Staff Paper 20 July 1979

The Demand for Natural Gas and Electricity for Nine Northeastern States in the Residential, Commercial and Industrial Sector*

by

James G. Beierlein, James W. Dunn and
James C. McConnon, Jr.

Staff Papers are circulated without formal review by the Agricultural Economics and Rural Sociology Department. Content is the sole responsibility of the authors.

Agricultural Economics and Rural Sociology Department
College of Agriculture
The Pennsylvania State University
University Park, Pennsylvania 16802

*Presented at the 1979 American Agricultural Economics Association Annual meeting, Pullman, Washington, July 29-August 1, 1979.

The Demand for Natural Gas and Electricity
for Nine Northeastern States
in the
Residential, Commercial and Industrial Sectors

Biographical Sketch
of the Authors

James G. Beierlein is an Assistant Professor of Agricultural Economics at The Pennsylvania State University. He received his B.S. and M.S. degrees in Agricultural Economics from Rutgers University, and completed his Ph.D. in Agricultural Economics at Purdue University in 1977.

James W. Dunn is an Assistant Professor of Agricultural Economics at The Pennsylvania State University. He received his B.S. degree in chemistry and mathematics and his M.S. degree in Economics from South Dakota State University, and completed his Ph.D. in Agricultural Economics at Oklahoma State University in 1977.

James C. McConnon is a former Graduate Research Assistant in Agricultural Economics at The Pennsylvania State University. He received his B.S. in Business from Drexel College, his Master of Agriculture degree from The Pennsylvania State University and is currently pursuing a Ph.D. degree in Agricultural Economics at Iowa State University.

ABSTRACT

The Demand for Natural Gas and Electricity
for Nine Northeastern States
in the
Residential, Commercial and Industrial Sectors

by

James G. Beierlein, James W. Dunn, and James C. McConnon

Classification of energy demand into groups with homogeneous uses and motives, the use of simple demand theory and a quantitative technique that allows combining of time-series and seemingly unrelated regression resulted in six demand equations that are effective. Differences in the long price elasticity for natural gas and electricity are found between sectors.

*Assistant Professor of Agricultural Economics, Assistant Professor of Agricultural Economics, and former Graduate Research Assistant, The Pennsylvania State University.

The Demand for Natural Gas and Electricity for Nine Northeastern States in the Residential, Commercial and Industrial Sectors

Introduction

The events of the past several years have raised concerns about the availability and price of energy in the United States. Americans, who long believed that we possessed inexpensive, limitless resources are encountering higher energy prices and limited energy availability. Shortages have occurred nearly every winter since 1973.

The origins of the current situation can be found in the late-1960's and early 1970's when energy consumption accelerated while domestic reserves of natural gas and petroleum began to diminish. An examination of the nation's consumption by type of fuel shows that the economy is heavily dependent on the two major energy sources (natural gas and petroleum) that are in the shortest supply. Almost three quarters of our energy consumption is concentrated in fuels that comprise less than 10 percent of our proven reserves [6]. Clearly, we are confronted with a serious problem. It is the objective of this paper to develop an accurate up-to-date estimate of energy demand that can provide government officials with data to guide their policy formulation.

Accurately estimating energy demand requires development of sets and subsets of homogeneous energy users. We contend that such a classification can be developed by separating the country into regions that have similar economic makeup and weather. Within a given region, it is necessary to separate energy demand by economic sector. And finally, it is necessary to separate energy demand in a particular sector according to type of fuel. The application of such a classification system results in the estimation of demand schedules for homogeneous groups with similar motives and energy uses.

We applied this framework to an analysis of energy demand in the northeast.[1] The economy was separated into three sectors: residential, commercial, and industrial. The separation by type of energy used included natural gas and electricity.[2] As a result of this process, a separate demand schedule in each sector in the region was estimated for natural gas and electricity.

Previous Work

Energy demand modelling has received a great deal of attention from economists, especially in the period following the 1973 OPEC embargo. Despite this attention, the models have not given consistent measures of price and income elasticities. Because of the unique nature of market for natural gas and electricity, it is useful to review the previous work in each market separately.

