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Short-run Demand for Residential Electricity in Rural Electric Cooperatives Franchise Areas

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Abstract

A short-run demand model for residential electricity is estimated for households served by the Rural Electric Cooperatives using data from the 1997 Family Income and Expenditure Survey. The results support earlier findings that the short-run residential demand for electricity is income and price inelastic. The results also show that household size, urban location, age and educational level of the household head have significant positive effects on household electricity consumption.

JEL classification: C2, Q2, R2
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1. Introduction

In the last decade a milestone was passed in household electricity consumption in the Philippines. In 1989, electricity was used by 65 percent of the households, behind kerosene (74 percent) and fuelwood (67 percent). By 1994, electricity was used by 84 percent of the households displacing kerosene (80 percent) as the fuel used by the greatest number of households. During the period 1994-1997, residential electricity consumption grew at a yearly average rate of 9.4 percent from 8,134 gigawatt-hours (gWh) in 1994 to 10,650 gWh in 1997, and, electricity sales to the residential sector in 1998 reached 11, 618 gWh, accounting for 39 percent of total electricity demand (Figure 1).

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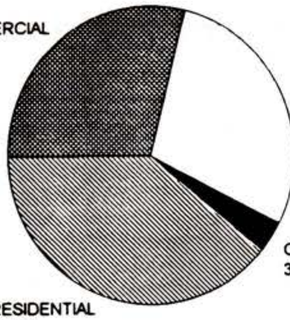
Figure 1. Electricity Sales by Type of User: 1998



The main sources of household electricity are Investor-Owned Utilities (IOUs) and Rural Electric Cooperatives (RECs). IOUs are privately-owned electric utilities which numbered 20 in 1997, the largest of which is MERALCO, the utility serving the National Capital Region (NCR). Rural Electric Cooperatives[1] are public electric utilities that operate under the supervision of the National Electrification Administration (NEA), a government agency attached to the Department of Energy (DOE). In 1997 there were 121 RECs spread throughout the country, each one covering a well-defined franchise area.

In 1997, seven out of ten households were connected to electric utilities of either type and of the connected households, 43.7 percent were served by the IOUs, split unevenly between MERALCO (32.6 percent) and the other IOUs (11.1 percent) (Figure 2). The majority of the connected households (56.7 percent) were served by the RECs. Since MERALCO serves mostly the households in the National Capital Region, while there is at least one REC in each province, the RECs clearly play a significant role in the distribution of electricity to the countryside.

The purpose of this paper is to estimate short-run price and income elasticities of demand for residential electricity among households served by the Rural Electric Cooperatives. Price elasticity estimates are useful in assessing the impact on consumer welfare of changes in the price of electricity.

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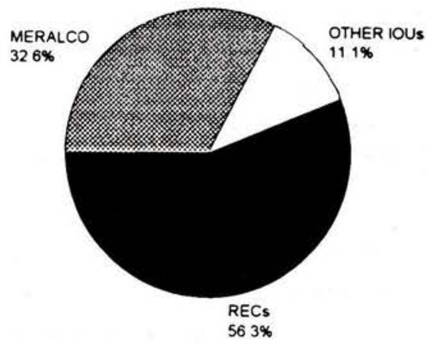
[1]The term "rural" does not mean that Rural Electric Cooperatives do not serve urban households. In fact, in 1997 58% of the households connected to RECs were classified as urban by the 1997 Family Income and Expenditure Survey.

Figure 2. Distribution of Households Connected to Electric Utilities: 1997



2. The short-run demand for electricity

The short-run residential demand for electricity arrives from the demand for the services (such as lighting, entertainment, refrigeration, and cooling) of a fixed stock of electric appliances. Thus, household electricity consumption in the short run depends upon the mix of household appliances and the intensity with which they are utilized.

Modelling the demand for residential electricity is based formally on household utility maximization subject to budget (or income) and other constraints. Utility maximization generates a demand function for electricity of the form

$$KWH = f(PE, B, X) \tag{1}$$

where KWH denotes the quantity of electricity consumed, PE is the price of electricity, B denotes household budget or income, and X is a set of other factors (e.g., demographic and locational factors). Numerous studies on the demand for residential electricity have used this type of equation to estimate price and income elasticities (e.g., Tiwari [2000]; Lyman [1994]; Branch [1993]; Maddigan et al. [1983]; Barnes et al. [1981]). These studies used various types of data, such as those based on households (Barnes et al. [1981]; Branch [1993]; Tiwari [2000]), franchise areas (Maddigan et al. [1983]; Lyman [1994]), and states (Halvorsen [1974]).

