مجلة بحوث الإدارة والاقتصاد

Management & **E**conomics **R**esearch **J**ournal
ISSN 2710-8856 (Online)
ISSN 2676-184X (Print)
Vol. 4 No. 2 (2022): September, pp. 1-24

https://doi.org/10.48100/merj.2022.192

Check for updates

Household Effective Demand for Electricity in Ghana: Analysis and Implication for Tariffs

Jonathan D. Quartey ♦[1], Wisdom D. Ametorwotia[2], Prosper B. Laari[3]

[1]Ph.D., Kwame Nkrumah University of Science and Technology (Ghana)
✉ jdquartey@yahoo.com
[2]M. Phil., Kwame Nkrumah University of Science and Technology (Ghana)
✉ amet02@live.com
[3]Ph.D., University for Development Studies, Wa (Ghana)
✉ laariking@gmail.com

Received: 03-02-2022 *Accepted: 03-04-2022* *Published online: 07-04-2022*

How to Cite:
Quartey, J. D., Ametorwotia, W. D., & Laari, P. B. (2022). Household Effective Demand for Electricity in Ghana: Analysis and Implication for Tariffs. *Management & Economics Research Journal*, *4*(2), 1-24. https://doi.org/10.48100/merj.2022.192

Abstract:

Outcomes of most developing country projects to secure inclusive growth through electricity provision appear to hinge on available information regarding households' response to electricity. This study assessed the determinants of household electricity demand and estimated households' willingness to pay for electricity in Ghana. The study used a Contingent Valuation modelling procedure involving over 3000 households to derive an effective demand function for electricity in Ghana. This was done through a national household survey. A mathematical programming analytical procedure was used to comprehensively analyze Ghana's block pricing tariff system. The study found that Ghanaian households are willing to pay a monthly mean electricity tariff of 50.40 Ghana cedis (US$11.56), which is

♦**Corresponding author:** Kwame Nkrumah University of Science and Technology (Ghana).
[✉ jdquartey@yahoo.com]

©2022 the Author(s). This is an open-access article distributed under the terms of (CC BY-NC 4.0) which permits use, distribution and reproduction in any medium, provided the original work is properly cited and is not used for commercial purposes.

lower than the average monthly tariff of 73.67 Ghana cedis (US$16.90) paid by households. Thus, the average tariff paid by households monthly is 46% higher than the mean willingness to pay. The study also found that Ghana's highest impact determinants of electricity demand were affordability of tariffs, usage of electrical appliances, and availability of electricity, respectively. This study employs a mathematical programming procedure to determine Ghana's mean willingness to pay for electricity. This procedure is theoretically more robust than the often-used differential calculus approach since it incorporates the block pricing of electricity in Ghana, which the calculus approach ignores. Also, it uses the largest and most inclusive known sample, specifically designed to elicit households' willingness to pay for electricity in Ghana. The study is also unique in its findings.
Keywords: Contingent Valuation, Demand for Electricity, Electricity Tariffs, Ghana, Households, Willingness to Pay.
JEL Codes: O55, Q41, Q48, Q51.

1. Introduction

The expectation that households would opt for electricity, if available, appears untenable for several households in developing countries. In such countries, many issues remain unclear regarding households' effective demand for electricity. While many governments in developing countries have built some infrastructure for electricity supply, many households cannot meet the requirements for effective demand and thus remain deprived of electricity. Many households in developing countries do not have effective demand for electricity (Lee et al., 2016; World Bank, 1993).

While some subsidies have assisted households, such subsidies had to be substantial, leading to the nearly free provision of utility services (Whittington et al., 1993). In the absence of tariff payments that are high enough to provide adequate resources to service providers for investments in plant and equipment, initial installations deteriorate, bringing the systems down within short periods. This is due to a lack of equipment maintenance and improvement funds to cater to growing populations' increasing consumption. Thus, the structure of tariffs does not provide information regarding the responses of different households to different levels of electricity tariffs in these countries.

There is very little or no information on specific households' responses to electricity tariffs in Ghana. The absence of such information hinders the improvement of planning for electricity service delivery (Greenstone, 2014). The service is provided based on very little or no knowledge about how specific households will react, except a very generalised idea that households will respond favourably, even though on numerous occasions, such expectations have not worked in favour of service providers and investors (IMF, 2019; 2021). Thus, the reasons for such adverse responses to the expectations of electricity policymakers will have to be empirically ascertained to inform policy toward improving electricity planning and delivery in Ghana.

This study seeks to provide such information by eliciting from a random sample of over 3000 households in Ghana how much electricity they would want to use if provided at a specific tariff. Thus, it seeks to estimate the household's effective demand function for electricity in Ghana. This will determine how much different households will pay for electricity at different tariffs.

The following section provides some theoretical basis for the study and the research design. The factors determining household responses to electricity tariffs in Ghana are analysed in section 3. A discussion of the survey results with respect to how they can be employed to improve electricity delivery policy and planning is provided in section 4. The last section summarises the findings and concludes with some policy recommendations.

2. Theoretical framework and empirical studies

Demand functions are generated when consumers' utility functions covering N goods are maximised subject to their income constraints. Let D be the quantity of the good a consumer is willing and able to pay for, I being the consumer's income and $P_1, P_2, \ldots, P_N$ being the prices of the N goods. The consumer demand function (D) can then be stated in equation 1.

$$D = M\,(I, P_1, P_2, \ldots, P_N) \qquad (1)$$

While the quantity demanded of many goods depends on single prices, the electricity demand depends on a price schedule due to the block pricing of electricity. This makes the consumer's budget constraint for electricity non-linear. Thus, the consumer's equilibrium regarding electricity demand can theoretically only be determined using mathematical programming and not differential calculus (Taylor, 1975). This study estimates the demand for electricity in Ghana through mathematical programming based on the Contingent Valuation (CV) Model.

The conceptual framework for determining the household's demand for electricity is based on the household's indirect utility relationship (U). This is determined by the tariff paid for electricity (T), his income (I), the prices of all other commodities consumed by the household (P), and the tastes (S) of the household as depicted by its socioeconomic characteristics.