Natural Gas - over the years there has been little agreement among researchers as to whether the demand for natural gas is elastic or inelastic. Balestra and Nerlove studied the retail demand for natural gas for the combined residential and commercial sectors using a pooled

---

1/ For purposes of this paper the northeast includes the following states: Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, Pennsylvania, New Jersey and New York.

2/ The lack of adequate data on petroleum prices prevented analysis of the demand for the energy source.

time series cross-sectional approach [4], using data from 36 states and covering the period 1950-1962. Their model, which included a lagged consumption variable, found the demand for natural gas to be both income and price inelastic. Randell, Ives, and Ryan developed an ordinary least squares model of 139 communities in the southwest using a cross-sectional approach [17]. They found the log-log functional form the most appropriate, and the demand for natural gas to be price elastic. Mount and Tyrrell estimated a demand model for the 48 contiguous states using annual state observations for the period 1964-1975. The model estimated the demand for the industrial sector, and a combined residential-commercial sector and found the demand for natural gas to be income and price inelastic [14].

Electricity - Just as with natural gas, a wide range of estimates of the elasticity of electricity have been found. Taylor [19] reviews several of these studies and concludes that in the long run electricity is price elastic. The income elasticities vary more, with no definite pattern. Cross price effects are quite small in the short run, while some small cross price effect is present in the long run.

The variability in the estimates in each of the works cited above most probably stems from differences in assumptions, explanatory variables, periods studied, and estimation techniques utilized. While each sheds light on this complex matter, they fall short in one or more of the following areas: a) used only pre-embargo data; b) were highly aggregated; c) used estimation procedures that prevented the simlutaneous handling of differences over time and between locations; and d) failed to deal with the energy demand in each sector of the economy. The models developed in this paper attempt to overcome these four deficiencies by using both pre- and post-embargo data, concentrating on a single region of the country, using a pooled time series cross-sectional approach, and dealing with the energy demand in the residential, commercial and industrial sectors separately.

The Model

The models developed in this paper draw heavily on the basic theory of demand. The quantity of each fuel in each sector is made a function of its own price, the price of the substitute fuel, and income.[3] A partial adjustment model is felt to be appropriate so lagged quantity is included in the Nerlove fashion. To remove the effect of inflation all retail prices and personal income are deflated by the consumer price index. All wholesale prices, and incomes are deflated by the wholesale price index. Because of the wide variation in population in the study area a logarithmic functional form is used. The data for these models was collected for the northeast region for the period 1967-1975.

3/ A proxy for space heating requirements - heating degree days - was included in the explanatory variables in each equation but was dropped because of consistently strange results. This result is similar to the attempts by most other studies to account for weather.

The following statistical models are to be estimated:

(1) $$\text{Log } QN_{itj} = \alpha_{oj} - \alpha_{1j}\text{Log } PN_{itj} + \alpha_{2j}\text{Log } PE_{itj} + \alpha_{3j}\text{Log } Y_{itj} + \alpha_{4j}\text{Log } QN_{it-1j} + \varepsilon_{itj}$$

(2) $$\text{Log } QE_{itj} = \beta_{oj} - \beta_{1j}\text{Log } PE_{itj} + \beta_{2j}\text{Log } PN_{itj} + \beta_{3j}\text{Log } Y_{itj} + \beta_{4j}\text{Log } QE_{it-1\,j} + \varepsilon_{itj}$$

where i = the state

t = the year (1=1967 . . . 9=1975)

j = the sector (1=residential, 2=commercial, 3=industrial)

QN_{itj} = the natural gas consumed in the i-th state, in the t-th year, in the j-th sector in thousands of therms [9].

QE_{itj} = electricity consumed in the i-th state, in the t-th year in the j-th sector in millions of kilowatt hours (KWH) [7].

PN_{itj} = average deflated price per 1,000 therms of natural gas in the i-th state, t-th time period, in the j-th sector [9].

PE_{itj} = average deflated price per million KWH of electricity in the i-th state, in the t-th time period, in the j-th sector [5].

