Journal of the Ghana Institution of Engineering (2024) 24:3
https//doi.org/10.56049/jghie.v24i3.226

CASE STUDY

Determinants of access to electricity in Ghana: the role of petroleum products prices

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Received: 4th September, 2024 / **Accepted:** 22nd October, 2024
Published online: 5th December, 2024

Abstract
This study probes the intricate interplay between petroleum product prices and access to electricity in Ghana, alongside other critical determinants, including electricity prices, GDP per capita, rural population growth, and foreign direct investment. Spanning the years 2000 to 2022, the research employs robust correlation and regression analyses to uncover significant relationships among these socioeconomic variables. The findings reveal compelling evidence that prices of petroleum products have substantial effects on electricity access, primarily through their impact on operational costs, and that rising prices of diesel have more negative impacts than corresponding rising petrol prices. Also, increased GDP per capita and electricity prices positively affect improved electricity access, suggesting that economic growth and revenue generation are key to expanding access. However, the effects of rural population growth and foreign direct investments on electricity access were insignificant, although the constructs were statistically significantly correlated. The findings highlight the importance of stabilizing petroleum product prices and improving economic conditions to enhance electricity access. Additionally, prioritizing investments in rural electrification and infrastructure development is crucial to accommodate the growing rural population. This study fills a gap in the literature by providing empirical evidence on the determinants of electricity access in Ghana, with a novel focus on petroleum product prices. Aside from the theoretical implications of this research, its recommendations aim to inform policymakers and stakeholders in their efforts to achieve universal electricity access, aligned with the seventh Sustainable Development Goal.

Keywords: Electricity Access, Petrol Price, SDG 7, Energy Economics, GDP per Capita

Introduction
Energy is a fundamental aspect of nearly all major global challenges and opportunities, supporting the push for universal access to modern energy services (UN, 2018). It drives growth and is crucial for national development, with increased energy consumption indicating rising GDP and economic growth. Electricity, hailed as a transformative invention, is currently the most utilized form of modern energy for economic activities, playing a vital role in the socio-economic development of countries like Ghana (Alam *et al*., 2016; Onisanwa and Adaji, 2020). Access to electricity directly impacts income, reduces inequality, and is essential for poverty alleviation in developing nations. It enables lighting, heating, cooking, and various economic activities necessary for producing goods and services, as economic growth heavily relies on transforming raw materials into finished and semi-finished products, where electricity is a key input. Accessible electricity allows consumers to engage in profitable economic activities, significantly improving their livelihoods. Electricity is considered a crucial driver of social and economic transformation in Africa (Blimpo, 2019). Consequently, many electrification projects have been undertaken to increase household electricity connections. Despite these efforts, over half of the population in many sub-Saharan African countries lack access to electricity (International Energy Agency (IEA), 2019). According to the IEA, over 95 per cent of the estimated 1.3 billion people worldwide without electricity live in developing countries, with about 60 per cent in Africa. Approximately 16 per cent of the global population (1.18 billion people) lack electricity access, and 40 per cent (2.74 billion) rely on traditional biomass for cooking (IEA 2016).

Factors in developing nations contribute to increasing electricity demand (Twerefou *et al*., 2018), but access remains low despite rapid urbanization and growing energy needs. In Ghana, utilities and the government's inadequate investments in the energy sector have affected electricity generation, transmission, and supply networks (Adom, 2017). The cost of credit to investors, linked to their access to financial services (Dorhetso *et al*., 2023), and the rising debt owed to independent power producers (IPPs) by the government have worsened electricity generation and supply issues. Additionally, since all IPPs use gas turbine engines powered by petroleum products, the impact of petroleum product prices and taxes on investor savings and investments (Dorhetso, 2024) is significant. Recently, substantial steps have been taken to increase national generation and distribution capacity to stabilize electricity access. By 2016, 82.5 per cent of Ghana's population had access to electricity, with universal access expected by 2020 at an annual electrification rate of 4.38 per cent (Kumi, 2017). However, by 2022, grid-connected electricity access had only increased to 85 per cent (Energy Commission, 2022). From 2011 to 2021, overall electricity generation grew from 14,068 GWh to 22,051 GWh, reflecting an 11 per cent annual growth rate. Electricity consumption also increased from 13,036 GWh in 2017 to 18,067 GWh in 2021, with an average annual growth rate of 8 per cent. The industrial and residential sectors increased their share of total electricity consumption in 2021 to 32 per cent and 45 per cent, respectively, from about 30.4 % and 43 % in 2020 (Energy Commission, 2023). This demand growth is due to urbanization, population growth, increasing GDP per capita, advancing technology, economic structural changes, government subsidies, and rural electrification efforts (Adom, 2017; Mensah *et al*., 2016).

