Price Reform and Household Demand for Electricity

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September 2009

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Abstract

This paper estimates a model of residential electricity demand to project the impact of proposed tariff changes on a representative sample of 130 Barbadian households. The results from the demand function suggest that the price elasticities of demand for particular appliances varied significantly, with households that utilize solar water heating being more price elastic than households that use air conditioning and electric water heating . The income effects were, however, statistically insignificant as they may have been captured by choices of appliances rather than utilisation. The income elasticity for households with solar water heating was found to be negative, probably reflecting the substitution impact arising from the use of solar power to provide water heating. The database also allowed the authors to breakdown price and income elasticities by individual households and these results suggest that middle-income households tend to be more prices sensitive, indicating that these households may be more able to reduce their usage of discretionary appliances than low-income households. The propose changes in the electricity rate structure was investigated and determined to likely have very little influence on households demand for electricity. Changes in consumption will however be more noticeable within upper consumption and upper income households.

JEL Classification: Q41; C24; O54

Keywords: Electricity demand; Price Reform; Heckman estimator; Developing country

1. Introduction

The Barbados Light and Power Company (BL&P), which under current law, is the only electricity service provider in Barbados, has recently been given permission by the Fair Trading Commission (FTC), to submit its application for a review to its rates and rate structure, which have not been changed since 1983. This action was required as it was thought that the current rates do not permit the BL&P to maintain its reliability and efficiency as well as to satisfy lenders and attract new capital. One aspect of these proposed reforms that are likely to be important to the deliberations between the FTC and the BL& P is the effects of these price revisions on consumption which will depend on the price elasticity of demand for electricity. The latter would require knowledge of demand for electricity studies in as much details as possible.

This paper estimates a demand for electricity function for Barbados to assess the impact of the proposed rate changes on consumers. For the first time, survey data on Barbadian households are utilised. Past electricity demand studies for Barbados (Cox, 1978; Durant, 1991; Mitchell, 2009) have not addressed policy issues like the one proposed above and have been based on aggregate time series macro data of the country. For instance, aggregate electricity consumption is usually regressed on an income variable and a price variable over various time periods with stationary and non-stationary time series econometrics techniques. No work has been done employing micro-level data or micro-econometrics. Some authors have recently shown that the use of micro-level data, which reflects individual and household behaviour more closely, can add detail to an understanding of the nature of consumer responses (see, for instance, Hawdon, 1992; Nesbakken, 1999; Holtedahl and Joutz, 2004; Louw et al., 2008). Microeconomic approaches to energy and electricity demand modelling also enable an analysis across different heterogeneous household groups and allow for the incorporation of a wide variety of household characteristics within the estimated equations (see Hawdon, 1992).

The demand for electricity services is a derived demand where households desire certain energy-using appliances and require electricity to power these durable goods

(Dubin and McFadden, 1984). Hence, it would be appropriate to model the electricity demand for individual appliances; however, data at this level of disaggregation is not available. Electricity demand is therefore modelled as the sum of the electricity used by i appliance categories.

Like most electricity providers around the world, the price of electricity services supplied in Barbados are non-linear, in that on top of a fixed customer fee a three-tier price schedule is employed. This type of household demand function requires the application of the usual censored regression modelling techniques. In this paper, the model is estimated using the Heckman two-step approach (see Cameron and Trivedi, 2005 for details). Due to the existence of non-linear pricing, Reiss and White (2005) elasticities on the marginal and average price as well as income variables are calculated.

Once the electricity demand function is shown to give reasonable findings, it can be used to project the impact of the tariff changes on the Barbadian consumers, by adjusting the price variables while leaving the other variables unchanged. The results imply that the propose new rate structure is generally not likely to have a significant impact on households demand for electricity.

In the following section, the background to the rate adjustment is discussed. After that, a brief review of the demand for electricity literature is provided. Then the empirical approach, which consist of the conceptual set up, the econometric methodology and data is presented. Next the statistical results are discussed and the paper closes with a brief conclusion.