Y_{itj} = deflated income in the i-th state, t-th [18] time period, for j=1 (residential) = personal income

j=2 (commercial) = value of retail sales

j=3 (industrial) = value added by manufacturing

The six equations are estimated jointly using a combination of pooled time series cross-sectional methods and seemingly unrelated regressions. The estimation method is outlined in Avery [3], but inclusion of the lagged dependent variable makes Avery's estimates of the error terms inefficient. Instead, the method suggested by Nerlove [16] for such models is generalized in this more complex problem. In each demand model, the expected sign of the own price is negative, while the expected signs on the substitute fuel, and income, are positive. The lagged quantity should have a positive coefficient between zero and one.

Empirical Results

The results of the estimation of the coefficients are given in Table 1. The results will be discussed by sector.

In the residential sector the own price was significant for both natural gas and electricity with short run price elasticities of -0.59 and -0.24 respectively, and the short run price elasticity of electricity on the demand for natural gas was 0.24. The price of natural gas had a negligible effect on the demand for electricity. Income had a positive effect for electricity and a negative insignificant effect for natural gas. Electricity has a short run elasticity of 0.06. The lagged quantity variable had coefficients of 0.56, and 0.76 making the elasticity of adjustment 0.44 for natural gas and 0.24 for electricity. This makes the long run own price elasticity of natural gas - 1.35 and of electricity -0.98, and the cross price elasticities 0.54 for the price of electricity on natural gas and -0.01 for the price of natural gas on electricity demand. The long run income elasticities are -0.16 and 0.25 for natural gas and electricity respectively. These elasticities are summarized in Table 2.

For the commercial sector prices and the real value of retail sales are relatively less important than their residential sector counterparts. Only the own price elasticity of natural gas is significant, with a short run value of -0.74 and a long run value of -1.02. The electricity equation exhibited insignificant values for all three short run elasticities and the natural gas equation showed insignificant coefficients for the electricity price and income. The adjustment elasticity was very high (0.73) for the natural gas demand, and moderately high (0.41) for electricity. The relatively minor effect of these traditional explanatory variables is probably due to the ability of the sector to pass cost increases on to the consumer.

The industrial sector exhibits a more traditional response structure. The short run own price elasticities are significant and have values of -0.93 and -0.16 for natural gas and electricity respectively. The cross price effects are insignificant, which is not surprising since natural gas and electricity are only weak substitutes for most industrial users. Value added by Manufacturing was significant for both fuels with a short run elasticity of 0.13 for each and long run elasticities of 0.27 and 0.45 respectively. The elasticity of adjustment, derived from the coefficient for lagged quantity was 0.49 for natural gas and 0.30 for electricity.

Comparison with Other Studies

In Tables 3 and 4 the elasticities estimated here are compared to those estimated elsewhere. These elasticities are generally consistent with other studies with a long run residential sector own price elasticity for natural gas in the residential sector of -1.3, -1.0 in the commercial, and -1.9 in the industrial. The adjustment rate in this study was faster than that found in previous studies, a finding consistent with the higher interest rates for the period studied. The cross price effects of electricity price on natural gas demand were more substantial than discovered in previous studies and the income elasticities were less. For electricity, where more attention has been focused, the own price elasticities estimated here are less than generally found. The cross elasticities found here are similar to those generally found, with a negligible cross effect. The income effects are very similar to those found in recent studies. Older studies in general found greater income effects than current studies find, probably reflecting a completion of the electrification process and the slowing in the rate of accumulation of major electric appliances.

Conclusions

The models developed in this paper are generally quite effective and support the model formulation hypotheses developed earlier. In the long run elasticity of demand for natural gas is price elastic while for electricity they are inelastic. In the commercial sector the long run elasticity of demand is nearly equal to unity for both fuels. The cross elasticities are not significant except in the residential sector where the price of electricity is found to have a significant impact on the demand for natural gas. In all sectors except the industrial income is a relative unimportant variable. The adjustment factor is faster than has been previously suggested and may reflect a speed up in the overall economy as well as heightened concern over energy prices and availability.

The results presented here mark a first step in the analysis of energy demand, and reflect the need to use the most up to date data, and quantitative procedures that utilize the greatest amount of information.

Table 1. Natural Gas and Electricity Demand Model Coefficient Estimates, Northeastern U.S., 1967-1975.