A change in the household's electricity provision from D_1 to D_2 will generate a willingness to pay (WTP) based on equality between two indirect utility functions represented by equation 2.

$$U (I_1 – WTP, P, D_2, S) = U (I_1, P, D_1, S) \quad (2)$$

Equation 3 represents the relationship between a household's willingness to pay for electricity and the change from D1 to D2. As such, the change from D1 to D2 is a key determinant of a household's willingness to pay for electricity.

$$WTP = m (D_1, D_2, I_1, P, S) \quad (3)$$

The study employed various formulations of demand analysis of households' willingness to pay (WTP) bids for electricity in Ghana. These are an Ordinary Least Squares (OLS) formulation, the Interval Regression Model, and an Ordered Logit Model approach. These formulations are theoretically depicted as equations 4, 5, and 6, respectively.

$$WTP = m (D_1, D_2, I_1, P, S) + e \quad (4)$$

$$WTP^{lower} < m (D_1, D_2, I_1, P, S) + e < WTP^{upper} \quad (5)$$

$$V^{lower} < n (D_1, D_2, I_1, P, S) + e < V^{upper} \quad (6)$$

The OLS model explains WTP bids in equation 4, where the household willingness to pay for electricity is a point estimate, with e as the error term. WTP responses are estimated as intervals in equation 5, which occur between one of the categories within the low and high starting points (WTP^{lower} and WTP^{upper}) bids. The assumption carried out by equation 5 is that households' preferences for electricity are only depicted as ordered by the responses households provide, V^{lower} being the lower-ranked and Vupper being the higher-ranked bids. This means the elicited bids indicate that one is higher than the other in rank, not as a numerical quantity. The endpoints represent the WTP endpoints, estimated as parameters through the ordered logit model.

Beginning with Houthakker (1951) as a pioneer, several empirical studies have modelled household demand for electricity, providing some analysis of its determinants. Within the past two decades, the works of Alberini and Filippini (2011), Mohammadi (2009), and others estimated household demand for electricity using data aggregation procedures.

The use of disaggregated data made the works of some later researchers more innovative than many earlier ones. Household demand for electricity was studied by Agostini et al. (2014), employing national data from Chile, and disaggregated at the household level. The results, however, were not too different from earlier studies.

Also, cointegration and error correction functions were employed by Fullerton et al. (2015) in a dynamic analysis study of household demand for electricity in Arkansas. They found a positive relationship between household income and demand for electricity due to the long-run effect of electricity-dependent asset acquisition.

Roy and Wolak (2021) estimated a model of household demand for electricity services and electricity demand in the Rajasthan State of India through a combination of household-level surveys and administrative data. Their model incorporated customer-level demographic characteristics, billing cycle-level weather variables, and the fact that households faced increasing block prices of electricity. Their structural demand model helped compare the welfare implications of current energy tariffs to those based on normative principles of efficient retail electricity pricing.

In addition, Ye et al. (2018) combined electricity tariff data with South African Income and Expenditure Survey data to explore the determinants of residential electricity demand in South Africa. They found household demand for electricity higher among appliance-rich households, households with large family sizes, and households living in large houses in urban areas.

Athukorala et al. (2019), studying electricity demand in Sri Lank, used survey data over five years to determine the effect of policy measures. They found that policy measures that used price changes would not be effective because price changes altered existing subsidies and reversed the objective of the price change. Also, Maboshe et al. (2018) found electricity tariff subsidies highly regressive in Zambia. They suggest a first-best response based on raising prices while targeting the vulnerable with social interventions.

3. Research design

This study adopts a quantitative research design based on a household field survey in Ghana. The questionnaire was used to elicit responses from households through face-to-face interactions. The questionnaire was a four-section document, beginning with questions on household demographic and socioeconomic characteristics. This was followed by questions on household electricity characteristics and how they assess it. The third section posed questions on how willing households were to pay for electricity. It began with a market description of electricity, after which willingness to pay was elicited through a bidding game procedure. The last section probed further to ascertain whether the respondent had a good concept of the value of electricity. Table 1 shows the descriptions of the variables used and their expected signs.

Eight interviewers carried out questionnaire administration. This lasted for approximately two weeks within a zone. Trained teaching assistants selected from the Kwame Nkrumah University of Science and Technology's Department of Economics in Ghana served as enumerators for the survey alongside the core research team.

Table 1. Variables, their descriptions, and expected signs

Variable	Description	Sign expected
	Household characteristics.	
Gender	Male respondent, 1; Female, 0.	+
Age	Respondent's age in years.	?
Dependents in school	Number of members of household schooling	-
Income	Total income of the head of household per month in Ghana cedis.	+
Education	Highest number of years of schooling of the household head.	+
Water	Monthly expenditure on water.	+
Savings	Monthly savings.	+
	Electricity use characteristics.	
Service rating	How well the service provider was doing on a scale of 1-5, 1 being the least and 5 being the highest performance.	+
Availability	Average number of hours of electricity in a normal day.	+
Usage	Number of appliances used by the household.	+
Lighting Needs	Number of electricity bulbs used by the household.	?
Commercial	Use of electricity for commercial purposes at home, 1; non-commercial use, 0.	+
Consumption	Monthly electricity consumption in kWh.	?
Cost of a power outage (CPO)	Amount of money spent on lighting during power Outages per day in Ghana cedis.	+
Reason for conserving Electricity (RFEC)	Cost-saving reasons for conserving electricity, 1; Non-cost saving reason, 0.	?
Affordability	Monthly tariff affordable, 1; not affordable, 0.	+
WTP (Dependent variable)	Amount household is willing to pay for the 24-hour daily provision of reliable electricity in Ghana cedis.	

Source: Authors' construct

3.1. Method

A hypothetical market was constructed, described to respondents as comprised of the supply and payment characteristics of electricity services to be provided. The service was a 24-hour supply of electricity a day through private service providers. The payment was through a pre-payment arrangement. The question to elicit the household's willingness to pay asked how much they would pay for such a service daily. The iterative bidding game procedure was employed to obtain households' maximum bids due to their familiarity with purchasing goods and services within their communities.

3.2. Sampling procedure

Ghana was divided into three zones as an initial stage of the multi-stage sampling approach. The next stage was the selection of regions, followed by selecting districts within the selected regions from the various zones. Probability selection procedures were employed based on the official classification from the 2010 Ghana population census data. The sampling function in the R software (Becker et al., 1988) was used to select communities for the survey. Households were then selected through a systematic sampling from the communities.

