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Abstract

Regional economic, demographic, and climatic data are used to analyze residential electricity demand in the United States. Results indicate that electricity is an inferior good for households in the United States. This confirms earlier research compiled using data for less geographically extensive regional and metropolitan markets. The results imply that demographic growth may place fewer pressures on electricity generation capacity than was previously assumed.

Key Words: Residential Electricity Demand, Regional Economics
JEL Classification: Q41, Energy Demand; R15, Regional Econometrics

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1. Introduction

Resource constraints have raised questions regarding electric energy availability and policy options in the United States (Espey and Espey, 2004). In that context, questions have also been asked about the determinants of electricity demand. To adequately examine gigawatt hour (GWH) consumption issues requires assembling a fairly comprehensive regional data set. This paper utilizes one such sample to study residential GWH demand in the United States.

Data are collected for all 50 states and the District of Columbia. Explanatory variables include the average price of residential electricity, number of households, personal income, heating degree days, and cooling degree days. Dummy variables are also included for each of the nine regions defined by the Census Bureau.

Section 2 provides a brief overview of previous studies of residential GWH demand in the United States. A discussion of the data, modeling approach and empirical results are summarized in Section 3. Concluding remarks follow in Section 4.

2. Literature Review

Private and public institutions have an interest in determining the demand for electricity. Both private sector electric companies and public sector cooperatives frequently employ fairly extensive econometric models for short-range and long-run planning purposes (Kamerschen and Porter, 2004). Periodic electricity shortages and rate hikes tend to heighten ongoing interest in this topic (McMahon, 1987; Reiss and White, 2008).

Among some of the studies that examine electricity consumption, results in Mount, Chapman, and Tyrell (1973) indicate that commercial and residential demands are more price elastic than industrial demand. Taylor (1975) observes that marginal costs cover only part of the needed information because of block pricing in the electricity sector. Halvorsen (1975) concludes that empirical results using average price measure are likely to be more accurate than those using other approaches. Roth (1981) uses both marginal and average prices of electricity to estimate electricity demand under block pricing and concludes that electricity is an inferior good.

There is widespread international agreement that residential electricity demand is price inelastic (Silk and Joutz, 1997; Fillipini, 1999; Holtedahl and Joutz, 2004). Less consensus exists with respect to income elasticity estimates. Although a number of studies indicate that residential electricity is a normal good, many also indicate that its income elasticity is fairly low (Dergiades and Tsoulfidis, 2008). Roth (1981) employs data for a single metropolitan market, while many recent efforts rely on nationally aggregated data estimates.

To shed additional light on the issue of residential electricity demand, this study takes advantage of a cross-sectional data set for all 50 states and the District of Columbia. The explanatory variables are largely the same as in Dergiades and Tsoulfidis (2008), although personal income is employed rather than gross domestic product. Empirical results are summarized below.

3. Data and Empirical Results

The basic implicit function form of residential GWH demand per household is

$$GWHR/HH = f(PR, INC/HH, HDD, CDD) \quad (1)$$

It is specified as a linear equation similar to those in earlier studies (Silk and Joutz, 1997; Filippini, 1999). Consumption is in gigawatt-hours per household (GWHR/HH). Other variables include average price per kilowatt-hour (KWH), personal income per household, heating degree days, and cooling degree days. Heating degree-days are calculated as differences between average temperatures and 65^0F during cool weather days. Cooling degree-days are calculated in the same manner except they measure days when energy will be used to cool a residence. All data employed are from official federal and state government agencies. They are available from the authors upon request.

Table 1. Variable Names

Mnemonic	Description
GWHR	Residential Electricity Usage in Gigawatt Hours
PR	Average Price for Res. Electricity, Cents per Kilowatt Hour
HH	State Number of Households
INC	State Personal Income, Thousand Dollars
HDD	State Heating Degree Days
CDD	State Cooling Degree Days
NE	Dummy Variable for New England Census Region
MIDATL	Dummy Variable for Mid-Atlantic Census Region
ENC	Dummy Variable for East North Central Census Region
WNC	Dummy Variable for West North Central Census Region
SA	Dummy Variable for South Atlantic Census Region
ES	Dummy Variable for East South Central Census Region
WSC	Dummy Variable for West South Central Census Region
MOU	Dummy Variable for Mountain West Census Region
PAC	Dummy Variable for Pacific Coast Census Region

Dummy variables are included for each of the nine regions defined by the United States Census Bureau. A value of one is assigned if a state belongs to a region and zero if it does not. Because the dependent variable is logarithmically transformed and regional indicator variables are not, the latter coefficients are first transformed using exponential functions. To avoid matrix singularity, the Pacific Region is excluded from estimation and is assigned a value of zero, so its exponential transformation will equal one. A negative coefficient for the regional indicator variable will indicate lower GWH purchases than the Pacific Region; a positive sign will indicate greater consumption than in the Pacific region.