2.1 The treatment of the stock of appliances

Electricity demand studies involving aggregated data usually ignore the issue of the stock of appliances for lack of data on such stocks. On the other hand, studies using household data have information on the electric appliances possessed by the households since these data are usually drawn from consumer expenditure surveys. Thus, these studies take into account the presence of the various types of appliances in the demand function. The approach taken by Barnes et al. [1981] and Parti and Parti [1980] is to estimate a separate demand function for each type of major electric appliance. This requires appliance-specific electricity consumption data which are not usually available since end-use appliance metering is not a common practice. (But see Parti and Parti [1980] for an econometric method for estimating appliance-specific electricity consumption without using end-use appliance metering).

Another approach is to include in the demand function a zero-one dummy explanatory variable for each major appliance [Branch 1993]. The resulting model assumes that the differential effect of each appliance dummy is constant across price levels. That is, while the level of electricity consumption of households with a specific appliance is different from that of households without the appliance, these two types of households will react to a change in electricity price in the same way since they have a common slope. The remedy is to include an interaction term between price and the appliance dummy. As we found in the case of Philippine data, however, the price variable and the interaction term between price and the appliance dummy are highly correlated resulting in a high degree of multicollinearity. To avoid this multicollinearity problem, the approach taken in this paper, somewhat akin to Barnes et al. [1981], estimates the demand function not for each appliance separately but for a set of appliances. Thus, we partition the households into appliance classes, with each class holding the same set of major appliances. We then estimate a demand function for each class. The demand functions are estimated using household data drawn from the 1997 Philippine Family Income and Expenditure Survey.

3. The model

The economic variables in equation (1) – household budget and the price of electricity – are standard variables in a demand function. We use the following demographic and locational characteristics as attributes of the household: household size, age of household head, education of household head, and residential location (urban, rural). Household size affects the demand for electricity because, in general, larger households use their electrical equipment more intensively than smaller households (the user effect). However, for poorer households, with generally fixed budgets household budgets, an increase in household size means a reduced allocation for electricity (the income effect). Thus, depending on which of these two effects dominates, it is possible for household size to have a positive or a negative relationship with electricity consumption. This ambiguity may be resolved by using household budget per capita in the model since, in this case, only the user effect will be captured by the model. The age and education of the household head introduce social and cultural habits that affect the use of electricity. The urban/rural characteristic of the area where the household is located has an impact on electricity consumption since urban and rural areas differ in the availability of substitutes for electricity.

As mentioned earlier, we partition the households into classes, each of which consists of households owning the same set of appliances. In the interest of parsimony, the households are classified according to the following "ladder" of appliance ownership: H_N consists of the households with none of the appliances specified in the 1997 FIES[2]; H_E consists of households that own an entertainment appliance (a radio, TV set or stereo or VCR) but neither a refrigeration (refrigerator or freezer) nor a cooling (airconditioner) appliance; H_R consists of households that own a refrigeration but not a cooling appliance; and H_A consists of households that own a cooling appliance (airconditioner). The characteristics of these classes of households and the distribution of their electricity consumption are shown in Table 1.

One remarkable feature of Table 1 is that although households with refrigerators and airconditioners (H_R and H_A) constitute only 46 percent of the households, they account for 72 percent of electricity consumption, showing the considerable use of electricity by refrigerators and airconditioners. We also note the big jump in electricity consumption with the acquisition of a refrigerator.

3.1 Model specification

The most common functional form used in short-run electricity demand studies is a modified double- log form (Fisher and Kaysen [1962]; Betancourt [1981]; Branch [1993]; Murray et al. [1978]; Tiwari [2000]). In the double-log form, the dependent as well as the independent variables are in logarithms while in the modified double-log form some independent variables, such as zero-one dummy variables, are not in logarithms. Moreover, some explanatory variables, such as household size, are better left in the linear form to make the interpretation of its effect on the dependent variable more natural. Thus, we specify the model as follows:

$$\begin{aligned}\ln(KWH) = \beta_1 &+ \beta_2 \ln(PE) + \beta_3 \ln(Y) + \beta_4 HSIZE \\ &+ \beta_5 AGEHH + \beta_6 ELEM + \beta_7 HIGHSCH \\ &+ \beta_8 COLLEGE + \beta_9 URB\end{aligned} \quad (2)$$

where *KWH* is the annual household electricity consumption in kilowatt-hours, *PE* is the price of electricity, *Y* is annual household expenditure, *HSIZE* is household size, *AGEHH* is age of the household head, *ELEM*, *HIGHSCH*, and *COLLEGE* are dummies for household head with elementary education, high school education, and college education, respectively, and *URB* is a dummy for urban/rural location.