2. Background to Rate Application

The BL & P submitted an application for a review of its rates and rate structure to the Fair Trading Commission (FTC) on May 8, 2009. The previous application for a review of rates by the BL&P was in 1983 when the then Public Utilities Board granted the company an increase in its basic electricity rates. The BL & P indicated that the present rate application is being made because the current rates are inadequate for the

Company to continue to meet its operating and maintenance expenses, satisfy lenders and attract new capital to replace older plant. Some of the main objectives of the rate application as outlined by the Company include:

i. The provision of fair rates and to apportion the total cost of service among the different classes of customers in a fair manner, sensitive to any impact on customers.
ii. To encourage customers to use electricity more efficiently by, revising the existing rates to more closely reflect the unit cost of serving customers, thereby reducing the inter and intra class subsidies that presently exist;
iii. To shift the 2.64 cents per kWh of fuel cost from the base energy rate to the Fuel Clause Adjustment (FCA) so that the full fuel cost is collected through the FCA;
iv. To revise the Service Charges so that they may more closely reflect the cost of service; and
v. To lessen the rate impact of the overall revenue increase on customers in the lower income bracket.

The rate application is proposed to affect the structure of all of the Company's existing tariff groups. The Domestic Service tariff group which services residential customers, is expected to see changes to its fixed domestic customer fee and the base energy charge. Currently domestic service customers are first charged a BDS$3 fixed customer fee, on top of an inclining three-tier price schedule (Figure 1). Customers using up to 100 kWh presently have to pay BDS$0.176 per kWh. Those customers utilizing in excess of 100 kWh are charged BDS$0.196 for the next 900 kWh and BDS$0.216 for each additional kWh above of 1000 kWh. The BL&P is therefore seeking permission to adjust the customer charge to an inclining block price structure where customers that consume less than 100 kWh on average over a twelve month period will be charged a BDS$6 monthly fee, while the customer price will increase to BDS$10 for those consuming between 101 and 500 kWh and BDS$14 for those customers consuming a monthly twelve month average above 500 kWh.

A four-tier inclining block rate is proposed for the base energy charge that is expected to see the exclusion of the 2.64 cents per kWh that presently goes towards the fuel cost being shifted from the base energy rate to the FCA. It is proposed that customers using up to 100 kWh will be charged BDS$0.150 per kWh, while those consumers utilising in excess of 100 kWh would have to pay BDS$0.176 per kWh for the next 400 kWh. Customers using in excess of 500 kWh will pay a price of BDS$0.200 per kWh for the next 1,000 kWh and BDS$0.224 per kWh for any consumption greater than 1,500 kWh (Figure 1).

3. A Brief Review of the Literature

The demand for electricity is a derived demand in that consumption of electricity does not yield any utility but rather is an input into durable goods that do yield utility. Taylor (1975) argues that it is important to understand from the outset the differences between long-run and short-run electricity demand. In the short-run, electricity demand generally arises from the utilisation of durable goods, while in the long-run demand can be influenced by the stock of these goods the consumer demands.

One of the earliest studies on residential household demand is provided by Houthakker (1951), using observations from 42 provincial towns in the United Kingdom between 1937 and 1938. The annual average electricity consumption per customer was regressed on average money income per household, the marginal price of electricity, the marginal price of gas and average holdings of heavy equipment. Houthakker reports that the income elasticity of demand for electricity was about 1.2, while the price elasticity of demand was -0.9. One of the main shortcomings of this early study was that the author did not explicitly attempt to model either the short-run or the long-run. In a follow-up study, however, Houthakker and Taylor (1970) use a two-equation model of personal consumption expenditures on electricity, where consumption is modelled as a function of stocks, income and relative prices, while the change in stocks of durable goods is equal to electricity consumption and depreciation. The study finds that while in the long-run the absolute values for income and price elasticity of demand are around 2, in the short-run, electricity demand tends to be relatively price and income inelastic (about 0.1); comparable results are obtained by Mount et al., (1973), Anderson (1973), Houthakker et al., (1973) and Griffin (1974). Taylor (1975) notes that most of this early literature finds that the price and income elasticity of demand for electricity is larger in the long-run and electricity demand tends to be fairly price and income elastic in the long-run. These results were by and large derived from highly aggregated data.

Given this criticism of the early literature, Parti and Parti (1980) employ a database of more than 5,000 individual households from the San Diego County in 1975. Noting that the consumption of electricity is derived from the utilisation of appliances, the study first attempts to account for the expected electricity usage given the appliances in the household. Actual usage is then explained by the presence of the following characteristics: an air conditioner; square footage of residence; weighted average of the average electricity prices in the previous two months; household income; presence of electric space heater; presence of electric water heater; number of people in household; number of appliances in the common effect category, and; the number of non-refrigerator appliances in the common effect category possessed by the household. The results suggest that the short-run price elasticity of demand was about -0.6 and the income elasticity of demand was 0.2. These estimates were quite similar to the earlier papers using aggregate time series data. Rather than separating the demands for non-durables and electricity separately, Dubin and McFadden (1984) develop a unified model of the demand for consumer durables and the derived demand for electricity. When this is done, the price elasticity estimates for income fall to 0.02, while that for price elasticity declines to -0.3. Similar lower short-run elasticities are obtained by Munley et al., (1990) for multi-family, renter-occupied residences as well as Maddock et al., (1992) in the case of Colombia.

