ELECTRICITY DEMAND ELASTICITIES FOR FLORIDA: 1965-71

Stephen Baron and Rafael Lusky

January 30, 1975

ABSTRACT

Title: Electricity Demand Elasticities for Florida: 1965-71*

Authors: Stephen Baron and Rafael Lusky

This paper pools time series and cross section data for nine utility service areas in Florida. A simultaneous model is used to take into account the dual causality between the price of electricity and the quantity demanded. Only the model of the residential sector is described in this paper. The equations and results of the econometric model of the commercial and industrial sectors are included in the appendix. A price elasticity of -.79 indicates that the demand for electricity is reasonably sensitive to price. The estimated income elasticity of only .63 is probably due to the higher level of consumption in Florida (10,303 KWH per household in 1972, compare with 7,691 for the U.S.) Certainly, simple extrapolations of the past which ignore price and income will result in inappropriate capital investment in new generation, transmission, and distribution facilities.

---

*Funding for this project was received from the Public Utility Research Center and the Division of Sponsored Research, both of the University of Florida. Results of the project were delivered in a paper before the Atlantic Economic Society, September, 1974. James Herden (Research Associate, PURC) assisted in restructuring the Atlantic paper to provide a basis for this presentation.

ELECTRICITY DEMAND ELASTICITIES FOR FLORIDA: 1965-71

by

Stephen J. Baron
and
Rafael Lusky

Before the

Public Utility Research Center
Conference on Issues in the
Regulation and Management
of Public Utility Companies

February 4-5, 1975

An Estimate of Residential Demand for Florida

Although there are numerous techniques and model specifications which have been successfully utilized to estimate electricity demand, only a few of these methodologies have practical significance in estimating demand for a single state because of data limitations.

There are two sources of data available for estimating individual state demand: a time series of yearly state aggregates or a cross section of Standard Metropolitan Statistical Areas (SMSA) as used by Wilson (1969). There are serious limitations in using either of these two data sources because of structural shifts in demand behavior over time and insufficient degrees of freedom for cross section analysis of nine SMSA's in Florida. However, combining cross section data for the nine utility service areas in Florida for the years 1965 to 1971 (chosen on the basis of data availability) yields 63 observations for the estimation of residential demand.

The Residential Model

Since electricity demand is a derived demand for appliances that consume electricity, one method of estimating demand for electricity is to estimate the demand for appliances, assuming a constant use rate for each appliance regardless of the price of electricity or level of household income. However, if households react to changes in economic and demographic conditions, they may vary their use of existing appliances in accordance with the price of electricity, the level of income, weather conditions and other appropriate determinants of demand.

The basic formulation of the model used to estimate residential demand follows the specification of Halvorsen (1973), with some adjustments for the Florida data base. _/

_/ Specifically, because SMSA data are used, the dependent variable is average household consumption rather than total consumption. Since the number of residential customers is not an explanatory variable, the number of equations in the system is reduced from three to two.

In addition, a further adjustment is made to Halvorsen's specification in order to ensure consistent estimates with the pooled data base. Dummy variables are used to form separate intercepts for each of the nine SMSA's in the sample. In effect, the estimated elasticities are assumed constant for all of the Florida SMSA's. Only the intercepts differ, reflecting varying degrees of urbanization, industrialization, geographic conditions, population density and other non-measurable determinants of electricity demand. By employing dummy variables, these effects are indirectly specified in the model.

The use of dummy variables to represent cross sectional differences leads to a modified error component assumption about the model. The standard error component technique used in dealing with pooled data is based on the belief that the error term is composed of three independent elements; a random error, a cross section error term and a time related error term. The usual procedure in this situation is to employ a generalized least squares estimator as discussed in Johnson and Lyon (1973). In the present study a further assumption is made that the time related error is not present in the sample time period (1965-1971). This assumption was tested by including in the model a dummy variable representing time variation. Results indicate that time is not a significant determinant of demand in the observation period; it is concluded therefore, that the assumption of no time related error is essentially correct. Cross section errors are accounted for by the dummy variables representing SMSA variation. The only remaining error is assumed to be random, leading to consistent estimates of coefficients.

The residential model consists of two equations which form a simultaneous system. Such a model is necessary because of the interdependence and dual causality between the price of electricity and the quantity demanded. Because of the declining block rate structure of electricity prices, the average of price of electricity is dependent upon the quantity of electricity purchased; as more electricity is consumed the average price declines. This relationship between price and quantity causes inconsistent estimates of elasticities when a single equation approach is employed, as has been the case in most studies.

The two-equation residential model which appears in (2.1) is a quantity dependent demand function and a price dependent supply function which incorporates the dual causality assumption between the price and quantity variables.