Table 1 contains variable names, descriptions, and their respective units of measure. All data are collected for 2002. Because the variables are logarithmically transformed prior to estimation, the regression coefficients represent demand elasticities. The basic specification for GWHR per household is shown in Equation (2).

$$Log(GWHR/HH) = \alpha_0 + \alpha_1 LogPR + \alpha_2 Log(INC/HH) + \alpha_3 LogHDD + \alpha_4 LogCDD + e \quad (2)$$

Given the wide range of market sizes in the sample, results are tested for heteroscedasticity (White, 1980). As shown in Table 2, test statistics for per household residential consumption fall below the respective F- and Chi-square 1-percent critical values. Failure to reject the null hypothesis of homoscedasticity indicates a fairly uniform pattern of regional per household GWH sales once price and other factors are taken into account.

The price elasticity in Table 2 is -0.59 and satisfies the 5-percent significance criterion. It is slightly more inelastic than the median value that has been historically reported for residential electricity sales (Espey and Espey, 2004). It is, however, well within the range of values reported in many prior studies.

The estimated income per household elasticity for residential electricity is -0.44 and also satisfies the significance criterion. The negative sign implies electricity is an inferior good and confirms the conclusions reached in earlier region-specific electricity studies such as Lyman (1973) and Roth (1981). This result, however, differs substantially from many of the other positive income estimates previously reported (Espey and Espey, 2004). It is robust to specification changes, although total personal income has a negative sign and total households has a positive sign when those two variables are split to allow for parameter heterogeneity (Filippini, 1999).

Heating degree-days have an elasticity of 0.0004. The positive sign indicates residences increase electricity usage as temperatures falls. With a t-statistic of 0.012, the heating degree-days elasticity coefficient is not statistically significant. Kamerschen and Porter (2004) report a heating degree elasticity of 0.08 that is significant. Filippini (1999) also obtain statistically significant heating degree parameters with elasticities that range between 0.272 and 0.297.

Table 2. Estimation Results

Dependent Variable:	LOG(GWHR/HH)
Method:	Ordinary Least Squares
Sample Observations:	51

Variable	**Coefficient**	**Std. Error**	**t-Stat.**	**Prob.**
Constant	-1.7075	0.9457	-1.8054	0.0789
LOG(PR)	-0.5936	0.1890	-3.1416	0.0032
LOG(INC/HH)	-0.4377	0.1826	-2.3969	0.0216
LOG(HDD)	0.0120	0.0303	0.3957	0.6946
LOG(CDD)	0.0475	0.0402	1.1819	0.2446
NE	-0.0974	0.1145	-0.8508	0.4002
MIDATL	-0.0832	0.1355	-0.6141	0.5428
ENC	-0.1224	0.1128	-1.0842	0.2851
WNC	-0.0525	0.1130	-0.4649	0.6447
SA	0.1193	0.1070	1.1152	0.2717
ESC	0.1200	0.1348	0.8905	0.3788
WSC	0.1176	0.1315	0.8943	0.3768
MOU	-0.1941	0.1062	-1.8284	0.0754

R-squared	0.7830	Dependent Variable Mean	-4.4659
Adjusted R-squared	0.7145	Dep. Var. Standard Dev.	0.2899
Std. Err. Regression	0.1549	Akaike Inf. Criterion	-0.6764
Sum Sq. Residuals	0.9119	Schwarz Inf. Criterion	-0.1840
Log likelihood	30.2476	Hannan-Quinn Inf. Crit.	-0.4882
F-statistic	11.4268	Durbin-Watson Statistic	2.1706
Probability (F-stat.)	0.0000		

White Heteroscedasticity Test:

F-statistic	1.2168	Probability, F(12, 38)	0.3076
Obsvn.*R-squared	14.1569	Probability, Chi-Square(13)	0.2908
Scaled explained SS	11.7005	Probability, Chi-Square(13)	0.4700

As anticipated, the Census Region dummy variables carry different signs and magnitudes. None of the t-statistics for the regional indicator variables indicate that these parameters are significantly different from zero. Collectively, those outcomes imply that residential GWH consumption per household does not exhibit much regional heterogeneity after price, income, and weather are taken into account.

4. Conclusion

This study confirms earlier work suggesting that pricing policies offer effective tools for encouraging decreased household electricity usage. In contrast to a large number of earlier results, the elasticity coefficient for income per household is both negative and significant. That result is robust to alternative specifications. If residential electricity is an inferior good, it implies that better income performance alone will not translate into greater load pressures for electric utilities. Weather variables and Census Region market designations are not found to improve model performance, potentially indicating greater household energy usage homogeneity across the United States than might otherwise be expected.

To date, only a minority of studies indicate that residential electricity is an inferior good. Accordingly, additional research on this topic would be welcome. One potential avenue for expansion is to collect data for a greater number of years and examine whether panel estimates confirm the various results reported above. Empirical analyses of commercial, industrial, public and total electricity consumption patterns may also be useful from a comparative perspective. Similarly, empirical analyses using regional market data from other nations may provide a stronger contextual base from which to examine this general topic area.

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