Reiss and White (2005) estimate a model of residential electricity demand using a representative sample survey of 1307 California households. The survey collects information not only on electricity consumption, but also on household appliances, physical characteristics of the residence as well as demographic household information.

The reported results suggest that the price elasticities of demand for particular appliances varied significantly. However, air conditioning had the highest price elasticity of demand of the five appliance types considered. The income effects were, however, statistically insignificant as these effects may have been captured by choices of appliances rather than utilisation and agree with studies by Parti and Parti (1980) and Dubin and McFadden (1984). In terms of household price and income elasticities, Reiss and White report that the mean annual electricity price elasticity for California households was about -0.4, which is within the range reported by previous studies, while the income elasticity was zero.

4. Empirical Approach

4.1 Conceptual Framework

In electricity demand studies it is customary (see Dubin, 1985; Varian, 1992; Filippini and Pachauri, 2002; Holtedahl and Joutz, 2004; Louw et al., 2008) to assume that the household demand for electricity is derived from the demand of the commodity itself (electricity) and the service that electricity provides (i.e. being able to operate domestic appliances, televisions, etc.). Therefore, a general household utility function incorporating the household's electricity demand would generally take the form of

$$U = u(x\{E, A, F\}, y, z) \qquad (1)$$
$$s.t. \;\; m < p_x x + p_y y$$

where x is the energy services consumed by the household, E is electricity, A are appliances, F are other fuels consumed by the household, y are goods and services consumed by the household, z represents the tastes and preferences of the household, m is the income of the household, p_x is the price of energy services and p_y are the prices of the other goods and services consumed. With maximising household utility being the objective, the Lagrange function given below can be formed:

$$\mathcal{L} = u(x\{E, A, F\}, y, z) - \lambda(p_x x + p_y y - m) \qquad (2)$$

The first-order conditions from this Lagrange function allow us to derive Marshall Demand function for the household's demand for energy services as follows:

$$x = x^{*}(p_x, m, z, \varepsilon) \qquad (3)$$

The household's tastes and preferences (z) are incorporated in the demand function as they form part of the decision process in determining which fuels are used by the household as well as they reflect any externalities that may impact on health and productivity. The stochastic term, ε , is added to the equation for estimation purposes.

4.2 Econometric Approach

Like most electricity providers around the world, the price of electricity services supplied in Barbados are non-linear. As mentioned in Section 2 domestic services are first charged a BDS$3 fixed customer fee, on top of this fee a three-tier price schedule is then employed (Figure 1).

Given this non-linear pricing schedule, Reiss and White (2005) note that the stochastic term in Equation (3) conveys information about the willingness-to-pay of the consumer, i.e. consumers self-select the marginal price they are willing to pay. The demand function for the household under a three-tier pricing schedule therefore takes the following form:

$$x^{*} = \begin{cases} x(p_x^1, m^1, z; \beta) + \varepsilon & if \ \varepsilon < c_1 \\ x(p_x^2, m^2, z; \beta) + \varepsilon & if \ c_1 < \ \varepsilon < c_2 \\ x(p_x^3, m^3, z; \beta) + \varepsilon & if \ c_2 < \varepsilon < c_3 \end{cases} \qquad (4)$$

Equation (4) is a censored regression model that can be estimated using the usual censored regression modelling techniques. The model is estimated utilising the Heckman two-step approach (see Cameron and Trivedi, 2005).

As noted in Section 3.1, the demand for electricity services is a derived demand where individuals consume certain energy-using appliances and therefore desire electricity to power these durable goods (Dubin and McFadden, 1984). In this instance, modelling the electricity demand for individual appliances would be preferred; however, data at this level of disaggregation is not available. Consequently, electricity demand is modelled as the sum of the electricity used by i appliance categories:

$$x_i = x_i^*(p_x, m, z; \beta) + \varepsilon_i \tag{5}$$

where $\beta = \sum_i d_i \beta_i$ are the slope coefficients that depend on the household's holdings of particular appliances with d_i being a dummy variable that takes a value of 1 if the household holds appliance i and 0 otherwise. Following Dubin and McFadden (1984), the choice of space cooling and water heating are isolated, while the other appliances are treated as statistically exogenous. There are two motivations for making this simplifying assumption: (1) this approach increases the degrees of freedom as a smaller set of interaction terms are employed, and; (2) space and water heating are major consumption decisions that require significant retrofitting of the house. In contrast, the other appliances usually do not require such substantial investments.

