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Abstract.

The present empirical study focuses on identifying key economic factors and other conditions that have influenced the *per customer commercial and industrial consumption of electricity* in the U.S. during recent years. Unlike most previous studies, this study uses a state-level panel data set for the period 2002 through 2005. The three panel two-stage least squares (P2SLS) estimates provided in this study imply that per customer commercial and industrial electricity consumption is an increasing function of the annual number of cooling degree days, per capita real disposable income (a *de facto* "control" variable), and the peak summer electricity generating capacity. Furthermore, per customer commercial and industrial electricity consumption is a decreasing function of the average real unit price of electricity to commercial and industrial enterprises.

Keywords: Electricity consumption; electricity prices

Introduction

Largely within the context of environmental economics, an extensive empirical literature concerned with energy consumption in the U.S. and in other nations has developed during recent decades. A significant component of this research literature is concerned with the consumption of electricity, including the residential consumption thereof [1, 2, 3, 4, 5, 6. 7]. The consumption of electricity in the U.S. may continue to rise, especially if claims of global warming are correct [3, 8], making it all the more important for both policymakers and energy firms as well as other interested and/or affected parties to understand factors that influence electricity consumption.

The present study focuses on identifying key economic factors and other conditions that have influenced the *per customer commercial and industrial consumption of electricity* in the U.S. during recent years. Unlike most previous studies, this study uses a state-level panel data set for the period 2002 through 2005. By focusing on this time period, the evidence provided in this study is relatively current. The next section of this study provides the framework for the analysis, whereas the subsequent section provides the panel two-stage least squares (P2SLS) estimates based on that framework. The closing section of this study summarizes the findings of the study.

An Eclectic Model

The analysis *in principle* initially follows [3, 4, 5, 6, 7] and others in modeling electricity consumption as a function of a number of essentially demand-driven forces. However, one essentially supply-side force is also integrated into the model. Unlike much of the existing literature, the focus in this study is on the combined commercial and industrial consumption of electricity.

Firms (whether commercial or industrial) are treated as either profit maximizers or maximizers of share value. The latter of course is the perspective typically adopted in corporate finance circles [9]. Firms are treated as purchasing electricity as an input and naturally attempt to do so in accordance with cost minimization, whether as part of the pursuit of their profit maximization or share value maximization objective. Hence, to begin, it is expected that the higher the real price of electricity per kilowatt hour to commercial and industrial firms, the lower will be the quantity demanded of electricity by said firms, *ceteris paribus*. The notion that the higher the unit price of commercial and industrial electricity (ELPRjt), the lower the consumption of same is consistent with studies of residential electricity consumption [2, 3, 4] .

Next, it is expected that the greater the number of cooling degree days (CDDjt), the greater the expected demand for/consumption of electricity in order to cool the interior of commercial and industrial structures, *ceteris paribus* [2, 3, 4, 5, 7].

The variable PCRDIjt is defined as the per capita real disposable income in a state j in year t. PCRDIjt is included in the model to "control" for the potential impact on commercial and industrial electricity consumption of greater the household demand for services and goods in state j in year t resulting from a higher per capita real disposable income. In other words, as PCRDIjt rises, so does the consumer demand for consumer goods and services in state j in year t. To the extent that these household services and goods are provided within state j in year t, the greater will be the commercial and industrial consumption of electricity within state j in year t, *ceteris paribus*. This commercial and industrial demand for electricity is in effect a *derived* demand for electricity.

A potentially interesting endeavor is to investigate the impact on electricity consumption (demand) by commercial and industrial enterprises resulting from the level of state government involvement in the establishment and perpetuation of energy efficiency programs [7]. A measure of such involvement is provided by a LEEP score, where the term "LEEP" stands for **L**evel of **E**nergy **E**fficiency **P**rograms [10]. To accomplish this extension, this study adopts this cardinal measure (1, 2, 3) reflecting whether a given state j in year t was weakly (LEEP =1), moderately (LEEP = 2), or strongly (LEEP = 3) engaged in energy efficiency program activities. It is hypothesized that the stronger a state government's commitment to energy efficiency programs, i.e., the higher the LEEP score in a state, the lower the commercial and industrial consumption of electricity in the state, *ceteris paribus*. This argument is found in the analysis of household electricity demand in [7].