Empirical evidence (Adom, 2017; Kim, 2018) on electricity demand drivers helps address the consequences of inadequate access and informs decisions on electricity access management. However, specific evidence on electricity access determinants is rare, with literature focusing more on demand. Providing empirical evidence on the effects of relevant determinants on electricity access can help forecast future electricity requirements and implement appropriate measures. Previous research has not analyzed the impact of petroleum product prices on electricity access. The petroleum sub-sector, which complements the power sub-sector in the energy sector, is crucial for electricity generation in Ghana. The proportion of electricity generated from oil, gas, and coal indicates a country's dependence on fossil fuels for electricity (Atuahene and Sheng, 2023). Ghana's national power generation mix includes thermal plants that rely on fossil fuels. In 2021, thermal power plants accounted for 65.3 per cent of total power produced, hydropower plants for 34.1 per cent, and renewable energy sources for about 0.55 per cent (Energy Commission,

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2023). Therefore, petroleum products are necessary for powering these generation units or in-house generators, making petroleum product prices/taxes an opportunity cost for electricity prices/tariffs. This study examines the influence of petroleum product prices, among other variables, on electricity access in Ghana. It addresses the research gap by investigating the determinants of electricity access in Ghana, focusing on how petroleum product prices compare with electricity prices, GDP per capita, rural population growth, and foreign direct investment.

The study uses data from 2000 to 2022 collected from the World Development Indicators (WDIs) of the World Bank, the National Energy Statistical Bulletin (NESB) of the Energy Commission, and the National Petroleum Authority (NPA). Correlation and regression techniques, facilitated by the statistical package for the social sciences (SPSS), were used to analyse the data. This study theoretically augments our understanding of electricity access in Ghana by analyzing economic, demographic, and energy sector variables. It highlights the importance of petroleum pricing policies that promote economic growth and attract investments to improve access. Practically, the study offers recommendations for stakeholders to facilitate diversification of the energy mix and an equitable resource distribution to improve electricity access in Ghana.

Hypotheses Development

Previous research on electricity demand drivers can be categorized based on varied criteria. The first criterion includes studies using time-series data. Most of these studies identified economic structure fluctuations, economic output, urbanization, electricity tariffs, and technological changes as factors affecting electricity usage in Ghana (Dramani *et al*., 2012; Adom, 2017). Adom (2017) found an inverted U-shape relationship between electricity tariff and demand, indicating that tariff hikes are affordable up to a certain point, beyond which demand declines to zero. Additionally, Adusah-Poku *et al*. (2022) used time-series data to examine the effects of income, urbanization, economic structure, and power crises on electricity demand, finding that power crises adversely affect long-term electricity demand. Nkansah *et al*. (2022) found that GDP, foreign direct investment, trade openness, industry output, and total population growth positively and significantly relate to electricity usage. The second criterion involves studies using cross-sectional and survey data to investigate electricity demand drivers (Ali *et al*., 2020; Bouznit *et al*., 2018; Deryugina *et al*., 2020; Kim, 2018). Kim (2018) found that electricity usage depends on the quantity of electricity-drawing equipment. Bouznit et al. (2018) found that GDP variations determine African electricity consumption. Ali et al. (2020) found that electricity access and consumption drive income changes and economic development.

The third criterion focuses on how power crises impact electricity demand by reducing firm performance and household well-being (Abeberese *et al*., 2021; Allcott *et al*., 2016; Chen et al., 2023; Dzansi *et al*., 2018; Nduhuura *et al*., 2021). Nduhuura et al. (2021) found that power outages affect household access to food, social services, security, and electrical equipment functionality. Dzansi *et al*. (2018) found that households exposed to rolling power outages accumulate more unpaid balances than those on critical feeders. Chen *et al*. (2023) found that power outages affect different countries differently, with greater impacts in lower-income countries with vast land and lower electrification rates. Allcott *et al*. (2016) found that power outages decreased manufacturing output by 5 per cent in India and increased self-generation costs by 0.5 per cent. Abeberese *et al*. (2021) found that eliminating power outages could boost firm productivity by 10 per cent, noting that firms using generators to mitigate outages face negative productivity impacts due to capital shifts towards electricity generation instead of productive assets. This underscores the need to examine the influence of petroleum (generator fuel) prices on electricity access.