4.3 Data

The empirical electricity demand data employed in this study is taken from the Residential Customer Survey (RCS) of consumers conducted by the Barbados Light and Power in 1997 as part of a larger study. The survey collects information on the electricity consumed by the particular household, their portfolio of appliance holdings along with demographic information. It provides information on 129 Barbadian households, which is less than 0.2 percent of households on the island. It is a nationally representative probability sample of households, with representative sub samples among usage levels. The survey was conducted by in-home interview. Interviewers inventory the household's appliances, assess physical characteristics of the residence, and collect demographic information. To minimize measurement error, each household's metered energy consumption data are sourced directly from the electric utility. Approximately one hundred and thirty-three interviews were completed among residential customers, thus representing a response rate of 97 per cent.

The variable descriptions are provided in Table 1. The consumption of electricity, x , is approximated by the monthly electricity usage. Two price variables are employed in the study: the average price of electricity and the marginal price of electricity. The average price is obtained by dividing the consumer's monthly bill in Barbados dollars by the amount of electricity (kWh) used, while the marginal price is the highest per kWh tier price that the consumer presently pays. Income is approximated by an interval variable ranging from 1, where the household's monthly income is less than BDS$1,200 to 5, if the household's income exceeds BDS $10,000 on a monthly basis. In terms of other household characteristics, variables representing the number of persons and bedrooms in the household are employed as well as the type of housing unit. The appliance portfolio is made up of dummy variables for the existence of televisions, refrigerator, washing machine, dryer, freezer, electric stove, toaster oven, wall fan, and security lighting.

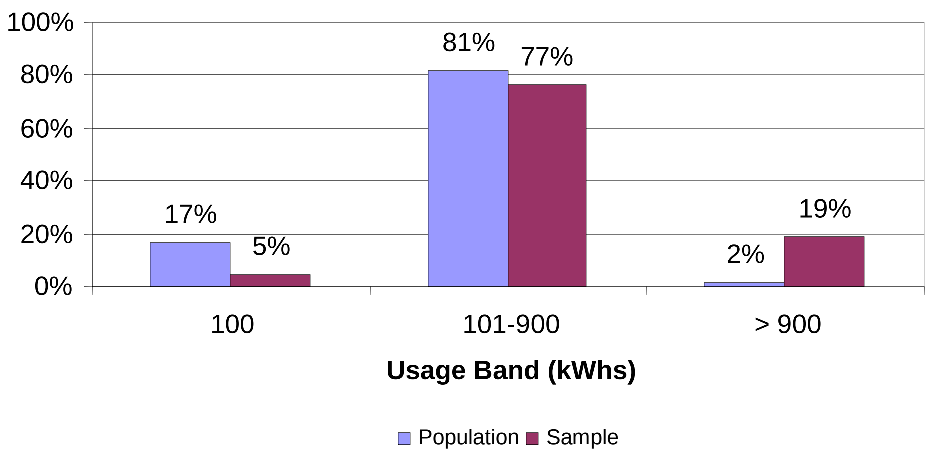
Table 1: Description of Variables

Mnemonic	Description	Scale
MONKWH	Monthly electricity usage of households	kWh
P	Average price of electricity (monthly electricity bill/monthly electricity usage)	Barbados Dollars
MP	Marginal price of electricity	Barbados dollars
INCOME	Monthly Income of household	1 = under $1200; 2 = $1200 - $2399; 3 = $2400-$4399; 4=$4400-$6399; 5=$6400-$10000;6=more than $10000
NTEL	Number of televisions	Scalar
PERSONS	Number of persons in household	Scalar
BEDROOMS	Number of bedrooms in residence	Scalar
FRIGE	Household has a refrigerator	1 if household has a refrigerator and 0 otherwise

WASHING	Household has a washing machine	1 if household has a washing machine and 0 otherwise
DRYER	Household has a dryer	1 if household has a dryer and 0 otherwise
FREEZER	Household has a freezer	1 if household has a freezer and 0 otherwise
ELESTOVE	Household has an electric stove	1 if household has an electric stove and 0 otherwise
TOASTERO	Household has a toaster oven	1 if household has a toaster oven and 0 otherwise
WALLFAN	Household has a wall fan	1 if household has a wall fan and 0 otherwise
MULUNT	Household is a multi-unit property	1 if household is a multi-unit property and 0 otherwise
SELIGHT	Household has security lighting	1 if household has security lighting and 0 otherwise
ELECHEAT	Household uses electric water heating	1 if household uses electric water heating and 0 otherwise
AC	Household has air conditioning	1 if household has air conditioning units installed and 0 otherwise
SOLAR	Household has solar water heating	1 if household has a solar water heater installed and 0 otherwise