Finally, the variable denoted by PEAKjt measures a state's maximum electricity generating capacity per customer in state j in year t. This peak capacity is determined by the maximum output generated by the sources which supply electricity, whether it be generated from a hydro source, nuclear source, wind, solar source, coal, or any other generating method. The capacity is denoted as the peak summer capacity due to the fact that maximum electricity consumption in the U.S. traditionally occurs during peak consumption hours through the hot summer months.

The eclectic model of electricity consumption by commercial and industrial enterprises is expressed, as follows:

$$TCjt = f(CDDjt, ELPRjt, PCRDIjt, LEEPjt, PEAKjt) \quad (1)$$

where (data source in parentheses):

TCjt = the total consumption of electricity per commercial and industrial customer, measured as the ratio total *commercial and industrial* electricity consumption in state j in year t scaled by the total number of commercial and industrial customers in state j in year t [11];

CDDjt = total annual number of cooling degree days in state j in year t [12];

ELPRjt = the average real price of commercial and industrial electricity in state j in year t, measured in nominal cents per kilowatt hour [11], scaled by the state cost of living index for state j in year t [13];

PCRDIjt = per capita real disposable income in state j in year t , measured as the nominal per capita disposable income in state j in year t [14, 15, 16] scaled by the state cost of living index for state j in year t [13];

LEEPjt = a cardinal measure (1, 2, 3) reflecting whether a given state j in year t was weakly (LEEP =1), moderately (LEEP = 2), or strongly (LEEP = 3) engaged in energy efficiency program activities [7, 10]; and

PEAKjt= per customer peak/maximum summer electricity generating capacity for state j in year t, i.e., peak summer electricity generating capacity for state j in year t, expressed as kilowatt hours per customer (residential plus commercial plus industrial) in state j in year t [11].

This study uses a state-level panel for the U.S. for the period 2002 through 2005. The panel consists of the 48 contiguous states, with Alaska and Hawaii excluded as outliers. Washington, D.C. data are included in the study by being measured along the data for the state of Maryland, i.e., as part of the Maryland data set. Thus, j = 1,…,48, and t = 2002, 2003, 2004, 2005. Two of the explanatory variables (ELPRjt and PCRDIjt) are scaled by the state cost of living index so as to make them comparable; such an adjustment was necessary, given the large interstate differentials in the overall cost of living [13]. For the interested reader, the correlation matrix among the explanatory variables in equation (1) is provided in Table 1; based on the pattern of these correlation coefficients, there are no multicollinearity problems. The descriptive statistics for the variables in the model are provided in Table 2.

Table 1. Correlation Matrix for Explanatory Variables

	CDDjt	ELPRjt	PCRDIjt	LEEPjt	PEAKjt
CDDjt	1.0				
ELPRjt	0.449	1.0			
PCRDIjt	-0.089	0.138	1.0		
LEEPjt	-0.054	-0.179	-0.045	1.0	
PEAKjt	0.426	0.407	0.094	-0.068	1.0

Table 2. Descriptive Statistics for Variables in the Model

Variable	Mean	Standard Deviation
TCjt	177,470	319,836
CDDjt	1125	778.95
ELPRjt	0.0644	0.0147
PCRDIjt	27,662	2,877
LEEPjt	1.9958	0.7056
PEAKjt	89.04	165.39

In any event, predicated upon the aforementioned arguments, it is hypothesized in this study that the following signs on the partial derivatives apply:

$f_{CDD} > 0$, $f_{ELPR} < 0$, $f_{PCRDI} > 0$, $f_{LEEP} < 0$, $f_{PEAK} > 0$ (2)

The Empirical Estimations

Based on the model provided in (1) and (2) above, the following three reduced-form equations are to be estimated in this study:

$$\log TCjt = a_0 + a_1 \log CDDjt + a_2 \log ELPRjt + a_3 \log PCRDIjt + a_4 \log LEEPjt + a_5 PEAKCAPjt + \mu \quad (3)$$

$$\log TCjt = b_0 + b_1\, CDDjt + b_2\, ELPRjt + b_3\, PCRDIjt + b_4\, LEEPjt + b_5\, PEAKCAPjt + \mu' \quad (4)$$

$$TCjt = c_0 + c_1\, CDDjt + c_2\, ELPRjt + c_3\, PCRDIjt + c_4\, LEEPjt + c_5\, PEAKCAPjt + \mu'' \quad (5)$$

where a_0, b_0, and c_0 are constants, "log" indicates the natural log of a variable, and μ, μ', and μ'' are stochastic error terms. Equation (3) is in log-log form; hence, the estimation will generate elasticities. The generation of elasticities has the virtue of yielding very easily interpreted findings. Equations (4) and (5), respectively, are semi-log and linear estimates. These latter equations are estimated to demonstrate the robustness of the results of the basic log-log model.