Notably, specific studies on the effects of petroleum product prices on electricity access in Ghana are scarce. To address this research gap and enrich the literature on universal electricity access, aligned with the seventh sustainable development goal (SDG 7), which seeks to safeguard access to affordable, reliable, sustainable and modern energy for all (UN, 2018), this study uses regression analysis on annual time -series data to determine electricity access determinants, introducing petroleum products price as a new variable. The following hypotheses are proposed:

Hypothesis 1 (H_1): *Petroleum product prices affect access to electricity.*

H_0: *Petroleum product prices do not affect access to electricity.*

Hypothesis 2 (H_2): *Electricity prices, GDP per capita, rural population growth, and foreign direct investment affect access to electricity.*

H_0: *Electricity prices, GDP per capita, rural population growth, and foreign direct investments do not affect access to electricity.*

***Decision Rule of Hypotheses*:** Reject an alternate hypothesis when the significance level is not within the 95% confidence interval ($P \geq 0.05$). Failing to accept an alternate hypothesis implies acceptance of its corresponding null hypothesis (H_0).

Materials and Methods

Data on electricity access, GDP per capita, rural population growth, and foreign direct investment were sourced from the WDIs of the World Bank, electricity price data from the NESB of the Energy Commission, and petroleum products (petrol, diesel, and liquefied petroleum gas (LPG)) price data from the NPA. Data were collected from 2000 to 2022 and analyzed with correlation and regression analyses facilitated by SPSS.

Model specification

The following models were specified to assess the effect of petroleum product prices on electricity access:

$$EA = f(P, D, LPG) \ldots\ldots\ldots \quad (1)$$

$$EA = f(EP, GDPPC, RPG, FDI) \ldots\ldots \quad (2)$$

Where EA denotes electricity access (given as a percentage of the population), P denotes petrol price, D denotes diesel price, LPG denotes the price of liquefied petroleum gas, EP denotes electricity price, GDPPC denotes GDP per capita, RPG denotes rural population growth, and FDI denotes foreign direct investment. Equations (1) and (2) can be econometrically modelled as:

$$EA = \alpha_0 + \alpha_1 Pt + \alpha_2 Dt + \alpha_3 LPGt + \beta_0 \ldots\ldots\ldots \quad (3)$$

$$EA = \alpha_0 + \alpha_4 EPt + \alpha_2 GDPPCt + \alpha_3 RPGt + \alpha_4 FDIt + \beta_0 \quad (4)$$

Where α_0 is the intercept, α_1 to α_4 represent the sensitivities of the independent and control variables, measured by P, D, LPG, EP, GDPPC, RPG, and FDI, and β_0 is the error term.

Results and discussion

Results of correlation analysis

The Pearson's product-moment correlation analysis results (see Table 1) evinced strong, positive, and statistically significant correlations between access to electricity and the price of petrol ($r = .837^{**}$, $n = 23$, $p = .000$), diesel price ($r = .792^{**}$, $n = 23$, $p = .000$), LPG price ($r = .839^{*}$, $n = 23$, $p = .000$), electricity price ($r = .943^{**}$, $n = 23$, $p = .000$), GDP per capita ($r = .964^{**}$, $n = 23$, $p = .000$) and foreign direct investment ($r = .747^{**}$, $n = 23$, $p = .000$). However, there was a strong, negative, and statistically significant correlation between access to electricity and rural population growth ($r = -.931^{**}$, n

= 23, p = .000). This negative correlation could be explained by the slow pace of rural electrification in relative opposition to the fast growth rate of rural populations.

Regression analysis results

Based on the statistically significant correlations logged, two sets of multiple regressions were run to predict access to electricity from petrol price, diesel price, LPG price, electricity price, GDP per capita, rural population growth, and foreign direct investments. The results from the analyses run using SPSS 20 are chronicled in Tables 2 and 3, and each table is explained.

