefficient [std. error]	Model 5 Coefficient [std. error]
LYPC	6.366***[1.416]	5.736***[0.735]	6.346***[1.400]	5.2160***[0.996]	5.085***[1.205]
PR	–0.028***[0.007]	–0.023***[0.004]	–0.028***[0.007]	–0.018***[0.004]	–0.026***[0.006]
LFD-BP	–0.440**[0.207]				
LFD-BRM		–1.087***[0.330]			
LFD-CB			–0.442***[0.202]		
LFD-FDI				0.268**[0.111]	
FIINDEX					–0.217***[0.081]
LPOPDEN	1.386***[0.429]	1.1495***[0.281]	1.403***[1.400]	–0.884[0.857]	1.483***[0.564]
C	–62.675***[13.717]	–49.737***[7.580]	–62.813***[13.507]	–20.997[19.541]	–53.285***[16.578]

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

3.3. Diagnostic tests for regression results

The error correction term ECM (–1) for each model presented in Table 8 is negative and statistically significant. This is an indication that there is a long run relationship between electricity consumption and the explanatory variables in this study. Also, the results in Table 10 demonstrate that generally the models are free from the problems of instability, non-normality, heteroskedasticty and serial correction. It therefore means that the estimated results are robust. Similarly, the CUSUM test and CUSUM of squares shown in figure 1 and figure 2 respectively confirm that the models are stable.

Table 10. Diagnostic test results for ARDL estimation.

Test	Model 1 Statistic (Probability)	Model 2 Statistic (Probability)	Model 3 Statistic (Probability)	Model 4. Statistic (Probability)	Model 5 Statistic (Probability)
Stability	1.81 (0.08)	5.96 (0.01)	1.84 (0.08)	1.07 (0.29)	0.23 (0.81)
Normality	2.49 (0.28)	3.79 (0.15)	2.48 (0.29)	0.24 (0.88)	0.02 (0.98)
Serial correlation	0.03 (0.96)	1.21 (0.31)	0.04 (0.95)	1.46 (0.25)	1.58 (0.23)
Heteroscedasticity	10.76 (0.10)	1.24 (0.30)	1.41 (0.23)	1.27 (0.29)	0.97 (0.50)

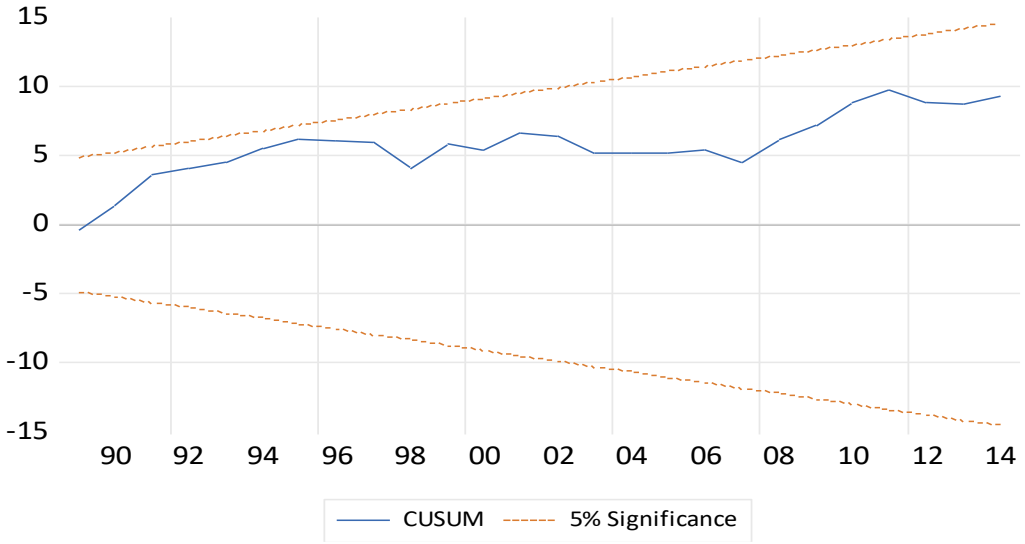

Figure 1. CUSUM stability results.