Given that the quantity demanded of residential electricity per commercial and residential customer (log TCjt) and the unit price of electricity (ELPRjt) are contemporaneous, the clear possibility of simultaneity bias exists. Accordingly, the model in (3) is estimated by P2SLS, with the instrument being the one-year lag of the Gross State Product for state j, GSPjt-1 [14, 15, 16]. The choice of this variable as the instrument was based on the finding that GSPjt-1 was highly correlated with ELPRjt while not being correlated with the error terms in the system.

The P2SLS estimate of equation (3), after adopting the White [17] heteroskedasticity correction, is provided in column (a) of Table 3, where terms in parentheses are t-values. In equation (a), all five of the estimated elasticities exhibit the expected signs and are statistically significant at the one percent level. In addition, the F-statistic is statistically significant at far beyond the one percent level, attesting to the overall strength of the model. Thus, this P2SLS estimate implies that per customer commercial and industrial electricity consumption is an increasing function of the annual number of cooling degree days, per capita real disposable income, and the peak summer generating capacity. Furthermore, per customer commercial and industrial electricity consumption is a decreasing function of the average real unit price of electricity to commercial and industrial enterprises and the state's LEEP score.

Table 3. Results from Three Estimations

Variable\Estimate	(a)	(b)	(c)
Constant	-4.81	3.87	-77.8
Log CDDjt	0.117** (9.46)	-----	-----
Log ELPRjt	-0.887** (-7.66)	-----	-----
Log PCRDIjt	1.57** (8.65)	-----	-----
Log LEEPjt	-0.181** (-5.46)	-----	-----
Log PEAKjt	0.441** (88.99)	-----	-----
CDDjt	-----	0.00017** (15.58)	0.034** (20.89)
ELPRjt	-----	-0.155** (-7.62)	-17.78* (-2.05)
PCRDIjt	-----	0.0061** (30.06)	.051** (7.18)
LEEPjt	-----	-0.0466** (-3.68)	6.37** (-13.83)
PEAKjt	-----	0.00199** (40.57)	1.647** (79.70)
F	47.76**	56.16**	217.9**

Terms in parentheses are t-values. **indicates statistical significance at the one percent level, and * indicates statistical significance at the five percent level.

The result for the variable CDDjt implies that a 1% increase of one unit in the annual number of cooling degree days would elicit a 0.117% increase in per customer commercial and industrial electricity consumption. The result for the variable ELPRjt implies that an increase of 1% in the real unit price of electricity would *reduce* per customer commercial and industrial electricity consumption by 0.89%. As for the control variable PCRDIjt, an increase of 1% in per capita real disposable income would elevate per customer commercial and industrial electricity consumption by 1.57%. A 1% increase in LEEP would reduce commercial and industrial electricity consumption by 0.18%. Finally, the results indicate that per customer commercial and industrial electricity consumption will increase by 0.44% percent if the peak summer generating capacity increases by 1%.

Referring next to columns (b) and (c) of Table 3, all ten of the estimated coefficients exhibit the expected signs, with nine statistically significant at the one percent level and one statistically significant at the five percent level. Thus, the semi-log and linear estimates found in columns (b) and (c) both provide further support for the basic hypotheses being tested in this study and in particular for the log-log results found in column (a) of the Table.

Conclusion

The P2SLS estimates provided in this study imply that per customer commercial and industrial electricity consumption is an increasing function of the annual number of cooling degree days, per capita real disposable income (a *de facto* “control” variable), and the peak summer electricity generating capacity. Furthermore, per customer commercial and industrial electricity consumption is a decreasing function of the average real unit price of electricity to commercial and industrial enterprises and the state's LEEP score. The latter result provides evidence that public policies to promote energy efficiency yield some benefits, albeit modest, in terms of reducing commercial and industrial electricity consumption.

Competing Interests

The authors declare that they have no competing interests.

Authors' contributions

RJC developed the framework, carried out the final estimations and statistical analysis, and drafted the manuscript. NH gathered all the data, performed preliminary estimates, and edited the final draft.

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