[2]The following electrical appliances were specified in the 1997 Family Income and Expenditure Survey: radio, stereo, TV, VCR, refrigerator, freezer, and airconditioner.

Table 1. Characteristics of the Classes of Households: H_N, H_E, H_R, H_A

Appliance Class	*Distribution (%)*	*Electricity Consumption Distribution (%)*	*Mean Annual Electricity Consumption (kwh)*	*Mean Per Capita Household Expenditure* (₱)*	*Mean Household Size*	*Share of Urban (%)*
H_N	4.43	1.70	287	12,506	4.79	58
H_E	49.77	26.07	389	15,236	5.28	53
H_R	43.46	64.48	1102	29,663	5.18	68
H_A	2.34	7.75	2461	54,579	5.48	85
All Households	100.00	100.00	743	22,305	5.22	61

One virtue of this functional form is that the coefficient β_2 is the price elasticity of demand for residential electricity since price elasticity ε_{PE} is given by

$$\varepsilon_{PE} = \frac{\partial \ln(KWH)}{\partial \ln(PE)} = \beta_2 \tag{3}$$

This means that a one percent change in price *PE* leads to a β_2 percent change in household electricity consumption. Similarly, the coefficient β_3 is the budget (income) elasticity of demand for residential electricity.

4. The data

The unit of analysis is taken to be the individual household because it is the decision-making unit as well as the "customer" of the electric utility. This also avoids the problem of aggregation bias. Household data on electricity consumption expenditure, total expenditure, household size, age of household head, education level of household head, stock of electrical appliances, and the urban/rural classification of the area where the household resides were drawn from the 1997 Family Income and Expenditure Survey (1997 FIES) of the National Statistics Office.

To get the electrified households from the FIES sample, the geographical location of a household was matched with the electric utility serving that particular location. We then obtained from the National Electrification Administration the prices of electricity in effect during the survey period.

Households connected to a REC face a single electricity price but with a minimum bill where the customer pays for a first block quantity of kilowatt-hours called the minimum kilowatt-hours (MKWH). The minimum bill is equal to MKWH times the marginal price. Any electricity consumption less than or equal to the MKWH is charged the minimum bill. Consumption above the MKWH is charged the level of kilowatt-hours times the marginal price.[3]

The 1997 FIES does not report the quantity of electricity consumed by the household. But his quantity can be calculated by using the prices obtained from the National Electrification Administration and the household expenditure for electricity.

Household budget (or income) is measured by total household expenditure, a preferred measure since experience with household survey data analyses suggests that expenditure data are generally collected with greater accuracy than income data. The expenditure data were adjusted using provincial consumer price indices to reflect real income differences across provinces.

Table 2 presents the description of the variables used in the model together with their sample means.

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[3]There is a wide range of MKWH among the RECs. For example, in 1997 MKWH ranged from 6 kWh per month at Php 3.8054/kWh or a minimum bill of Php 22.83 (MASELCO, Region V) to 35 kWh per month at Php 2.6149/kWh or a minimum bill of Php 91.52 (LASURECO, Region XII). The average MKWH was 12.47 while the average minimum bill was Php 44.29 per month.

Table 2. Variable Descriptions and Sample Means

Variable	*Description*	*Sample Means*				
		All	H_N	H_E	H_R	H_A
KWH	Annual household electricity consumption in kilowatt-hours	743	287	389	1,102	2,461
PE	Price of electricity (pesos)	3.72	3.66	3.77	3.67	3.66
Y	Annual household expenditure per capita, adjusted for provincial price differences (pesos)	22,305	12,506	15,236	29,663	54,579
HSIZE	Household size	5.2	4.8	5.3	5.2	5.5
AGEHH	Age of household head	48.4	48.0	47.7	49.2	48.8
URB	1 if household is urban; 0, otherwise	0.61	0.58	0.53	0.68	0.84
ELEM	1 if household head had elementary education; 0, otherwise	0.33	0.42	0.40	0.25	0.10
HIGHSCH	1 if household head had high school education; 0, otherwise	0.35	0.22	0.31	0.41	0.33
COLLEGE	1 if household head had college education; 0, otherwise.	0.14	0.02	0.05	0.23	0.53

5. Model estimation

The demand equations were estimated using subsamples totaling 14,160 regular billers (those with electricity consumption above the minimum kilowatt-hours per month) since the electricity consumption of minimum billers cannot be determined. The subsample also excluded households with missing or absurd data. The bias that might be introduced by the absence of the minimum billers is mitigated by the presence of regular billers in some franchise areas whose electricity consumption would classify them as minimum billers in other franchise areas. Indeed the characteristics of the minimum billers and regular billers with less than 15 kWh consumption per month are similar (Table A, Appendix).