The study was policy-oriented and followed the accepted recommendation for sample size, as outlined by Garrod & Willis (2000), Mitchell & Carson (1989), and Arrow et al. (1993). Thus, based on the accuracy of WTP bids being ten per cent of the actual WTP with a 95% probability of success, the populations of the various communities, and a reasonable allowance for incomplete responses, a sample size of 3100 households was estimated.

3.3. Reliability of contingent valuation procedure

The Arrow report (1993) guidelines for CV studies were strictly adhered to in the CV procedure. In addition, some suggested procedures in the literature and practical experience from conducting CV studies were applied as and when necessary.

3.3.1. Protest bids

The NOAA panel report considers nonresponse rates of up to 20% appropriate for a good Contingent Valuation study. The nonresponse rate for this study (including protest bids) was 8.4%. Protest bids constituted 2.3% of the responses. Carson and Hanemann (2005) observed nonresponse bids from respondents protesting payment. These bids were dropped during the analysis until recent evidence showed that most were similar to (no) or (low) responses or amounts from discrete choice and continuous response formats, respectively.

Excluding the protest, bids bring the sample to 3026 (The protest bids were 74, 2.3% of the original sample, i.e., 3100). Thus, including the protest bids, the overall nonresponse rate becomes 8.4%. This percentage, based on the NOAA guidelines, is excellent. The NOAA report recommended a nonresponse rate of up to 20% as an acceptable benchmark (Arrow et al., 1993). Thus, the occurring nonresponse rate passed the NOAA test.

3.3.2. Validity

The traditional problem of the CV method has not been undervaluation but overvaluation of benefits yet obtained. If consumers want to be crafty, they would say a higher value so they can be provided with the good (hypothetical bias) from the Independent Power Providers (IPPs). The test for hypothetical bias was done by establishing whether actual payments were consistently lower than the willingness to pay (Blumenschein et al., 2008). This test showed that the study did not have a hypothetical bias.

Contingent Valuation studies determine consistency by assessing whether WTP correlates with household income and other socioeconomic characteristics (Whittington & Pagiola, 2012). In addition, Mitchell and Carson (1989) recommend a test to determine whether respondents will pay what they have stated in the hypothetical case for the CV study. Going by the results of the consistency tests, the respondents in this study are very consistent consumers of electricity. They were paying beyond what they were willing and/or able to pay, and their willingness to pay is related to their incomes and socioeconomic characteristics. Thus, the study passed the CV validity test.

3.3.3. Data cleaning

Responses that were outliers, those showing inconsistency and those not fully answered represented about 1.8 per cent of the administered questionnaire. Such responses were discarded. After cleaning the data, the sample size came to 3100. In addition, all protest bids were excluded from estimating the mean willingness to pay, as discussed under the protest bids above. This brought the final sample size to 3026.

3.3.4. Estimation procedure

Mathematical programming was used to estimate the willingness of households to pay for the daily 24-hour supply of electricity to households. This was to provide a demand function for electricity that met the theoretical plausibility criterion described in section 2 above. Here, block tariffs are reliably captured in the demand function, depicting a real and applicable demand relationship specific to electricity. A standard econometric procedure was employed using the R software framework to explain the determinants of the electricity demand function.

4. Presentation and analysis of results

The cross-tabulation (Table 2) of independent variables against their mean willingness to pay values shows that income, electricity consumption, and educational level of household heads positively related to households' willingness to pay for a day's worth of electricity. The age of the household head was also positively related to willingness to pay only up to 55 years, after which it declined. The Table also shows that only about 13% of households used electricity for some commercial purpose among households. These relationships show a consistency of the respondents in their choice decisions regarding electricity demand.

Table 2. Household characteristics and willingness to pay cross-tabulation

Variables	Categories	Percentage	Mean WTP
Age (in years)	Less than 25	9.42	1.8163
	25-35	34.60	1.8518
	35-45	32.32	2.0342
	45-55	14.08	1.8475
	55-65	6.05	1.7252
	65-75	3.54	1.7150
Commercial	Non-commercial	87.05	1.8824
	Commercial	12.95	1.9740
Consumption group	1.0-50	7.04	1.0510
(In kilowatt hours)	51-150	67.75	1.6971
	151-300	18.90	2.4962
	301-600	5.75	3.0123
	601 and above	0.56	4.5488
Education level	No Formal Education	11.04	1.5725
	Primary Education	9.22	1.7101
	Junior High Education	28.88	1.7019
	Senior High Education	32.88	1.9753
	Tertiary	17.97	2.5961
Gender	Male	55.58	1.9865
	Female	44.42	1.7789
Income group	Less than 100	7.04	1.4264
(In Ghana cedis)	100-500	42.99	1.6222

Variables	Categories	Percentage	Mean WTP
	500-1000	35.96	1.9880
	1000-1500	8.72	2.5700
	1500-2000	2.84	2.9873
	2000-2500	0.59	2.5911
	2500 and above.	1.85	2.7591

4.1. Regression analysis

4.1.1. Determinants of WTP for electricity

Analysis regarding the determinants of WTP for electricity sought to provide insight into the factors influencing household willingness to pay bids significantly. This was carried out through multivariate analysis to estimate the functional relationship between the factors and WTP bids for households.

4.1.2. Diagnostic tests

Many diagnostic tests were conducted to verify the genuineness of the relationships established in our models. A multicollinear test based on the variance inflation factor (VIF) showed that the study was free from multicollinearity. The results of the (imtest) and (hottest) showed the presence of heteroskedasticity, which was corrected using robust standard methods.

The specification tests were also performed. The tests for bias in the specification of the WTP model revealed the presence of specification errors. This was corrected by including the squares of consumption and income in the model.

4.1.3. Regression results

Tables 3, 4 and 5 show results for two different model specifications of 3 estimators. These estimators are the OLS, the interval regression, and the ordered logit models. For each estimator, the two specifications are—first, an estimation comprising the full list of explanatory variables used in the survey. Second, the estimation consists of a restricted list of explanatory variables. The use of this approach demonstrates the sensitivity of the model to specification variations. Thus, the results all show six different formulations, giving consistent results and attesting to the WTP model's robustness.