Figure 3 provides an indication of the distribution of electricity usage in Barbados and within the sample. On the whole, most consumers (over 70 percent), tend to consume 100 – 900 kWh on a monthly basis and therefore fall in tier 2 of the BL & P three-tier price schedule. Of the remainder, just fewer than 20 percent consume more than 900 kWh on a monthly basis while a relatively small proportion of Barbadian households (below 10 percent) consume less than 100 kWh of electricity on a monthly basis.

Figure 2: Comparative Proportion of Customers by Usage



Descriptive statistics for the variables employed in the study are shown in Table 2. They suggest that the average Barbadian household uses about 546 kWh of electricity per month which translates to about BDS$105, or about BDS$0.19 per kWh. The average household sampled had a monthly income of BDS$4,400, lived in three-bedroom house with three individuals in the household.

Table 2: Descriptive Statistics

	Mean	Max	Min	Std. Dev.	Skewness	Kurtosis	Jarque-Bera
MONKWH	546.426	2636.000	54.000	449.038	1.749	6.889	147.076*
P	0.190	0.210	0.180	0.006	0.703	5.136	35.139*
MP	0.203	0.220	0.180	0.009	0.484	3.980	10.199*
INCOME	3.124	6.000	0.000	1.541	0.241	2.370	3.386
NTEL	1.085	5.000	0.000	1.250	0.681	2.483	11.417*
PERSONS	3.271	6.000	0.000	1.638	0.319	2.224	5.423
BEDROOMS	3.085	6.000	0.000	1.125	-0.036	4.195	7.707*
FRIGE	0.977	1.000	0.000	0.151	-6.326	41.024	8631.741*
WASHING	0.853	1.000	0.000	0.356	-1.991	4.962	105.882*
DRYER	0.147	1.000	0.000	0.356	1.991	4.962	105.882*
FREEZER	0.488	1.000	0.000	0.502	0.047	1.002	21.500*
ELESTOVE	0.318	1.000	0.000	0.467	0.782	1.612	23.515*
TOASTERO	0.411	1.000	0.000	0.494	0.362	1.131	21.593*
WALLFAN	0.690	1.000	0.000	0.464	-0.821	1.674	23.945*
MULUNT	0.093	1.000	0.000	0.292	2.802	8.853	352.937*
SELIGHT	0.178	1.000	0.000	0.384	1.681	3.826	64.416*
ELECHEAT	0.186	1.000	0.000	0.391	1.614	3.604	57.935*
AC	0.248	1.000	0.000	0.434	1.167	2.361	31.458*
SOLAR	0.318	1.000	0.000	0.467	0.782	1.612	23.515*

5. Results

5.1 Electricity Demand Function

Table 3 displays the estimated electricity demand function for Barbados using the Heckman two-step procedure, where the Mills ratios are omitted because their economic interpretation is unclear. The second stage of the Heckman estimator was estimated using ordinary least squares (OLS) as well as full information maximum likelihood techniques. However, the results from both techniques were quite similar. Consequently, only the findings from the OLS estimation approach are displayed, with the reported standard errors being White heteroskedasticity-consistent standard errors. The model is able to account for a large proportion of the cross-sectional variation in electricity consumption, 85 percent. The calculated Jarque-Bera statistic for the model residuals suggested that the null hypothesis of normality could not be rejected at normal levels of testing.

Given that the model is a reasonably adequate representation of electricity demand in Barbados, an analysis of the estimated coefficient estimates is now given. The coefficient estimates on the appliance holdings show the proportional change in electricity consumption based on consumers' portfolio holdings (washing and elestove). The other appliances were statistically insignificant and therefore dropped out with the use of stepwise least squares. The coefficient for the existence of a washing machine was positive and statistically significant, suggesting that the presence of a washing machine is noteworthy in explaining the demand for electricity in Barbadian households.

It was somewhat surprising that the number of bedrooms had a significant positive effect on the demand for electricity while the size of the household effect was insignificant. One would have expected that household size would have a positive coefficient as larger families would consume more electricity, as well as utilise more electricity to light and cool or heat the rooms in the house depending on the seasonal requirement. Halvorsen (1975) however notes that households with larger numbers may substitute electrical power consumption with the use of natural gas for certain requirements that would be energy intensive. Leth-Peterson (2001) found evidence of such substitution for Danish households.