The model was estimated by ordinary least squares with White's Consistent Covariance Matrix Estimator [White 1980] to get the correct standard errors in view of the presence of heteroskedasticity as indicated by the Cook-Weisberg Test [Cook and Weisberg 1983]. There were no serious multicollinearity problems as the variance inflation factors were all less than 10 and the highest mean VIF was only 2.83. The regression results for the entire sample (ALL) and for each appliance class are shown in Table 3.

As seen in Table 3, all parameter estimates for the entire sample have the expected signs – positive budget effect, negative price effect, positive urbanization effect, positive age effect, positive education effect, and positive household user effect. All parameter estimates are highly significant in explaining the residential demand for electricity. However, the age, education, and location variables are insignificant in some appliance classes. These are discussed below.

5.1 Budget and price effects

Budget elasticities for the various household classes range from 0.32 to 0.81 (Table 4), showing that electricity is a normal good and that residential demand is income inelastic. Thus, in the class H_E, a one-percent increase in budget leads to a 0.46 percent increase in electricity consumption. The price elasticities range from – 0.85 to – 0.49. In H_E a one percent increase in the price of electricity leads to a 0.67 percent decrease in electricity consumption. Households with refrigerators but no airconditioners (H_R) are the least sensitive to price changes, since households do not turn refrigerators on and off with price changes.

Table 3. Regression Results
Regression with robust standard errors

LNKWH	H_N	H_E	H_R	H_A	*ALL*
LNPE	-.61976	-.66807	-.49302	-.84945	-.74105
	(-9.64)*	(-25.92)	(-17.65)	(-6.74)	(-35.57)
LNY	.31503	.46493	.47866	.81185	.74944
	(6.06)	(31.92)	(33.52)	(12.34)	(76.63)
HSIZE	.07080	.09050	.10195	.17099	.12972
	(6.41)	(227.66)	(28.27)	(10.45)	(49.68)
AGEHH	.00335	.00187	.00246	-.00116	.00417
	(2.33)	(3.90)	(4.34)	(-0.43)	(10.38)
ELEM	.08614	.03417	.03712	.22665	.07235
	(1.91)	(2.12)	(1.36)	(1.14)	(4.72)
HIGHSCH	.15312	.12581	.08177	.19792	.22458
	(2.42)	(6.91)	(3.04)	(1.08)	(13.64)
COLLEGE	.37368	.11662	.11596	.24611	.31100
	(2.25)	(3.79)	(3.92)	(1.34)	(14.38)
URB	.05370	.12768	.07982	.14364	.11513
	(1.31)	(10.26)	(5.20)	(1.59)	(10.58)
CONSTANT	2.73002	1.53512	1.83968	-1.32585	-1.20761
	(5.36)	(10.73)	(12.54)	(-1.913)	(-12.58)
F	22.51	274.89	252.64	41.96	1636.65
Prob > F	0.0000	0.0000	0.0000	0.0000	0.0000
R-squared	0.2047	0.2523	0.2669	0.5140	0.4655
n	627	7048	6154	331	14160

* numbers in parentheses are *t* values

Table 4. Short Run Budget and Price Elasticities

Appliance Class	*Budget Elasticity*	*Price Elasticity*
H_N	0.32	– 0.62
H_E	0.46	– 0.67
H_R	0.48	– 0.49
H_A	0.81	– 0.85
ALL	0.75	– 0.74

5.2 Household size and location effects

Household size has a significant effect on electricity consumption. Other things equal, electricity consumption (for the entire sample) rises by an average of 13.8 percent per additional household member (see Appendix for the calculation). By a similar calculation, we get the percent increases in electricity consumption per additional household member for the different appliance classes:

Table 5. Marginal Effect of Household Size on Electricity Consumption

Appliance Class	*Percent Increase*
H_N	7.3
H_E	9.5
H_R	10.7
H_A	18.6

These percentages rise, since going up the appliance ladder means that an additional household member has more appliances to use.