Table 3. Ordinary least squares regression results

WTP	Coefficient	Robust Std. Error	P-value	Coefficient	Robust Std. Error	P-value
Constant	0.077175	0.148002	0.6020	0.109701	0.129228	0.3960
Gender	0.087371	0.044881	0.0520			
Age	-0.006832	0.001960	0.0000	-0.007577	0.001880	0.0000
Dep. in school	-0.013763	0.012923	0.2870			
Income	0.0004223	0.000096	0.0000	0.000446	0.000091	0.0000
Income square	-0.000000	0.000000	0.0000	-0.000000	0.000000	0.0000
Availability	0.123651	0.034427	0.0000	0.123635	0.033039	0.0000
Affordability	0.394160	0.054832	0.0000	0.403655	0.054743	0.0000
CPO	0.025255	0.006554	0.0000	0.025844	0.006452	0.0000
Service rating	0.010298	0.019984	0.6060			
Education	-0.002737	0.005415	0.6130			
Usage	0.110607	0.018121	0.0000	0.113624	0.017117	0.0000
Lighting needs	0.002412	0.000510	0.0000	0.002437	0.000503	0.0000
Commercial	0.007236	0.073263	0.9210			
Consumption	0.007624	0.000847	0.0000	0.007500	0.000836	0.0000
Cons. squared	-0.000006	0.000006	0.0000	-0.000006	0.000002	0.0000
RFEC	-0.036341	0.053446	0.4970			
Water	0.000073	0.000282	0.7960			
Savings	0.000263	0.000178	0.1410			
Observations		=	3,0260		=	3,0260
F (18, 3007)		=	41.390		=	72.4200
P-value		=	0.0000		=	0.0000
R-squared		=	0.2545		=	0.2522
Root MSE		=	1.1832		=	1.1834

The results from all three estimators being consistent for all variables also show the reliability of the WTP model. Affordability of tariffs, availability of electricity, age and income of household head, cost of a power outage, the type of electricity usage, household consumption of electricity, and household lighting needs were all statistically significant determinants of WTP for electricity in Ghana. Each of these explanatory variables positively influenced WTP except for the age of the household head.

Table 4. Results for interval regression

WTP	Coefficient	Robust Std. Error	P-value	Coefficient	Robust Std. Error	P-value
Constant	-0.045193	0.134711	0.7370	-0.011495	0.116618	0.9210
Gender	0.076794	0.041029	0.0610			
Age	-0.005724	0.001809	0.0020	-0.006485	0.001714	0.0000
Dep. in school	-0.011807	0.011461	0.3030			
Income	0.000385	0.000087	0.0000	0.000413	0.000083	0.0000
Income square	-0.000000	0.000000	0.0000	-0.000000	0.000000	0.0000
Availability	0.121891	0.031395	0.0000	0.122428	0.030279	0.0000
Affordability	0.385214	0.050889	0.0000	0.393856	0.050834	0.0000
CPO	0.026108	0.006284	0.0000	0.026644	0.006185	0.0000
Service rating	0.012333	0.018698	0.5090			
Education	-0.002188	0.004987	0.6610			
Usage	0.109351	0.016535	0.0000	0.113277	0.015649	0.0000
Lighting needs	0.002240	0.000413	0.0000	0.002267	0.000407	0.0000
Commercial	-0.015901	0.066177	0.8100			
Consumption	0.007520	0.000717	0.0000	0.007391	0.000711	0.0000
Cons. squared	-0.000007	0.000001	0.0000	-0.000006	0.000001	0.0000
RFEC	-0.039322	0.048880	0.4210			
Water	0.000046	0.000254	0.8560			
Savings	0.000292	0.000164	0.0760			
/lnsigma	0.070779	0.0228003	0.0020	0.0726228	0.022735	0.0010
sigma	1.073344	0.0244726	1.026435	1.075325	0.024447	1.0285
Observations			3026			3026
	Wald $Chi^2(18)$		865.67			849.91
P-value			0.0000			0.0000

In addition, the explanatory variables that were statistically insignificant were the educational level and gender of the household head, the number of dependents in school, and the way a household rates the current electricity service. Also, whether a household used electricity for some commercial purpose, the reason the household conserves electricity, and the amount of money paid as a water bill by the household was not statistically significant in determining WTP. The WTP model is statistically significant, with an F-statistic of 41.39. An R^2 of 0.2545 meets the standard of reliability based on the expected R^2 for CV studies. Whittington (1992) and Mitchell and Carson (1989) established the standard as a minimum R^2 of 0.15 for CV studies.

Table 5. Ordered logit regression results

WTP	Coefficients	Robust Std. Error	P-value	Coefficients	Robust Std. Error	P-value
Gender	0.121146	0.066965	0.0700			
Age	-0.007537	0.003030	0.0130	-0.008118	0.002879	0.0050
Dep. in school	-0.012981	0.018070	0.4730			
Income	0.000541	0.000139	0.0000	0.000551	0.000136	0.0000
Income square	-0.000000	0.000000	0.0000	0.000000	0.000000	0.0000
Availability	0.189496	0.051573	0.0000	0.177569	0.049191	0.0000
Affordability	0.639029	0.085916	0.0000	0.647813	0.085982	0.0000
CPO	0.031330	0.008459	0.0000	0.032660	0.008323	0.0000
Service rating	-0.015071	0.031293	0.6300			
Education	-0.001217	0.008546	0.8870			
Usage	0.255768	0.029221	0.0000	0.252753	0.028053	0.0000
Lighting needs	0.003262	0.000565	0.0000	0.003336	0.000556	0.0000
Commercial	-0.135430	0.107596	0.2080			
Consumption	0.015395	0.001154	0.0000	0.015185	0.001153	0.0000
Cons. squared	-0.000016	0.000002	0.0000	-0.000016	0.000002	0.0000
RFEC	0.012574	0.081349	0.8770			
Water	0.000055	0.000446	0.9020			
Savings	0.000684	0.000233	0.0030	0.0007305	0.000232	0.0020
Observations			3026			3026
Wald Chi^2 (18)			876.71			867.68
P-value			0.0000			0.0000
Pseudo R^2			0.0846			0.0841

4.2. Highest-impact variables

The three significant independent variables with the consistently largest effects on willingness to pay for electricity in each model provide a direct economic explanation relevant to policy. These variables were affordability of tariffs (0.64), usage of electrical appliances (0.25), and availability of electricity (0.19), respectively.