Table 3: Electricity Demand Model Coefficient Estimates – Heckman Two-Step Approach

Explanatory Variable	Baseline Use	Interaction Effects		
		Electric Water Heating	Solar Water Heating	Air conditioning
Constant	1.914 (5.113)	-175.589 (33.224)***	9.007 (4.157)**	-9.564 (4.015)**
p	-0.183 (0.0366)***	-1.272 (0.237)***	-	-
mp	0.061 (0.019)***	-0.473 (0.092)***	0.055 (0.025)**	-0.057 (0.024)**
income	0.029 (0.042)	-	-0.105 (0.064)*	0.135 (0.057)**
bedrooms	0.099 (0.034)***	-0.145** (0.061)	-	-
washing	0.259 (0.112)**	-	-	-
elestove	0.085 (0.076)	-	-	-
mulunt	-0.243 (0.226)	-	-	-
persons	-	-	0.086 (0.046)*	-
R-squared	0.853			
s.e.	0.335			
Jarque-Bera	0.207 [0.901]			

Notes: (1) White heteroskedasticity-consistent standard errors provided in parentheses, while p-values are given in parentheses.
(2) ***, ** and * indicates significance at the 1, 5 and 10 percent levels of significance.

Due to the existence of non-linear pricing, the coefficients on the marginal and average price as well as income variables cannot be interpreted as elasticities. As a result, following Reiss and White (2005) the non-linear price elasticity which accounts for the substitution and income effects is estimated using the following equation:

$$\eta = \frac{mp}{x} . [\beta_{mp} + \beta_y x] \qquad (6)$$

The calculated price and income elasticities are provided for all households as well as those with electric water heating, air conditioning and solar water heating (Table 4). The computed price elasticity of demand for Barbadian households was -0.778, which is somewhat lower than that obtained by Houthakker (1951), but in line with studies which also use less aggregated data (Parti and Parti, 1980; Dubin and McFadden, 1984; Munley et al, 1990; Maddock et al, 1992). For electric water heating, the price elasticity of demand fell to -0.756, suggesting that these households tend to be less price sensitive relative to the average Barbadian household. In contrast, households with solar water heaters were more price sensitive, which might be explained by the fact that these households substitute the electricity demanding water heaters, for the heater that had no reliance on electricity. The price elasticity of households with air conditioning was generally consistent with those obtained for the average household.

Table 4: Price and Income Elasticities for Barbadian Households

Explanatory Variable	Price Elasticity	Income Elasticity
All households	-0.778	0.015
Electric water heating households	-0.756	-
Air conditioning households	-0.775	0.031
Solar water heating households	-0.783	-0.002

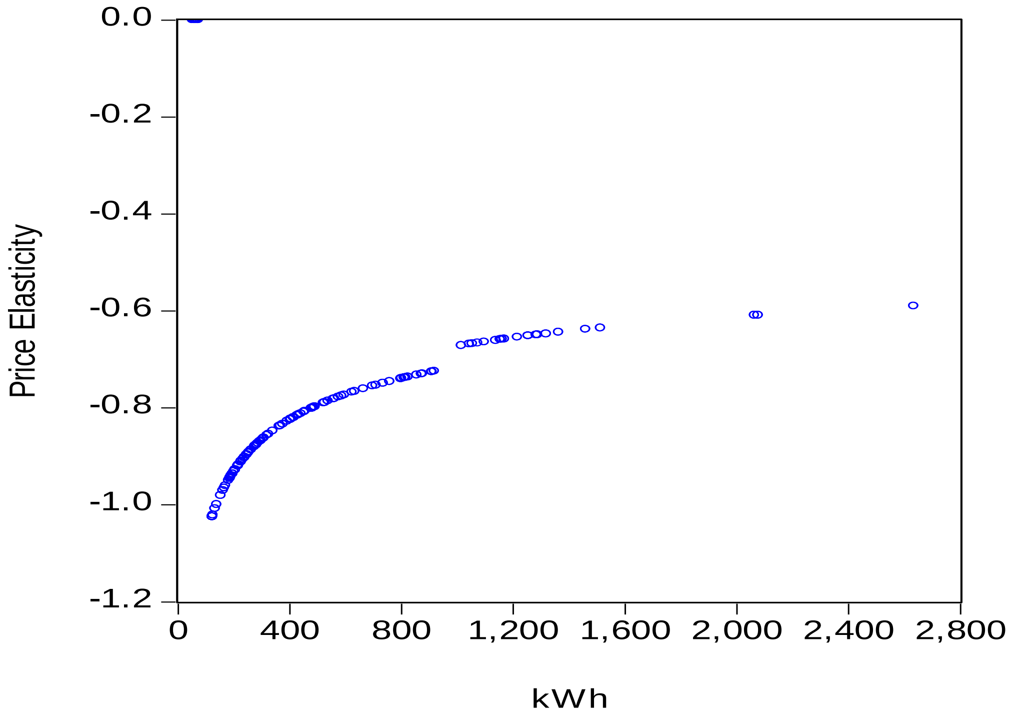
The income elasticity of demand was calculated in a similar fashion as the price elasticities. The income elasticities estimates were small, suggesting that the demand for electricity is relatively income inelastic. As noted earlier, electricity demand is a derived demand that is based on the household's portfolio of appliances. Therefore fluctuations in demand for electricity seem to be more a function of appliance holdings rather than income fluctuations. These results are similar to those obtained by Reiss and White (2005). Note that the income elasticity for households with solar water heating was negative reflecting the substitution effect arising from the use of solar power to provide water heating.