The R^2 values of 89.4 % for the first model, which encapsulates petroleum prices, means that 89.4 % of the variation in access to electricity is explained by petroleum prices. The remaining 11.6 per cent of the variation in electricity access may be explained by other independent variables which were not included in the model. The F-statistic value for the model was 53.512, with a 0.000 significance value at 1 per cent. Henceforth, the null hypothesis is rejected at a 1% significance level. Thus, it can be concluded that the regression model statistically significantly predicts access to electricity.

The results of the first multiple regression (Model 1) run revealed that two independent variables out of the three significantly predict the dependent variable (p < .05). The prices of petrol and diesel statistically significantly predict access to electricity, F (3, 19) = 53.512, p =.000, R^2= .894. Thus, the study's hypothesis regarding the effects of petroleum product prices is supported, as petrol and diesel prices stimulate access to electricity. However, LPG prices did not have a statistically significant effect on electricity access in Ghana, albeit it evinced a strong and positive correlation. The coefficients of the independent variables depict that while a unit increase in petrol price causes electricity access to rise by 0.42 units, a unit increase in diesel price reduces access by 0.253 units at a statically significant level of 1 per cent. This implies that rising diesel prices have more severe negative impacts on electricity access than the relative rising petrol prices. The results of the second multiple regression (Model 2) revealed that two of the four independent variables significantly predict the dependent variable (p < .05). Electricity prices and GDP per capita were statistically significant predictors of access to electricity. However, the bearings of foreign direct investments and rural population growth on electricity access were insignificant, although the dependent and independent variables were statistically significantly correlated. The findings of this study corroborate the studies of Adom (2017), Adusah-Poku *et al*. (2022), Bouznit *et al*. (2018), and Dramani et al. (2012). Adom's

Table 1 Correlation analysis results

		EA	P	D	EP	LPG	GDPPC	RPG	FDI
EA	Pearson Correlation	1	.837	.792**	.943**	.839**	.954**	-.931**	.747**
	Sig. (2-tailed)		.000	.000	.000	.000	.000	.000	.000
	N	23	23	23	23	23	23	23	23
P	Pearson Correlation	.837**	1	.995**	.867**	.996**	.784**	-.907**	.423*
	Sig. (2-tailed)	.000		.000	.000	.000	.000	.000	.044
	N	23	23	23	23	23	23	23	23
D	Pearson Correlation	.792**	.995**	1	.821**	.987**	.739**	-.871**	.372
	Sig. (2-tailed)	.000	.000		.000	.000	.000	.000	.080
	N	23	23	23	23	23	23	23	23
EP	Pearson Correlation	.943**	.867**	.821**	1	.873**	.879**	-.927**	.653**
	Sig. (2-tailed)	.000	.000	.000		.000	.000	.000	.001
	N	23	23	23	23	23	23	23	23
LPG	Pearson Correlation	.839**	.996**	.987**	.873**	1	.779**	-.909**	.395
	Sig. (2-tailed)	.000	.000	.000	.000		.000	.000	.062
	N	23	23	23	23	23	23	23	23
GDPPC	Pearson Correlation	.954**	.784**	.739**	.879**	.779**	1	-.907**	.824**
	Sig. (2-tailed)	.000	.000	.000	.000	.000		.000	.000
	N	23	23	23	23	23	23	23	23
RPG	Pearson Correlation	-.931**	-.907**	-.871**	-.927**	-.909**	-.907**	1	-.644**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000		.001
	N	23	23	23	23	23	23	23	23
FDI	Pearson Correlation	.747**	.423*	.372	.653**	.395	.824**	-.644**	1
	Sig. (2-tailed)	.000	.044	.080	.001	.062	.000	.001	
	N	23	23	23	23	23	23	23	23

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Table 2 Model summaries and analysis of variance (ANOVA) results

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.946[a]	.894	.877	5.30469	1.805
2	.979[a]	.958	.948	3.44098	1.815