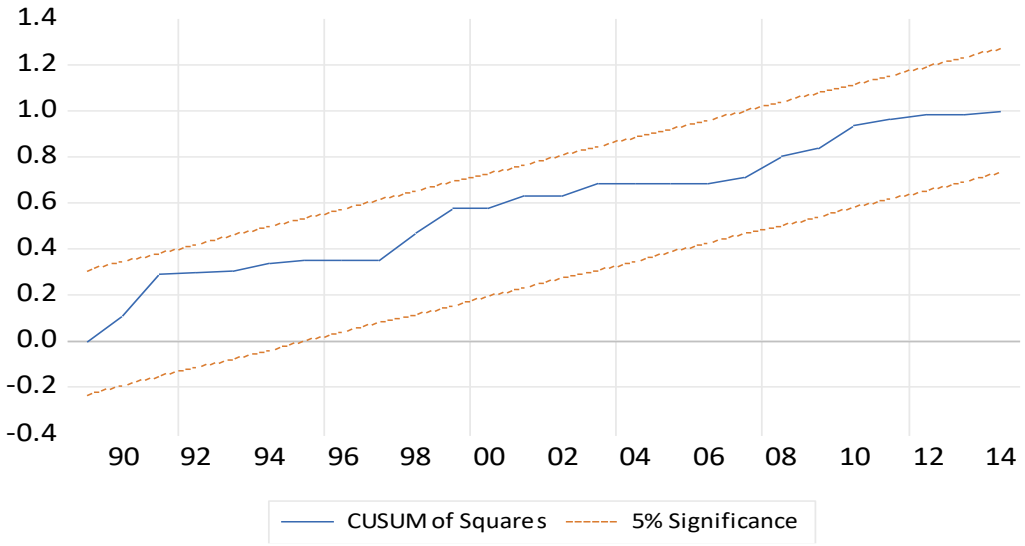

Figure 2. CUSUM of squares stability results.

Finally, a vector error correction granger causality is analyzed among the variables (electricity consumption, income, population density and financial development index, representing financial development) to ascertain their direction of causality (Table 11). In the short run electricity consumption is granger caused by income, price and population density. In the long run income, price, financial development and population density are also found to granger cause electricity consumption. The above gives weight to previous results discussed above. Also, a unidirectional causality from price, financial development and population density to income is observed in the short run. Financial development is granger caused by population density in the short run and long run; while a bidirectional causality runs between population density and price in the short run. The unidirectional causality from income to electricity consumption is similar to Kwakwa (2012). The above finding is an indication that policies to influence electricity consumption may have a feedback effect on population density without affecting the other variables.

Table 11. VECM Granger Causality test.

Dependent variable	Short-run chi-square value					Long run t-statistic
	DLEC	DLYPC	DPR	DFINDEX	DLPOPDEN	ECT-1
DLEC		6.265***	3.157*	0.379	16.816***	–3.744***
DLYPC	0.142		11.606***	2.917*	2.467	0.152
DPR	0.037	2.412		0.043	5.312**	–0.106
DFDINDEX	0.068	0.667	0.980		4.476**	–3.252***
DLPOPDEN	3.311*	2.046	2.885*	0.243		5.240***

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

4. Conclusions and policy recommendations

This paper modelled electricity consumption in Ghana and assessed the effect of financial development on it. The study used the time series data from 1971 to 2019 to model electricity consumption in Ghana as a function of income, price, population density and financial development. Financial development was measured using five proxies namely domestic credit to private sector, domestic credit to private sector by banks, broad money supply, foreign direct investment net inflows and an index constructed from the four indicators. The ARDL cointegration method was employed to determine the long run relationship among the variables. The results indicated that there is a long run relationship between electricity consumption and income, price, population density and financial development indicators. The regression analysis showed that income and population density increase electricity consumption while price reduces its consumption. All the financial development indicators were found to reduce electricity consumption except foreign direct investment which had the opposite effect. A VECM approach to granger causality test confirms income, price and population density granger cause electricity consumption in the short run while in the long run income, price, financial development and population density granger cause electricity consumption. In addition, a bidirectional causality runs between population density and price in the short run.