Table 5: Price and Income Elasticities by Household Income Level

Explanatory Variable	**Price**	**Income**
By household income level		
Under $1200	-0.725	0.004
$1200 - $2399	-0.852	0.010
$2400 - $4399	-0.805	0.015
$4400 - $6399	-0.788	0.019
$6400 - $10000	-0.727	0.022
More than $10000	-0.705	0.026

Table 5 disaggregates these price and income elasticites by household income level to further investigate the potential effect of income on household use of electricity. How elasticities vary by household income is of interest given that one of the objectives of the proposed rate adjustment was to lessen the impact of a rate increase on low income households. In general, the results suggest that middle-income households tend to be more price sensitive, even relative to low income households. This finding is somewhat surprising, given that low-income households should be expected to make greater adjustments to electricity consumption in order to offset the income effect of changes in the price of electricity, and may reflect the difference in appliance holdings of the two household groups. The relatively low-income households may have a portfolio of appliances that represents the necessities relative to middle-income households. As a result, relatively low-income households may be less price sensitive, since there is little they can do to adjust their electricity consumption. In contrast, the middle-income households may be able to reduce their usage of discretionary appliances. Table 5 also disaggregates the income elasticity by income group, but there was relatively little difference in the income elasticity estimates.

Figure 3: Price Elasticity of Demand by Monthly Consumption Level



An assessment of the price elasticity of demand for electricity based on the intensity of electricity use for Barbadian households is depicted in Figure 3 above. As should be expected, the price elasticity of demand falls with the intensity of electricity usage. Indeed, the price elasticity of demand for relatively low use customers is almost twice that of consumers utilising more than 1000 kWh in electricity per month.

5.2 Projected Impact of Rates Adjustment on Households

The paper now turns to investigating the impact of the proposed new rate structure on households demand for electricity. Table 6 demonstrates that the proposed changes in the electricity rates would result in a reduction in the mean marginal price of electricity. Figure 1 shows that the proposed new price schedule lays below and above the existing price schedule depending on the consumption level. The proposed four-tier system of prices will see the marginal price of electricity for households within the sample move from \$0.198 per kWh to \$0.184 per kWh, a decrease of 7%. Consumers that have consumption patterns under 500 kWh per month and between 1000 and 1500 kWh per month would benefit most from the changes in the marginal prices. Households however, with consumption patterns in excess of 1500 kWh and between 500 and 1000 kWh per month will face a higher marginal price.

Table 6: Marginal and Average Prices Before and After Rate Adjustments

Household monthly Consumption	Existing Average Price	Proposed Average Price	*Percentage Change*	Existing Marginal Price	Proposed Marginal Price	*Percentage Change*
Under 500 kWh	0.462	0.495	7.1	0.195	0.174	-10.5
500 to 1000 kWh	0.458	0.486	6.1	0.196	0.200	2.0
1000 to 1500 kWh	0.460	0.486	5.6	0.216	0.200	-7.4
More than 1500 kWh	0.467	0.492	5.5	0.216	0.224	3.7
Sample	**0.461**	**0.492**	**6.7**	**0.198**	**0.184**	**-7.0**

Table 7 further suggests that the proposed changes in the rate structure will result in an expansion in the average price of electricity for households at all consumption levels. This finding occurs because of the proposed increase in the monthly customer charge and the shifting of the fuel related $0.0264 from the base charge to the FCA.