	Model	Sum of Squares	df	Mean Square	F	Sig.
1	Regression	4517.402	3	1505.801	53.512	.000[b]
	Residual	534.655	19	28.140		
	Total	5052.057	22			
2	Regression	4838.932	4	1209.733	102.171	.000[b]
	Residual	213.126	18	11.840		
	Total	5052.057	22			

a. Dependent Variable: EA
b. Model 1 Predictors: (Constant), LPG, D, P
c. Model 2 Predictors: (Constant), FDI, RPG, EP, GDPPC

Table 3 Coefficients of regression

Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	**Std. Error**	**Beta**		
1 (Constant)	45.443	2.196		20.691	.000
P	.420	.083	7.124	5.033	.000
D	-.253	.043	-4.821	-5.844	.000
LPG	-.082	.048	-1.496	-1.725	.101
2 (Constant)	45.309	11.374		3.984	.001
EP	.022	.007	.428	3.224	.005
GDPPC	.011	.003	.537	3.080	.006
RPG	-2.356	7.397	-.052	-.318	.754
FDI	-8.472E-011	.000	-.008	-.081	.937

a. Dependent Variable: EA
b. Model 1 Predictors: (Constant), LPG, D, P
c. Model 2 Predictors: (Constant), FDI, RPG, EP, GDPPC

The regression equations are derived from the model equations as follows:

$EA = \alpha_0 + \alpha_1 Pt + \alpha_2 Dt + \alpha_3 LPGt + \beta_0 \ldots\ldots\ldots$ (3)

$EA = 45.443 + .420P - .253D - .082LPG \ldots\ldots\ldots$ (3b)

$EA = \alpha_0 + \alpha_4 EPt + \alpha_2 GDPPCt + \alpha_3 RPGt + \alpha_4 FDIt + \beta_0 \ldots\ldots\ldots$ (4)

$EA = 45.309 + .022EP + .011GDPPC - 2.356RPG - 8.472E-011FDI \ldots\ldots\ldots$ (4b)

(2017) study indicates that tariff hikes are affordable up to a given threshold, beyond which demand falls, and lends credence to the negative correlation between rural population growth and access to electricity found in this study. Furthermore, the study findings of Nkansah *et al*. (2022) regarding the positive relation between GDP, foreign direct investment and electricity usage support the findings of this research. The current findings also substantiate assertions by Abeberese *et al*. (2021) regarding the operating cost of generators (fuel price) and associated negative productivity effects.

Conclusion

This study has delved into the intricate dynamics of electricity access in Ghana from 2000 to 2022, focusing particularly on the influence of petroleum product prices alongside other key determinants such as electricity prices, GDP per capita, rural population growth, and foreign direct investment. The findings underscore the critical influence of petroleum product prices on electricity access, highlighting the adverse effects of rising diesel prices on electricity availability. Also, increased GDP per capita and electricity prices positively predict improved electricity access, suggesting that economic growth and revenue generation are key to expanding access. Additionally, the study reveals that rapid rural population growth (strongly, negatively, and statistically significantly correlated with electricity access) strains existing infrastructure and limits access, necessitating targeted investments in rural electrification to meet the rising demand. However, the findings prove that foreign direct investment complements

existing energy infrastructure, as it exhibited a strong, positive, and statistically significant correlation with access to electricity.

The study enhances the theoretical understanding of electricity access determinants in Ghana, revealing how economic, demographic, and energy sector variables interact. By integrating these factors, the research provides a framework for analyzing electricity access, contributing to energy economics and development literature. Key findings suggest stabilizing petroleum prices is crucial for mitigating adverse impacts on electricity access. Economic growth and foreign direct investment also positively influence access, highlighting the need for policies promoting economic development. The study emphasizes targeted rural electrification projects to address rapid rural population growth challenges. It offers practical insights for stakeholders, including government agencies, utility companies, and investors, involving stabilizing petroleum prices, boosting GDP per capita, and attracting foreign direct investment. Efforts should focus on financial sustainability, equitable resource distribution, expanding grid connectivity, promoting off-grid solutions, and ensuring affordability in rural areas. Increasing investment in renewable energy sources like solar and wind can diversify the energy mix and enhance security, aligning with SDG 7. Future research should monitor socio-economic indicators, energy consumption patterns, and policy impacts and explore technological advancements like smart grids, energy storage, and digital payment systems to improve electricity access and efficiency in Ghana.

Conflict of Interest Declarations

The author declares that no conflict of interest influenced the research conducted in this report.

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