The policy implications arising from the study include the need for authorities in the country especially the Bank of Ghana to impress upon financial institutions to further reduce the interest rate on credit taken from them. In addition, studies may be carried out to unearth why the lending rate from

financial institutions in the country remain high. Although the Bank of Ghana's policy rate has gradually reduced from about 26% in 2016 to 13.5% presently, the lending rate from commercial banks and other financial institutions has seen little reduction (hovering around 20–23%), a situation which has received complaints from many business managers. Ability by the Central Bank to persuade financial institutions to reduce their lending rate or when the factors behind the interest rate spread are identified and dealt with, it may enable more firms and households access funds to acquire energy efficient equipment. Since foreign direct investment is found to increase electricity consumption, authorities in the country may need to strictly regulate the activities of foreign firms or persuade foreign firms to ensure they are energy efficient in their operations. As the population pressure grows, and the economy expands and income levels of citizens' increase, there will be need for intensive education to the growing population on the need to conserve electricity in their bid to consume more.

Conflict of interest

All authors declare no conflicts of interest in this paper.

References

Abbasi K, Lv K, Nadeem MA, et al. (2020) Agricultural and Manufacturing Sector Determinants of Consumption, Price, and Real GDP from Pakistan. *North Am Acad Res* 3: 21–46. https://doi.org/10.5281/zenodo.3604943

Aboagye S (2017) The policy implications of the relationship between energy consumption, energy intensity and economic growth in Ghana. *OPEC Energy Rev* 41: 344–363. https://doi.org/10.1111/opec.12114

Abokyi E, Appiah-Konadu P, Sikayena I, et al. (2018) Consumption of Electricity and Industrial Growth in the Case of Ghana. *J Energy* 2018: 1–11. https://doi.org/https://doi.org/10.1155/2018/8924835

Abosedra S, Shahbaz M, Sbia R (2015) The Links between Energy Consumption, Financial Development, and Economic Growth in Lebanon: Evidence from Cointegration with Unknown Structural Breaks. *J Energy* 2015: 1–15. https://doi.org/10.1155/2015/965825

Adom PK (2011) Electricity consumption-economic growth nexus: the Ghanaian case. *Int J Energy Econ Policy* 1: 18–31.

Adom PK, Bekoe W (2013) Modelling electricity demand in Ghana revisited: The role of policy regime changes. *Energy Policy* 61: 42–50. https://doi.org/10.1016/j.enpol.2013.05.113

Adom, PK (2013) Time-varying analysis of aggregate electricity demand in Ghana: A rolling analysis. *OPEC Energy Rev* 37: 63–80. https://doi.org/10.1111/j.1753-0237.2012.00227.x

Adu, G, Marbuah G, Mensah JT (2013) Financial development and economic growth in Ghana: Does the measure of financial development matter? *Rev Dev Financ* 3: 192–203. https://doi.org/10.1016/j.rdf.2013.11.001

Adusah-Poku F, Adjei-Mantey K, Kwakwa PA (2021) Are energy-poor households also poor? Evidence from Ghana. *Poverty Public Policy* 13: 32–58. https://doi.org/10.1002/pop4.301

Alam MM, Murad MW, Noman AHM, et al. (2016) Relationships among carbon emissions, economic growth, energy consumption and population growth: Testing Environmental Kuznets Curve hypothesis for Brazil, China, India and Indonesia. *Ecol Indic* 70: 466–479. https://doi.org/10.1016/j.ecolind.2016.06.043

Al-Bajjali SK, Shamayleh AY (2018) Estimating the determinants of electricity consumption in Jordan. *Energy* 147: 1311–1320. https://doi.org/10.1016/j.energy.2018.01.010

Ali SSS, Razman MR, Awang A, et al. (2021) Critical determinants of household electricity consumption in a rapidly growing city. *Sustainability* 13: 4441. https://doi.org/10.3390/su13084441

Amoah A, Larbi DA, Offei D, et al. (2017) In gov we trust: the less we pay for improved electricity supply in Ghana. *Energy Sustain Soc* 7: 1–9. https://doi.org/10.1186/s13705-017-0133-0

Amoako S, Insaidoo M (2021) Symmetric impact of FDI on energy consumption: Evidence from Ghana. *Energy* 223. https://doi.org/10.1016/j.energy.2021.120005

Ansu-Mensah P, Bein MA (2019) Towards sustainable consumption: Predicting the impact of social-psychological factors on energy conservation intentions in Northern Cyprus. *Nat Resour Forum* 43: 181–193. https://doi.org/10.1111/1477-8947.12174

Ansu-Mensah P, Marfo EO, Awuah LS, et al. (2021) Corporate social responsibility and stakeholder engagement in Ghana's mining sector: a case study of Newmont Ahafo mines. *Int J Corp Soc Resp* 6: 1–22. https://doi.org/10.1186/s40991-020-00054-2

Asuamah YS (2016) Modelling financial development and electricity consumption nexus for Ghana. *Munich Personal RePEc Archive*.