Table 7: Distributional kWh Monthly Impact of Rate Adjustments

	Average Price Effect	Marginal Price Effect	Total Effect
Monthly Household Income			
Under $1200	-15 (-5.7%)	21 (7.3%)	6 (1.6%
$1200 - $2399	-19 (-6.3%)	19 (8.1%)	0 (0.0%)
$2400 - $4399	-22 (-5.5%)	21 (5.9%)	-1 (-0.4%)
$4400 - $6399	-26 (-4.6%)	22 (4.8%)	-4 (-0.2%)
$6400 - $10000	-36 (-4.1%)	22 (3.5%)	-14 (-0.6%)
More than $10000	-40 (-4.0%)	10 (1.1%)	-30 (-3.0%)
Monthly Consumption Band			
Under 500 kWh	-15 (-5.8%)	24 (8.4%)	9 (2.6%)
500 to 1000 kWh	-33 (-4.6%)	-11 (-1.5%)	-44 (-6.2%)
1000 to 1500 kWh	-44 (-3.7%)	58 (4.9%)	14 (1.2%)
More than 1500 kWh	-70 (-3.3%	-47 (-2.3%)	-117 (-5.6%
Sample	**-24 (-5.2%)**	**19 (5.5%)**	**-5 (0.0%)**

Note: percentage changes given parentheses below values

The results from the simulation exercises to examine the impact of the proposed rates on household electricity consumption are shown in Table 7. Households will generally alter their electricity consumption very little in response to the proposed changes to the four-tier structure and the increase in price. The findings indicate that the average monthly electricity consumption within the sample will be 5 kWh lower due to marginal price changes offsetting much of the effect of the average price increases. The model predicts that notable reductions in demand will only occur within upper income households. This is confirmed by the 5.6% decrease in demand projected for households consuming over 1500 kWh per month as households with these consumption levels are normally within the upper income bracket. Households with monthly consumption patterns between 500 kWh and 1000 kWh per month are expected to make the greater percentage adjustment in their demand for electricity. These households are likely to contract their monthly consumption by 6.2%.

The BL & P indicated that the proposed rate structure is designed to achieve a number of objectives. Evaluating how the proposed new pricing structure will meet those objectives is not very simple; however some inferences can be made from the results. The structure of the new pricing system seem likely to reach its primary objective of raising additional revenue as demonstrated by the across the board increase in the average price. The success of the secondary objective of minimizing the price impact on the lower income households is also evident. Low income households within the sample consume less than 500 kWh per month and therefore will benefit from a significant reduction in their marginal price. The objective of encouraging households to use electricity more efficiently and thus promote energy conservation will also likely be accomplished. The rise in marginal prices for higher levels of consumption will have the effect of lowering significantly the demand for electricity among households within the high and middle consumption bands.

6. Conclusions

With a review of the rates and rate structure of the Barbados Light and Power Company forthcoming, this paper estimated, for the first time, an electricity demand function using survey data of a sample of 130 Barbadian customers. This function is then employed to project the impact of the proposed change in the rates and rate structure on Barbadian households. As the demand for electricity services is a derived demand and data for the electricity demand for individual appliances is not available, electricity demand is modelled as the sum of the electricity used by i appliance categories. Following Dubin and McFadden (1984), the choice of space cooling and water heating are isolated in this paper, while the other appliances are treated as statistically exogenous. The non-linear pricing structure in Barbados is set up as a censored regression and estimated utilising the Heckman two-step approach where, due to the existence of non-linear pricing, Reiss and White (2002) coefficients on the marginal and average price as well as income variables are computed.

The reported results suggest that the price elasticities of demand for particular appliances varied significantly, with households with solar water heating more price elastic than those with air conditioning and electric water heating. The income effects were, however, statistically insignificant as these effects may have been captured by choices of appliances rather than utilisation and agree with studies by Parti and Parti (1980) and Dubin and McFadden (1984). The income elasticity for households with solar water heating was found to be negative, probably reflecting the substitution effect arising from the use of solar power to provide water heating. The database also allowed the authors to breakdown price and income elasticities by individual households and these results suggest that middle-income households tend to be more prices sensitive, even relative to low income households, indicating that the middle-income households may be more able to reduce their usage of discretionary appliances.

The impact of the introduction of the new tariff structure was also analysed and revealed that households with consumption patterns under 500 kWh will fear much better than higher consumption households. In general households will vary their consumption very little as a result of the introduction of the new rate structure. The more significant reduction in the demand for electricity is expected among upper income and upper consumption households.

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