Demand:

$$\begin{aligned} Q = b_0 &+ b_1(P) + b_2(Y) + b_3(\text{Temp}) + b_4(A) \\ &+ b_5(B) + b_6(C) + b_7(D) + b_5(E) \\ &+ b_9(F) + b_{10}(G) + b_{11}(H) + U_1 \end{aligned}$$

Supply:

$$P = a_0 + a_1(Q) + a_2(\text{Res7}) + U_2$$

where all variables are log linear and defined as follows:

Q = average kilowatt hour consumption per customer per year. a,b

P = average price of electricity per kilowatt hour. a,b

Y = per capita income. c

Temp = sum of heating degree days for the months of January, February and March. d

Res7 = Typical Electric Bill for 750 KWH per month. e

U_1 = random error.

U_2 = random error.

The following are dummy variables representing nine SMSA's in Florida.

A = Gainesville, Florida

B = Miami, Florida

C = Orlando, Florida

D = Jacksonville, Florida

E = Tampa, Florida

F = St. Petersburg, Florida

G = Lakeland, Florida

H = Tallahassee, Florida

I = Pensacola, Florida (part of intercept)

Data Sources

a) Statistics of Publicly Owned Utilities. Federal Power Commission (annual).

b) Statistics of Privately Owned Utilities. Federal Power Commission (annual).

c) Florida Statistical Abstract. Bureau of Economic and Business Research (annual).

d) Meteorological Data. Environmental Science Services Administration, U.S. Department of Commerce (Monthly).

e) Typical Electric Bills. Federal Power Commission. (annual)

The specification of the demand equation involves the assumption that besides price and income, that a number of demographic variables also play a role in influencing consumer behavior. However, because of the lack of sufficient data at the state level, the majority of these variables are not measurable. The inclusion of dummy variables representing cross section elements reduces the specification bias which is a direct consequence of this lack of data. The variable representing heating degree days (Temp) reflects the response of consumers to low temperatures, manifested in the operation of space heaters during winter months.

The absence of an explanatory variable representing summer temperatures is due to poor statistical results when this variable is included among the regressors. When summer temperatures are included in the equation, the resulting coefficient is negative and statistically insignificant. Since a priori theory indicates that a positive relationship should exist between these variables, summer temperature is excluded from the model. One possible explanation for the poor performance of this variable is the narrow range of variation among the nine cities with respect to summer temperatures, compared to winter temperatures. However, this does not necessarily mean summer temperature is not an important factor in electricity demand. Rather, it indicates that in the sample considered, summer tmeperature is an ineffective explanatory variable.

The price of natural gas is omitted as an explanatory variable in the demand equation, despite the fact that natural gas is the single most important substitute for electricity. However, there are a number of reasons for omitting the price of natural gas from (2.1). First, data on the price of natural gas (as published by the standard reference, Gas Facts[5]) is available only as a yearly state aggregate, precluding its compatibility with the pooled data base discussed above. Despite this incompatibility, an attempt was made to use this data (yearly state aggregate) in the model under an assumption that natural gas prices are constant among the nine SMSA's. This technique produced extremely poor results in the form of a negative cross price elasticity for natural gas. The result is not reconcilable with a priori expectations of a positive cross price elasticity. Finally, the nature of the distribution system of natural gas in Florida provides little variation in price among the sample SMSA's. The Florida Gas Company distributes natural gas to at least half of the cities comprising the sample and the gas is sold at uniform rates to all residential subscribers, thus narrowing the range of variation in the data and reducing the effectiveness in a Florida model.

The resultant specification bias produced by omitting the price of natural gas from the model is minimized because of the relatively lessor role of gas to that of electricity in Florida. Specifically, one of the major sources of electricity consumption in Florida, air conditioning, has almost no gas substitutes. Following this argument, a correctly specified model which includes the price of natural gas as an explanatory variable should yield a very small cross price elasticity indicating that demand for electricity is insensitive to the price of natural gas.

The specification of the price dependent supply equation is based on two assumptions; average price of electricity is a function of the quantity demanded, and a Typical Electric Bill is capable of characterizing the rate structure. The first assumption, as discussed previously, is a result of the declining block structure of electric utility pricing. The second assumption is justified because of the exogenous nature of the Typical Electric Bill-defined for a fixed quantity of electricity and thus it is free from the influence of quantity changes. It should be noted that the supply equation is employed here as an instrument for estimating the demand equation. No attempt is made to examine the behavior of the supply side of the electricity market.

Results

The regression results for the residential sector are presented in Table (2-1) and Table (2-2). Both the demand and the supply equations are estimated using Two Stage Least Squares. As a basis for comparison, ordinary least squares estimates are also presented.

Inspection of the results for the estimated demand equation reveals an extremely good fit of the data to the model, as evidenced by an R^2 of .9677 (more than 96% of the variation in demand is explained by the model). This high value of R^2 is partly a result of the inclusion in the model of the eight dummy variables. As Table (2-1) indicates, all but one of these variables is statistically different from zero. From examination of the residuals, it seems reasonable to conclude that the presence of these shift variables adds significantly to the explanatory capability of the model.