Asumadu-Sarkodie S, Owusu AP (2017) The relationship between carbon dioxide emissions, electricity production and consumption in Ghana. *Energ Source Part B* 12: 547–558. https://doi.org/10.1080/15567249.2016.1227885

Bhagat, RB (2011) Urbanisation and access to basic amenities in India. *Urban India* 31: 1–14.

Boakye NAB, Twenefour FB, McArthur-Floyd M (2016) The impact of power outage "dumsor" on the hotel industry: Evidence from Ghana. *J Energy Technol Policy* 6: 39–47.

Bohlmann JA, Inglesi-Lotz R (2021) Examining the determinants of electricity demand by South African households per income level. *Energy Policy* 148. https://doi.org/10.1016/j.enpol.2020.111901

Burgess, R, Greenstone, M, Ryan, N (2020) The consequences of treating electricity as a right. *J Econ Perspect* 34: 145–169. https://doi.org/10.1257/jep.34.1.145

Churchill SA, Ivanovski K, Munyanyi ME (2021) Income inequality and renewable energy consumption: Time-varying non-parametric evidence. *J Clean Prod* 296: 1–26. https://doi.org/10.1016/j.jclepro.2021.126306

Craig, MT, Jaramillo, P, Hodge, B (2018) Carbon dioxide emissions effects of grid-scale electricity storage in a decarbonizing power system. *Environ Res Lett* 13: 1–11. https://doi.org/10.1088/1748-9326/aa9a78

Diawuo FA, Pina A, Baptista PC, et al. (2018) Energy efficiency deployment: A pathway to sustainable electrification in Ghana. *J Clean Prod* 186: 544–557. https://doi.org/10.1016/j.jclepro.2018.03.088

Dramani JB, Tewari DD (2014) An economic analysis of residential electricity demand in Ghana. *Mediterranean J Soc Sci* 5: 209–222. https://doi.org/10.5901/mjss.2014.v5n16p209

Gore CD, Brass JN, Baldwin E, et al. (2018) Political autonomy and resistance in electricity sector liberalization in Africa. *World Dev* 120: 193–209. https://doi.org/10.1016/j.worlddev.2018.03.003

Huang H, Du Z, He Y (2018) The effect of population expansion on energy consumption in Canton of China: A simulation from computable general equilibrium approach. *Int J Eng Sci Manage Res* 5: 19–26.

Jiang Q, Iqbal S, Rahman UZ (2021) Measuring the simultaneous effects of electricity consumption and production on carbon dioxide emissions (CO_2e) in China: New evidence from an EKC-based assessment. *Energy* 229: 1–10. https://doi.org/10.1016/j.energy.2021.120616

Karmellos M, Kosmadakis V, Dimas P, et al. (2021) A decomposition and decoupling analysis of carbon dioxide emissions from electricity generation: Evidence from the EU-27 and the UK. *Energy* 231. https://doi.org/10.1016/j.energy.2021.120861

Kemausuor F, Ackom E. (2017) Toward universal electrification in Ghana. *WIREs: Energy Environ* 6: 1–14. https://doi.org/10.1002/wene.225

Kumar A (2015) Indian Urban Households' Access to Basic Amenities: Deprivations, Disparities and Determinants. *Margin: J Appl Econ Res* 9: 278–305. https://doi.org/10.1177/0973801015579754

Kwakwa PA (2012) Disaggregated energy consumption and economic growth in Ghana. *Int J Energy Econ policy* 2: 34–40.

Kwakwa PA (2017) Electricity consumption in Egypt: a long-run analysis of its determinants. *OPEC Energy Rev* 41: 3–22. https://doi.org/10.1111/opec.12091

Kwakwa PA (2018) Analysis of the determinants of electricity consumption in Benin. J Energy Manage and Technol 2: 42. http://dx.doi.org/10.22109/jemt.2018.125839.1075.