Households for whom the monthly tariff was affordable made higher bids than those for whom the monthly tariff was not affordable. Also, households better assured of getting electricity in a day made higher bids than those less certain whether they would get electricity in a day. In addition, households that used more electrical appliances made higher bids than those that used fewer.

The implication is that if tariff reduction makes electricity more affordable, it will attract more usage if only its availability can be guaranteed. This would lead to the demand for more electrical appliances, which could increase the productive use of electricity and the output of goods and services.

The other explanatory variables that were consistently statistically significant in all the models were the cost of a power outage, the amount of electricity consumed, the household head's age, lighting needs, and household income, respectively. Even though these variables were statistically significant, the strength of their coefficients was too weak compared to the first three. Thus, even though significant, household income consistently had the least effect on households' willingness to pay for electricity compared to all the other explanatory variables in all the models.

4.3. Estimating WTP

Computations leading to estimating the mean WTP for a day's worth of electricity are provided in Table 6, as explained below. The population in the various WTP intervals (column 3) is obtained by multiplying the sampling frequency (column 2) by households with access to electricity, which is 3509901. Also, the total WTP (column 4) is obtained by multiplying the WTP midpoint for each WTP interval (column 1) by the interval's population (column 3). Thus, the total WTP per day for electricity becomes 5 905,671.68 Ghana cedis (total of column 4) depicted by the area under the daily demand for electricity curve. This brings the mean WTP for a day's electricity in Ghana to 1.68 Ghana cedis (5,905671.68 divided by 3509901). This amounts to a monthly willingness to pay for electricity of 50.40 Ghana cedis (US$11.56).

Table 6. Total willingness to pay for electricity in Ghana

WTP interval midpoint	WTP frequency distribution (%)	Population	Total WTP for electricity	Cumulative population
0.25	14.04	492790	123197.53	3509901
0.75	21.78	764456	573342.33	3017111
1.25	13.38	469625	587030.94	2252654
1.75	24.75	868700	1520225.87	1783030
2.25	6.61	232004	522010.03	914329
2.75	8.20	287812	791482.68	682325
3.25	2.08	73006	237269.31	394513
3.75	2.97	104244	390915.22	321507
4.25	0.30	10530	44751.24	217263
4.75	4.36	153032	726900.50	206733
5.25	0.07	2457	12898.89	53701
5.75	0.43	15093	86782.30	51245
6.75	0.30	10530	71075.50	36152
8.5	0.73	25622	217789.36	25622
	100	3509901	5905671.68	

Source: Authors' construct

5. Discussion of findings and policy implications

5.1. Affordability of tariffs

The order in which affordability and availability of electrical work are of great importance to get the demand relationship right. If governments are bent on ensuring availability at all costs, they may enter into agreements with investors to supply electricity at a very high cost. This will work against the electricity demand, causing underutilisation of the capacity created through the agreements. This is due to the strength of the affordability effect. The relative strengths of the highest impact variables are affordability of tariffs (0.64), usage of electrical appliances (0.25), and availability of electricity (0.19), respectively. It is worth noting that the affordability effect (0.64) is more than three times greater than the availability effect (0.19).

Here an increase in affordability of one unit will increase demand by 1.08 units (i.e., 0.64 + 0.25 + 0.19), where availability comes only after affordability, to complement the role of affordability and induce usage of electricity through households purchasing electrical appliances. This effect tends to exceed the unit change in affordability that caused it, making the gain higher than any reduction in tariff that would cause electricity to be affordable. Thus, a multiplier effect is produced on demand for electricity if affordability becomes the most important consideration.

If, on the other hand, affordability is compromised, making availability the most important consideration, then the order is broken, making the affordability effect work against the availability effect (0.19 – 0.64), reducing effective demand by 0.45 units for a unit increase in availability. This dampens the electricity demand.

In addition, affordability decisions must be guided by the mean WTP. The monthly mean WTP of 50.40 Ghana cedis is lower than the average monthly tariff of 73.67 Ghana cedis households pay. Thus, the average tariff paid by households monthly is 46% higher than the mean WTP. This implies that household incomes must be increased to the extent that they can pay 46% higher than they are willing to pay without any loss in welfare to achieve optimal affordability of household electricity tariffs. If incomes remain the same, then existing tariffs must be reduced by at least 46%—about 87% of the households consume between 51 and 300 units of electricity monthly. From the PURC (2020) block tariff chart, a household consuming 300 units pays 203.71 Ghana cedis monthly. To make tariffs affordable, households consuming 300 units of electricity should enjoy income increases to offset the difference between what they are willing to pay and what they are paying. If incomes remain unchanged, then a 46% reduction in tariff, which is 93.72 Ghana cedis per household monthly, will be required.

If the government decides to subsidise tariffs for these consumers, then it would need to pay 93.72 Ghana cedis per household for the households every month. Even in the case of households willing to pay the modal monthly bid tariff of 52.50 Ghana cedis, a 40.3% reduction in current tariffs is required to reach affordable levels. This set of households would require a subsidy of at least 82.1 Ghana cedis per household monthly, amounting to at least 71.3 million Ghana cedis per month, making 855.6 million Ghana cedis (about US$196.24 million) per annum. This subsidy covers about 25% of households. Notably, 49.6% of households willing to pay less than the modal bid value would require a higher subsidy.

It is also worth noting that whether incomes are increased, or subsidies are provided, it will pay off in the long term. The additional income would induce electrical appliance expenditures, increasing household electricity demand. The only situation under which household welfare worsens is when the government does nothing about the unaffordable tariffs.

5.2. Affordability and current tariff payments

A discussion of affordability and current tariff payments is relevant for consumers whose current tariffs were higher than their average willingness to pay. Theoretically, this is possible because tariffs have been determined solely from the supply side, breaching the normal economic principle. If the tariff is a price, it must be determined by the interaction of demand and supply. However, this is not the case here; the cost of production and supply is imposed on consumers as a tariff. Thus, in economic theory, the tariff here does not qualify as the price. This has been the case because the Ghana Energy Commission recognised the very high rate of increase in tariffs, sending Ghana from a low tariff category to one of the highest in the world (Ghana Energy Commission, 2015).