Estimated elasticities for the price and income variables have both a high level of statistical significance and signs that are in accordance with *a priori* expectations. The values of these elasticities are of particular interest in formulating conclusions about the future demand behavior of consumers. A price elasticity of -.79 indicates that demand for electricity is quite sensitive to price, an important factor in a period of steadily rising energy costs. It appears that the estimated price elasticity for Florida is somewhat lower (in absolute value) than the values obtained for the United States in previous studies. Though a 95% confidence interval for the price elasticity contains values from -.59 to -1.00, there is still a statistically significant difference between the Florida elasticity value and the estimates obtained from national studies.

There are a number of explanations for the apparent difference in consumer behavior. The most obvious answer seems to lie in the difference between the consumption patterns of Florida and the total United States. Average yearly consumption of electricity per household in Florida for the year 1972 was 10,303 KWH, while for the U.S. it was only 7,691. It could be that a higher level of consumption yields a lower price elasticity. However, the Florida consumption level is due in large part to the dramatic rise in residential air conditioning in the state over the past ten to fifteen years. Because of the lack of available substitutes for this major consumption item, the price elasticity is extremely low relative to other household goods. Combining (in a weighted average) this low price elasticity of air conditioners with the price elasticities of other household consumption goods reduces the total residential price elasticity below the average U.S. value. Thus it is the lack of substitutes which causes both the high level of electricity consumption and the lower price elasticity.

The estimated elasticity of the income variable is also somewhat lower than previous estimates for the total United States. This result can be attributed to the higher level of consumption in Florida, following the arguments made for the price variable.

The remaining explanatory variable, degree heating days, contributes little to the explanatory capacity of the model. Though it has the correct sign, the standard error is so large that the coefficient is not statistically different from zero. An explanation for this result is speculative at best. Most likely, the poor performance is caused by the choice of an inappropriate variable to represent winter heating requirements. However, since the main objective of this study is to acquire information necessary for long run policy formulation, knowledge about the affect of weather conditions on demand is of little use; though a mis-specification could lead to biased elasticity estimates which would affect the overall performance of the model. Finally, the results of the supply equation presented in Table (2-2) indicate that a strong relationship exists between the average price of electricity and the quantity demanded. This confirms the dual causality assumption stated earlier. Both explanatory variables in the supply equation are statistically significant and possess the expected sign. A value of -.2 for the coefficient of the quantity variable suggests that a ten per cent increase in the quantity demanded will cause a two percent decline in the average price of electricity under the present structure of rates in Florida.

Residential Sector Supply Equation for Florida.

	TSLS		OLS	
Variable	Coefficient	T-STAT.	Coefficient	T-STAT.
constant	-4.96 (.71)	-6.98	-4.58 (.64)	-7.10
Q	-.20 (.05)	-3.75	-.23 (.04)	-4.73
RES7	1.07 (.08)	12.42	1.03 (.08)	12.9
R^2	.956		.956	

In summary, the estimation results clearly indicate that in Florida, residential demand for electricity is sensitive to price. The implications of this result are extremely significant for projections of future growth in demand.

Residential Sector Demand
Equation for Florida.

	TSLS		OLS	
Variable	Elasticity	T-STAT.	Elasticity	T-STAT.
constant	.705 (.87)	.809	.185 (.75)	.246
P	-.794 (.104)	-7.62	-.724 (.086)	-8.40
Y	.630 (.155)	4.05	-.728 (.132)	5.50
TEMP	.022 (.023)	.995	.027 (.022)	1.20
A	.104	4.26	.095	4.10
B	-.038	-.616	-.056	-.940
C	.198	6.27	.189	6.20
D	.078	2.87	.066	2.62
E	.054	1.54	.039	1.20
F	.151	4.35	.144	4.23
G	.079	2.07	.063	1.77
H	.128	5.70	.122	5.60
R^2	.967		.968	

3. Conclusions

Institutional changes usually are gradual, as information and knowledge increase and our conception of "best" policies change. A crisis situation can cause a rapid break-down of old institutions as the call for new laws and regulatory procedures is heard over the day-to-day pressures within government. In this context, the current situation may be viewed as a real opportunity for improving the pattern of energy use--through peak load pricing and more careful application of cost justified pricing policies. In addition, the collection of data necessary for evaluating alternative price structures should have top priority for electric utilities and regulators alike.

The present analysis provides an empirical estimate of price responsiveness by residential electric consumers. The econometric framework could benefit from microdata that had better proxies for marginal price. We are convinced that until regulators begin to collect and analyze data in this way, we will continue to implicitly redistribute income through the price mechanism - which most economists would agree is an inefficient policy.