Kwakwa PA (2021) The carbon dioxide emissions effect of income growth, electricity consumption and electricity power crisis. *Int J Mange Environ Qual* 32: 470–487. https://doi.org/10.1108/MEQ-11-2020-0264

Kwakwa PA, Adu G, Osei-Fosu AK (2018) A time series analysis of fossil fuel consumption in Sub-Saharan Africa: evidence from Ghana, Kenya and South Africa. *Int J Sustain Energy Plan Manage* 17: 31–44. https://doi.org/10.5278/ijsepm.2018.17.4

Kwakwa PA, Adusah-Poku F, Adjei-Mantey K (2021) Towards the attainment of sustainable development goal 7: what determines clean energy accessibility in sub-Saharan Africa? Green Financ 3: 268–286. https://doi.org/10.3934/GF.2021014

Kwakwa PA, Alhassan H (2018) The effect of energy and urbanisation on carbon dioxide emissions: evidence from Ghana. *OPEC Energy Rev* 42: 301–330. https://doi.org/10.1111/opec.12133

Kwakwa PA, Solomon K (2014) Energy Consumption in Ghana and the Story of Economic Growth, Industrialization, Trade Openness and Urbanization. *Asian Bull Energy Econ Technol* 1: 1–6. https://doi.org/10.1177/016224399502000203

Liddle B, Sadorsky P (2017) How much does increasing non-fossil fuels in electricity generation reduce carbon dioxide emissions? *Appl Energy* 197: 212–221. https://doi.org/10.1016/j.apenergy.2017.04.025

Lin B, Agyeman DS (2019) Assessing Ghana's carbon dioxide emissions through energy consumption structure towards a sustainable development path. J Clean Prod 238. https://doi.org/10.1016/j.jclepro.2019.117941

Liu J, Murshed M, Chen F, et al. (2021) An empirical analysis of the household consumption-induced carbon emissions in China. *Sustain Prod Consum* 26: 943–957. https://doi.org/10.1016/j.spc.2021.01.006

Lütkepohl H (2005) *New Introduction to Multiple Time Series Analysis.* Berlin: Springer Verlag.

Maddala GS, Kim IM (1998) *Unit Roots, Co-integration, and Structural Change.* New York: Cambridge University Press.

Mahalik MK, Mallick H (2014) Energy Consumption, Economic Growth and Financial Development: Exploring the Empirical Linkages for India. *J Dev Areas* 48: 139–159. https://doi.org/10.1353/jda.2014.0063

Matar A (2020) Does electricity consumption impacting financial development? Wavelet analysis. *Future Bus J* 6: 1–9. https://doi.org/10.1186/s43093-020-00017-w

Meles TH (2020) Impact of power outages on households in developing countries: Evidence from Ethiopia. *Energy Econ* 91. https://doi.org/10.1016/j.eneco.2020.104882

Mensah JT, Adu G (2015) An empirical analysis of household energy choice in Ghana. *Renew Sust Energ Rev* 51: 1402–1411. https://doi.org/10.1016/j.rser.2015.07.050

Muibi OS, Omoju OE (2016) Macroeconomic determinants of renewable electricity technology adoption in Nigeria. *Econ and Environ Stud* 16: 65–83.

Mukhtarov S, Humbatova S, Seyfullayev I, et al. (2020) The effect of financial development on energy consumption in the case of Kazakhstan. *J Appl Econ* 23: 75–88. https://doi.org/10.1080/15140326.2019.1709690

Nduhuura P, Garschagen M, Zerga A (2020) Mapping and Spatial Analysis of Electricity Load Shedding Experiences: A Case Study of Communities. *Energies* 13: 1–26. https://doi.org/10.3390/en13174280

Nduhuura P, Garschagen M, Zerga A (2021) Impacts of Electricity Outages in Urban Households in Developing Countries: A Case of Accra, Ghana. *Energies* 14: 1–26. https://doi.org/10.3390/en14123676

Omisakin AO (2009) Economic growth and environmental quality in Nigeria: Does environmental Kuznets curve hypothesis hold? *Environ Res J* 3: 14–18.