End-user tariffs in Ghana increased by more than 593.6% between 2006 and 2015 (Ghana Energy Commission, 2016), while incomes in the neighbourhood increased by 250%. This has increased the proportion of households' incomes that are paid for electricity, thereby reducing the welfare of consumers. If a commodity impoverishes a consumer, it's rational for them to refuse to pay a tariff that exceeds a reasonable proportion of their income. This is especially true if the consumer can access a substitute, as is often the case in Ghana.

A tariff determined solely by the cost of production is not worth being called a price! It is purely cost, and cost does not determine willingness to pay since the cost is from the supply side. This creates a big gap between required payments (bills) and consumers' WTP. The following paragraphs provide empirical evidence from some studies on utility consumers whose average WTP was effectively lower than what they currently pay as tariffs.

In their Kenya study, Lee et al. (2016) found the following. After a valuation experiment, households were asked whether they had made some sacrifices due to the electricity payments they had to make. About 29% of the households had to forgo some basic consumer goods, while about 19% had to skip payment of outstanding school fees for their children.

If a household has to sacrifice children's school fees to pay for electricity, it simply does not have what it takes to pay what it currently pays. So, given the opportunity, this household expresses its true value for electricity in a WTP lower than the payment made.

A study on Rwanda published by the Center for the Study of African Economies, University of Oxford, in 2016 found the average WTP for electricity to be far below market price (bills) (i.e., 40-50% of the market price) and changed only marginally even with a credit scheme. Households might have been facing binding budget constraints that do not allow them to spend on electricity. Here the households revealed WTP were between 20%-30% of their monthly expenditures. The conclusion was that the vast majority of households were not able to pay cost-covering prices. This means there was no effective demand for electricity.

Taale and Kyeremeh (2015) found that 244 households (25.7% of their sample) were unwilling to pay for improved electricity services in Cape Coast, Ghana. Over 26% of respondents in this category responded that current tariffs were already too high.

In their Anambra State Study, Whittington et al. (1990) found that WTP values were systematically related to income and socio-demographic variables but were very low. The perplexing result was that it was far lower than what households already paid as tariffs to obtain the water they consumed.

Based on this finding and another similar one, the World Bank (1993) recommended categorising demand for water utilities. This categorisation includes areas where residents were willing to pay for improved service but unable to pay, as WTP was very low relative to the cost of provision of the utility service. These are the realities on the ground. Any attempt to ignore these consumers or to revise their valuation upwards would result in a policy that will backfire.

It might appear that a large percentage of Ghanaians are paying electricity bills. However, bill non-payments for electricity in Ghana are one of the main difficulties the electricity sector faces.

5.3. Future expectations and installations and gadget investments

Consumers who had already invested in the connections for electricity supply and purchased gadgets over the periods when tariffs were good may be compelled to continue paying unaffordable tariffs (McNeil & Letschert, 2005). Thus, consumers feel compelled to continue consuming some electricity and therefore have to pay something, hoping that things may get better someday when they can get higher incomes to offset the welfare effect of current payments.

This is based on the premise that Ghana's government believes tariffs are too high for most consumers, which is why subsidies are paid to them. A proposal of the Government of Ghana, to the PURC in the 2018 Budget Statement, for a 13% reduction in residential electricity tariffs vindicated the respondents. The government explained that their calculations showed consumers were overcharged for electricity. Therefore, they requested reductions. The Minister for Finance in the previous government (Mr Seth

Terkper) commended the government for the reductions in an interview on Metro TV (Good Evening Ghana) on Wednesday, 16th November 2017 (also captured by the Daily Graphic of 20th November 2017). This shows that even state authorities had been looking for some opportunity to reduce tariffs and the economic burden on consumers for quite a long time.

5.4. Power theft, payment defaults, and illegal connections

Customer non-payment of electricity bills has been a serious problem for the Electricity Company of Ghana. So many illegalities have accompanied this in the household electricity sector for about a decade. For instance, in Accra, the Accra West Region of the Electricity Company of Ghana (ECG) reportedly lost about 3.9 million Ghana cedis annually due to illegal connections (GNA, 2021).

In 2017, the ECG was to retrieve about GHS2.89 million being illegally used electricity from the nation's grid by 464 households through meter bypass theft of electricity in Accra. This illegality was detected through ECG monitoring of 108,896 consumers that year. It was also found that about 17% of consumers were involved in illegal electricity activities. About 85 of them had carried out unauthorised service connections, while 156 households had altered the settings of their meters, with three households connecting illegally to the grid. Too many consumers were still not paying their bills even after disconnection, and court action was being considered by the ECG (Bonney, 2017).

5.5. Availability versus affordability

The move to ensure the availability of electricity without affordability considerations has landed Ghana in a quagmire of electricity sector debt. As of 2019, Ghana had about 4,600 MW of dependable capacity to generate electricity, which was about 70% more than the peak demand load. The country had to pay about US$500 million yearly for electricity generation capacity, which was not being used due to the nature of contracts with independent private power producers (IMF, 2019; 2021).

One result of the excess capacity coupled with inefficiency has been lower economic welfare. By late 2018, Ghana had owed arrears of about US$ 2.7 billion, comprising US$ 880 million in indebtedness to fuel and private power plant suppliers. The country's projection of the electricity sector shortfall in financing in 2019 was a minimum of US$ 1 billion, which amounted to about 1.5% of GDP. In terms of government cost accumulation, including current arrears, the estimate is US$ 12.5 billion by 2023 due to structural deficits in the sector and costly contracts with effect from 2020 (IMF, 2019; 2021).

Even amid excess electricity generation capacity, the lack of reliability of supply has further worsened uptake. ECREEE (2019) and Blimpo et al. (2019) have reported that Ghana's electricity service is unreliable. The ECG and GRIDCO have always blamed technical challenges for most power outages (Daily Graphic, 2021). Electricity unreliability has a two-way effect on tariffs and tax revenues for the government. First, it dampens the incentive of citizens to pay tariffs and taxes. Secondly, frequent and unplanned power outages would lead to lower output than expected, resulting in lower tax revenues and tariffs.