APPENDIX
EQUATIONS AND RESULTS OF AN ECONOMETRIC MODEL OF COMMERCIAL AND INDUSTRIAL SECTOR ELECTRICITY DEMAND

COMMERCIAL SECTOR

EQUATIONS

DEMAMD:

$$Q = b_0 + b_j P + b_2 CUS + b_3 Y + b_4 TEMP + b_5 A + b_6 B + b_7 C + b_8 D + b_9 E + b_{10} F + U_1$$

SUPPLY:

$$P = a_0 + a_1 QA + a_2 COM6 + a_3 COM7 + U_2$$

where all variables are log linear and defined as follows:

Q = total KWH consumption[3,4]

QA = average KWH consumption[3,4]

CUS = number of commercial customers[3,4]

TEMP = sum of heating degree days for the months of January, February and March[6]

Y = per capita income[10]

COM6 = Typical Electric Bill for 6,000 KWH per month in the commercial sector[2]

COM7 = Typical Electric Bill for 750 KWH per month in the commercial sector[2]

U_1 = random error

U_2 = random error

The following are dummy variables representing seven SMSA's in Florida:

A = Miami

B = Orlando

C = Jacksonville

D = Tampa

E = St. Petersburg

– = Pensacola

RESULTS OF THE ESTIMATED MODEL

Variable	DEMAND TSIS Elasticity*	T-STAT.	OLS Elasticity*	T-STAT.
constant	7.119 (2.49)	2.85	10.986 (1.65)	6.62
F	-.803 (.299)	-2.68	-1.312 (.179)	-7.32
CUS	.615 (.075)	8.12	.569 (.066)	8.59
y	.501 (.415)	1.20	-.170 (.264)	-.64
TEMP	-.007 (.050)	-.14	-.024 (.044)	-.55
A	.920	4.32	1.12	6.47
P	-.542	-4.27	-.385	-3.99
C	.035	.289	.228	2.90
D	.2177	3.27	.273	4.87
E	.519	4.84	.599	6.52
F	-.510	-4.00	-.425	-3.84
R^2	.997		.998	

*Standard errors are in parentheses.

SUPPLY

Variable	TSLS Elasticity	TSLS T-STAT.	OLS Elasticity	OLS T-STAT.
constant	-9.164 (.029)	-306.89	-9.175 (.028)	-321.91
QA	-.005 (.001)	-2.94	-.004 (.001)	-2.66
COM6	1.259 (.003)	355.42	1.260 (.003)	360.60
COM7	-.257 (.003)	-75.12	-.257 (.003)	-75.30
R^2	.999		.999	

INDUSTRIAL SECTOR

EQUATION

$$Q = b_0 + b_1P + b_2CUS + b_3A + b_4B + b_5C + b_6D + b_7E + b_8F + U$$

where all data are log linear and defined as follows:

Q = total KWH consumption[3,4]

P = average price of electricity[3,4]

CUS = number of commercial customers[3,4]

U = random error

The following are dummy variables representing seven SMSA's in Florida:

A = Miami

B = Orlando

C = Jacksonville

D = Tampa

E = St. Petersburg

F = Tallahassee

– = Pensacola

RESULTS OF THE ESTIMATED MODEL

Variable	Elasticity*	T-STAT.
constant	10.666 (.465)	11.05
P	-1.425 (.234)	-6.08
CUS	.655 (.068)	9.59
A	-1.046	-3.40
B	-1.020	-5.01
C	-.040	-.276
D	-1.049	-7.26
E	-.621	-3.52
F	-.644	-5.88
R^2	.990	

*Standard errors are in parenthesis.

Bibliography

Anderson, Kent P. Residential Demand for Electricity: Econometric Estimates for California and the United States. Santa Monica: The Rand Corporation, R-905-NSF, January 1972

Carter, Luther J. "Florida: An Energy Policy Emerges in a Growth State," Science, April 19, 1974, pp. 302-305.

Halvorsen, Robert, Demand for Electric Power in the United States, University of Washington: Institute for Economic Research, presented at the Winter Meetings of the Econometric Society, December 1973.

Houthakker, H.S., Dynamic Demand Analyses for Gasoline and Residential Electricity. Lexington, Massachusetts: Data Resources Inc., 1973.

Johnson, K.H. and Lyon, H.L., "Experimental Evidence on Combining Cross-section and Time Series Information," Review of Economics and Statistics, December 1973.

Mount, T.D., Chapman, L.D., and Tyrell, T.J., Electricity Demand in the United States: An Econometric Analysis. Oak Ridge, Tennessee: Oak Ridge National Laboratory, ORNL-NSF-EP-49, June 1973.

Wilson, J.W., "Residential Demand for Electricity," Quarterly Review of Economics and Business, Vol. 11, No. 1, Spring 1971, pp. 7-22.