Onisanwa ID, Adaji MO (2020) Electricity consumption and its determinants in Nigeria. *J Econ Manage* 41: 87–104. https://doi.org/10.22367/jem.2020.41.05

Osobajo OA, Otitoju A, Otitoju MA, et L. (2020) The impact of energy consumption and economic growth on carbon dioxide emissions. *Sustainability* 12: 1–16. https://doi.org/10.3390/su12197965

Ozcan B, Ozturk I (2019) Renewable energy consumption-economic growth nexus in emerging countries: A bootstrap panel causality test. *Renew Sust Energ Rev* 104: 30–37. https://doi.org/10.1016/j.rser.2019.01.020

Peñalvo-López E, Pérez-Navarro Á, Hurtado E, et al. (2019) Comprehensive methodology for sustainable power supply in emerging countries. *Sustainability* 11: 2–22. https://doi.org/10.3390/su11195398

Pesaran MH, Shin Y, Smith RJ (2001) Bounds testing approaches to the analysis of level relationships. *J Appl Econ* 16: 289–326.

Quartey J, Ametorwotia WD (2017) Assessing the total economic value of electricity in Ghana: A step toward energizing economic growth.

Rafindadi AA, Ozturk I (2016) Effects of financial development, economic growth and trade on electricity consumption: Evidence from post-Fukushima Japan. *Renew Sustain Energy Rev* 54: 1073–1084. https://doi.org/10.1016/j.rser.2015.10.023

Rehman A, Rauf A, Ahmad M, et al. (2019) The effect of carbon dioxide emission and the consumption of electrical energy, fossil fuel energy, and renewable energy, on economic performance: evidence from Pakistan. *Environ Sci Pollut Res* 26: 21760–21773. https://doi.org/10.1007/s11356-019-05550-y

Sbia R, Shahbaz M, Ozturk I (2017) Economic growth, financial development, urbanisation and electricity consumption nexus in UAE. *Econ Res-Ekon Istraž* 30: 527–549. https://doi.org/10.1080/1331677X.2017.1305792

Sekantsi LP, Thamae RI, Mohatonyane LE (2016) Electricity Consumption in Lesotho: The Role of Financial Development, Industrialisation and Urbanisation. *J Int Bus Econ* 4: 19–28. https://doi.org/10.15640/jibe.v4n1a2

Shahbaz M, Hye QMA, Tiwari AK, et al. (2013) Economic growth, energy consumption, financial development, international trade and CO2 emissions in Indonesia. *Renew Sustain Energ Rev* 25: 109–121. https://doi.org/10.1016/j.rser.2013.04.009

Shahbaz M, Lean H (2012) Does financial development increase energy consumption? The role of industrialization and urbanization in Tunisia. *Energy Policy* 40: 473–479. https://doi.org/10.1016/j.enpol.2011.10.050

Sichone YM, Mulenga P, Phiri C, et al. (2016) Electricity Load Shedding: An Econometric Analysis of the Productivity of Firms in the Manufacturing Sector in Lusaka. *Int J Commer Manage Res* 2: 151–157.

Solarin SA, Shahbaz M, Khan H, et al. (2021) ICT, Financial Development, Economic Growth and Electricity Consumption: New Evidence from Malaysia. *Glob Bus Rev* 22: 941–962. https://doi.org/10.1177/0972150918816899

Toda HY, Yamamoto T (1995) Statistical Inference in Vector Autoregressions with Possibly Integrated Processes. *J Econom* 66: 225–250. https://doi.org/10.1016/0304-4076(94)01616-8

Williams A, Porter S (2006) Comparison of hydropower options for developing countries with regard to the environmental, social and economic aspects. *Small* 1.

World Bank (2021) World Development Indicators 2021, Washington DC. Available from https://databank.worldbank.org/source/world-development-indicators#.

Xia XH, Hu Y (2012) Determinants of electricity consumption intensity in China: analysis of cities at subprovince and prefecture levels in 2009. *Energy Econ Policy* 2012. https://doi.org/10.1100/2012/496341

Zalengera C, Blanchard RE, Eames PC, et al. (2014) Overview of the Malawi energy situation and A PESTLE analysis for sustainable development of renewable energy. *Renew Sustain Energy Rev* 38: 335–347. https://doi.org/10.1016/j.rser.2014.05.050

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