The regression results show that putting availability first will not escape acute electricity problems since it breaks the order of flow of impact depicted by the relative strengths of the coefficients. The Ghanaian situation amply illustrates the error in giving preference to availability over and above affordability.

5.6. Uses of electricity

The regression results show that increasing electricity usage using more electrical appliances positively impacts electricity demand. Again, this must come in the right order, where affordability is prioritised, followed by usage and availability. Thus, if electricity tariffs are affordable and electricity is available, consumers will purchase more electrical appliances and create electricity demand. However, if the order is altered, the transmission mechanism's effect will be curtailed. The ability of consumers to purchase electrical appliances will depend on their incomes, the prices of the appliances, and the availability of credit or hire purchase schemes. Using electricity will tend to affect output growth and economic growth positively.

However, the problem with Ghana's electricity consumers with respect to output growth is that most household consumption is for nonproductive purposes. The WTP was expressed in the electricity demand based on what consumers perceive electricity, apart from the known household uses. Since most households (70%) use electricity mainly for non-commercial purposes, a large percentage of Ghanaians do not have the right information about the best uses of electricity. When electricity is perceived as a means for leisure and pleasure derived through entertainment and lighting, it will cease to influence output and economic growth significantly, even with 100% access.

6. Conclusion and recommendations for policy

This study sought to assess the factors that determine the demand for electricity in Ghana and how these factors could be harnessed to inform energy policy for inclusive growth. For many years African governments and development partners have hoped that increasing electricity availability would create effective demand for electricity, leading to increased growth. However, several efforts to provide households with electricity have not received the expected response in Ghana. This has led to excessive indebtedness to the state electricity service providers and the government (IMF, 2019; 2021). There is so much that needs to be known about the factors determining the electricity demand in Ghana.

The study, therefore, used a national survey of over 3000 households to derive an effective demand function for electricity in Ghana through a Contingent Valuation approach. It also assesses the determinants of electricity demand and estimates households' mean willingness to pay for electricity in Ghana.

The study found that Ghanaian households are willing to pay a monthly mean of 50.40 Ghana cedis (US$11.56) for electricity. This is lower than the average monthly tariff of 73.67 Ghana cedis (US$16.90) households pay. Thus, the average tariff paid by households monthly is 46% higher than the mean WTP.

The study also found that Ghana's highest impact determinants of electricity demand are affordability of tariffs, usage of electrical appliances, and availability of electricity, respectively. Furthermore, the study found that most households in Ghana demand electricity primarily for non-commercial purposes. Thus, Ghana's electricity demand is mainly for non-income generation uses.

It is recommended that the incomes of poor households be increased to the extent that it will compensate for their income loss due to expenditures on electricity tariffs, created by the difference between their mean willingness to pay and their actual payments for electricity. This would go a long way in improving household welfare. The income increase could also empower several households to acquire more electrical appliances and demand more electricity for increased economic output.

If incomes remain unchanged, then tariffs will have to be subsidised by at least 46% for consumers of electricity who spend more than 10% of their incomes on electricity, not to make them economically worse off for using electricity.

It is also recommended that electricity service providers prioritise the affordability of tariffs over and above the availability of electricity since the strength of affordability as a determinant of electricity demand generates a multiplier effect for household electricity demand in Ghana.

In addition, the government of Ghana would need to embark on an intensive educational campaign to educate households on the most productive uses of electricity. This will go a long way to help change the attitude of households toward electricity, such as for pleasure, leisure, and entertainment, toward more productive uses. Since energy is the ability to work, if electricity provided is not put to productive and commercial use, the needed growth in national output cannot be attained to break the vicious circle of household poverty in Ghana.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

This research was funded by: The International Growth Centre, London School of Economics, U.K.

References

Agostini, C. A., Plottier, C., & Saavedra, E. (2014). Elasticities of residential electricity demand in Chile. In *Energy & the Economy, 37th IAEE International Conference, June 15-18, 2014*. International Association for Energy Economics.

Alberini, A., & Filippini, M. (2011). Response of residential electricity demand to price: The effect of measurement error. *Energy Economics*, *33*(5), 889-895. https://doi.org/10.1016/j.eneco.2011.03.009

Arrow, K., Solow, R., Portney, P. R., Leamer, E. E., Radner, R., & Schuman, H. (1993). Report of the NOAA panel on contingent valuation. *Federal Register*, *58*(10), 4601-4614.

Athukorala, W., Wilson, C., Managi, S. & Karunarathna, M. (2019). Household demand for electricity: The role of market distortions and prices in competition policy. *Energy Policy*. Vol. 134 (110932). https://doi.org/10.1016/j.enpol.2019.110932

Becker, R. A., Chambers, J. M. & Wilks, A. R. (1988). *The New S Language*. Wadsworth & Brooks/Cole.

Benavente, J. M., Galetovic, A., Sanhueza, R., & Serra, P. (2005). Estimando la demanda residencial por electricidad en Chile : El consumo es sensible al precio. *Cuadernos de economía*, *42*(125), 31-61. https://doi.org/10.4067/S0717-68212005012500002

Blázquez, L., Boogen, N., & Filippini, M. (2013). Residential electricity demand in Spain: new empirical evidence using aggregate data. *Energy Economics*, *36*, 648-657. https://doi.org/10.1016/j.eneco.2012.11.010

Blumenschein, K., Blomquist, G. C., Johannesson, M., Horn, N., & Freeman, P. (2008).

Eliciting willingness to pay without bias: evidence from a field experiment. *The Economic Journal*, *118*(525), 114-137. https://doi.org/10.1111/j.1468-0297.2007.02106.x

Bonney, E. (2017). Accra West ECG Retrieves GHS2.89m from Errant Customers. Daily Graphic, No. 20501, Graphic Communications Group Limited, Accra: Ghana.