In determining the difference between urban and rural electricity consumption, it is important to remember that the dummy variable *URB* is defined with rural households as base category. Thus its positive sign indicates that urban households use more electricity than rural households, other things equal. This is consistent with the findings of the 1995 Household Energy Consumption Survey [Department of Energy 1995]. Over the entire sample, urban households use 12.2 percent more electricity than rural households (see Appendix for the calculation). For the various appliance classes, the percentage differences in electricity consumption of urban households over rural households are given in Table 6.

Table 6. Differential Electricity Consumption, Urban vs. Rural Households

Appliance Class	*Urban-Rural Differentials (in percent)*
H_N	5.5
H_E	13.6
H_R	8.3
H_A	15.4

5.3 Age and education effects

A higher age of the household head involves a higher use of electricity, although an increase of a year in age results in only a 0.4 percent increase in electricity consumption. This might be due to the fact that older families tend to be larger and have more electrical equipment. However, the age variable is not significant in the class H_A where the airconditioner is the dominant equipment. In this class, younger and older families probably have the same level of comfort provided by airconditioning, other things equal.

Turning to the educational level of the household head, we see that education is significant and has a positive effect on electricity consumption. An increase in education to the elementary level involves an increase of 7.5 percent in electricity consumption. Increasing the educational level of the household head to high school and college increases electricity consumption by 25.2 percent and 36.5 percent, respectively. Note, however, that in the class H_A, there are no significant differences in electricity consumption among households whose heads have different educational levels. This is probably due to the fact that education, like age, does not matter in the intensity of use of an airconditioner whose primary purpose is to provide comfort to the user.

6. Concluding remarks

A short-run residential demand for electricity model has been estimated based on the assumption that the short-run response of a household to price and income changes depends on the mix of electrical appliances that it owns. The results support earlier findings that the short-run residential demand for electricity is income and price inelastic. Price elasticities range from - 0.85 to - 0.49 while income elasticities range from 0.32 to 0.81. The results also showed that household size and urban location have significant effects on household electricity consumption. Age and educational level of the household head likewise have significant positive effects on electricity consumption.

Appendix

Determining the effects of household size on electricity consumption

Let KWH_0 = electricity consumption of a household H_0 of size $HSIZE_0$
KWH_1 = electricity consumption of a household H_1 of size $HSIZE_1$
β = coefficient of *HSIZE* in the demand equation

Then, holding other variables constant, we have

$$\ln KWH_1 - \ln KWH_0 = \beta(HSIZE_1 - HSIZE_0)$$

If household H_1 is just a person larger than H_0, then we have

$$\ln KWH_1 - \ln KWH_0 = \beta\left(HSIZE_1 - HSIZE_0\right)$$

or $$KWH_1/KWH_0 = e^{\beta} \qquad (\text{where } e \approx 2.71828)$$

Hence, $$\frac{KWH_1 - KWH_0}{KWH_0} = e^{\beta} - 1$$

As an example, take $\beta = 0.12972$ (the coefficient of *HSIZE* in the equation for the entire sample). Then

$$\frac{KWH_1 - KWH_0}{KWH_0} = e^{0.12972} - 1 = 0.1385$$

Thus, increasing household size by one person means increasing electricity consumption by 13.85 percent.

Determining the effects of a dummy variable on electricity consumption

Consider the location dummy variable *URB* whose coefficient in the equation for the entire sample is $\beta = 0.11513$. Let

KWH_1 = consumption of an urban household

KWH_0 = consumption of a rural similar household

Then, holding other variables constant,

$$\ln KWH_1 - \ln KWH_0 = \beta.$$

Following the derivation in A1, the percent difference in electricity consumption between the two households is

$$\frac{KWH_1 - KWH_0}{KWH_0} \times 100 = (e^{\beta} - 1) \times 100 = (e^{0.11513} - 1) \times 100 = 12.2\%$$

Thus, urban households have, other things equal, 12.2 percent higher electricity consumption than rural households.

Table A. Comparison of RECs minimum billers and regular billers with Monthly Consumption of 15 kWh or Less

Variable	*Mean*	
	Minimum Billers	*Regular Billers*
Expenditure per capita	12,666	13357
Poor	0.46	0.44
Elementary education of household head	0.41	0.42
High School education of household head	0.22	0.24
College education of household head	0.024	0.028
Age of household head	47	48
Urb	0.40	0.46
Household size	4.6	4.8
Radio	0.72	0.77

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