Carson, R. T., & Hanemann, W. M. (2005). Chapter 17 Contingent Valuation. In K.-G. Mler & J. R. Vincent (Eds.), *Handbook of Environmental Economics* (Vol. 2, pp. 821–936). Elsevier. https://doi.org/https://doi.org/10.1016/S1574-0099(05)02017-6

Daily Graphic. (2021). ECG, GRIDCo blame power outage on 'technical challenge', 'disturbances'. https://www.graphic.com.gh/news/general-news/ecg-gridco-blame-power-outage-on-technical-challenge-disturbances.html

ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE). (2019). Off-grid Solar Market Assessment and Private Sector Support Facility Design: Ghana Report. http://www.ecreee.org/sites/default/files/ecreee_rogep_regional_report.pdf

Fullerton, T.M., Resendez, I.M. & Wallke, A.G. (2015) Upward Sloping Demand for a Normal Good? Residential Electricity in Arkansas. *International Journal of Energy Economics and Policy*, 5(4), 1065 – 1072.

Garcia-Cerrutti, L. M. (2000). Estimating elasticities of residential energy demand from panel county data using dynamic random variables models with heteroskedastic and correlated error terms. *Resource and Energy Economics*, *22*(4), 355-366. https://doi.org/10.1016/S0928-7655(00)00028-2

Garrod, G. D., & Willis, K. G. (1999). Methodological issues in valuing the benefits of environmentally sensitive areas. *Journal of Rural Studies*, *15*(1), 111-117. https://doi.org/10.1016/S0743-0167(98)00046-1

Ghana Energy Commission. (2016). National Energy Statistics 2006-2015. Strategic Planning and Policy Division, Accra, Ghana.

Ghana Energy Commission. (2015). 2016 Energy (Demand and Supply) Outlook for Ghana. Accra, Ghana: The Energy Commission of Ghana.

Ghana News Agency (GNA). (2021). Accra West ECG loses GHS3.9 million in nine months through illegal connections. Accessible at myjoyonline.com on 30th October 2021.

Greenstone, M. (2014). Energy, Growth and Development. *International Growth Center Evidence Paper*.

Houthakker, H. S. (1951). Some calculations on electricity consumption in Great Britain. *Journal of the Royal Statistical Society. Series A (General)*, *114*(3), 359-371. https://doi.org/10.2307/2980781

Holtedahl, P., & Joutz, F. L. (2004). Residential electricity demand in Taiwan. *Energy Economics*, *26*(2), 201-224. https://doi.org/10.1016/j.eneco.2003.11.001

Hondroyiannis, G. (2004). Estimating residential demand for electricity in Greece. *Energy Economics*, *26*(3), 319-334. https://doi.org/10.1016/j.eneco.2004.04.001

International Monetary Fund (IMF). (2019). Ghana Staff Report for the 2019 Article IV Consultation. Country Report No. 19/367. IMF Washington DC. https://doi.org/10.5089/9781513523347.002

International Monetary Fund (IMF). (2021) Ghana Staff Report for the 2021 Article IV Consultation. Country Report No. 21/165. IMF Washington DC.

Lee, K., Miguel, E., & Wolfram, C. (2016). Experimental Evidence on the Demand for and Costs of Rural Electrification. 22292. Cambridge, MA. https://doi.org.10.3386/w22292

Lin, B. (2003). Electricity demand in the People's Republic of China: investment requirement and environmental impact. ERD working paper series no. 37. Asian Development Bank.

Maboshe, M., Kabechani, A. & Chelwa, G. (2018). The household effects of very large electricity tariff hikes in Zambia. Economic Research Southern Africa (ERSA) working paper 767. https://doi.org/10.1016/j.enpol.2018.10.041

McNeil, M. A., & Letschert, V. E. (2005). Forecasting electricity demand in developing countries: A study of household income and appliance ownership. *European Council for an Energy Efficient Economy-2005 Summer Study.* Mandelieu, France. LBNL-58283, 85, 90.

Miller, J. (2002). Modelling residential demand for electricity in the US: a semiparametric panel data approach. Unpublished manuscript, Department of Economics, Rice University.

Mitchell, R.C. & Carson, R.T. (1989) *Using Surveys to Value Public Goods: The Contingent Valuation Method*, Washington, D.C: Resource for the Future

Mohammadi, H. (2009). Electricity prices and fuel costs: Long-run relations and short-run dynamics. *Energy Economics*, *31*(3), 503-509. https://doi.org/10.1016/j.eneco.2009.02.001

Narayan, P. K., Smyth, R., & Prasad, A. (2007). Electricity consumption in G7 countries: A panel cointegration analysis of residential demand elasticities. *Energy Policy*, *35*(9), 4485-4494. https://doi.org/10.1016/j.enpol.2007.03.018

Roy, S. S. & Wolak, F. A. (2021). A Household-Level Model of Demand for Electricity Services and Welfare Analysis of Electricity Prices in Rajasthan. Policy Research Working Paper 9718. The World Bank.

Taale, F., & Kyeremeh, C. (2016). Households′ willingness to pay for reliable electricity services in Ghana. *Renewable and Sustainable Energy Reviews*, *62*, 280-288. https://doi.org/10.1016/j.rser.2016.04.046

Taylor, L. D. (1975). The demand for electricity: a survey. *The Bell Journal of Economics*, *6*(1), 74-110. https://doi.org/10.2307/3003216

Whittington, D., Briscoe, J., Mu, X., & Barron, W. (1990). Estimating the willingness to pay for water services in developing countries: A case study of the use of contingent valuation surveys in southern Haiti. *Economic development and cultural change*, *38*(2), 293-311. https://doi.org/10.1086/451794

Whittington, D., & Pagiola, S. (2012). Using contingent valuation in the design of payments for environmental services mechanisms: a review and assessment. *The World Bank Research Observer*, *27*(2), 261-287. https://doi.org/10.1093/wbro/lks004

Whittington, D., Smith, V. K., Okorafor, A., Okore, A., Liu, J. L., & McPhail, A. (1992). Giving respondents time to think in contingent valuation studies: a developing country application. *Journal of Environmental Economics and Management*, *22*(3), 205-225. https://doi.org/10.1016/0095-0696(92)90029-V

World Bank Water Demand Research Team. (1993). The demand for water in rural areas: determinants and policy implications. *The World Bank Research Observer*, 8(1),47-70. https://doi.org/10.1093/wbro/8.1.47

Ye, Y., Koch, S. F. & Zhang, J. (2018). Determinants of household electricity consumption in South Africa. *Energy Economics,* 2018(75),120-133. https://doi.org/10.1016/j.eneco.2018.08.005