I. Residential Sector

Dependent Variable	Constant	Price Natural Gas	Price Electricity	Income	Quantity (t-1)
Natural Gas	3.675 (0.533)	-0.5945 (0.1089)	0.2374 (0.1055)	-0.07005*[a] (0.04099)	0.5609 (0.0263)
Electricity	1.535 (0.163)	-0.002868*[a] (0.02439)	-0.2395 (0.0234)	0.06030 (0.01679)	0.7562 (0.0166)

II. Commercial Sector

Dependent Variable	Constant	Price Natural Gas	Price Electricity	Retail Sales	Quantity (t-1)
Natural Gas	3.636 (0.680)	-0.7433 (0.1545)	-0.04397*[a] (0.04184)	-0.05505*[a] (0.03737)	0.2697 (0.0283)
Electricity	3.507 (0.359)	-0.09762*[a] (0.06934)	-0.02837* (0.01842)	0.02052* (0.01754)	0.5897 (0.0285)

III. Industrial Sector

Dependent Variable	Constant	Price Natural Gas	Price Electricity	Manufacturing Value Added	Quantity (t-1)
Natural Gas	3.083 (0.542)	-0.9301 (0.1077)	0.1944* (0.1538)	0.1305 (0.0591)	0.5123 (0.0265)
Electricity	1.782 (0.229)	-0.02416*[a] (0.02607)	-0.1566 (0.0397)	0.1345 (0.0325)	0.7038 (0.0295)

* = Not significant at the 95 percent level.

a = unexpected sign

Note: Values in parentheses are standard errors.

Table 2. Short and Long Run Price, Cross-Price and Income Elasticities for Natural Gas and Electricity, Northeastern U.S., 1967-1975.

	Short Run	Long Run
I. Residential Sector		
Natural Gas		
Price Elasticity	-0.59	-1.35
Cross Price Elasticity	0.24	0.54
Income Elasticity	-0.07	-0.16
Electricity		
Price Elasticity	-0.24	-0.98
Cross Price Elasticity	-0.00	-0.01
Income Elasticity	0.06	0.25
II. Commercial Sector		
Natural Gas		
Price Elasticity	-0.74	-1.02
Cross Price Elasticity	-0.04	-0.06
Income Elasticity	-0.06	-0.08
Electricity		
Price Elasticity	-0.03	-0.07
Cross Price Elasticity	-0.10	-0.24
Income Elasticity	0.02	0.05
III. Industrial Sector		
Natural Gas		
Price Elasticity	-0.93	-1.91
Cross Price Elasticity	0.19	0.40
Income Elasticity	0.13	0.27
Electricity		
Price Elasticity	-0.16	-0.53
Cross Price Elasticity	-0.02	-0.08
Income Elasticity	0.13	0.45

Table 3. Comparison of Estimated Demand Elasticities for Natural Gas.

	Price Elasticity		Cross Elasticity with Electricity		Income Elasticity	
	Short Run	Long Run	Short Run	Long Run	Short Run	Long Run
Balestra & Nerlove						
Residential-Commercial	NE	- .63	NE	NE	NE	.62
Mount and Tyrrell						
Residential-Commercial	- .28	-1.22	- .08	- .31	- .05	- .19
Industrial	- .86	-2.15	- .06	- .15	.32	0.80
Randell, Ives & Ryan						
Residential	-1.12	NE	- .26	NE	- .23	NE
Commercial	-3.85	NE	- .79	NE	- .29	NE
Beierlein, Dunn & McConnon						
Residential	- .59	-1.35	.24	.54	- .07	- .16
Commercial	- .74	-1.02	- .04	- .06	- .06	- .08
Industrial	- .93	-1.91	.19	.40	.13	.27

Table 4. Comparison of Estimated Demand Elasticities for Electricity.

Study	Price Elasticity		Cross Price Elasticity with Natural Gas		Income Elasticity	
	Short Run	Long Run	Short Run	Long Run	Short Run	Long Run
Houthakker						
Residential	- .89	NE	.21	NE	1.16	NE
Fisher & Kaysen						
Residential	- .15	0	NE	NE	.10	0
Houthakker & Taylor						
Residential	— .13	-1.89	NE	NE	.13	1.94
Wilson						
Residential	-1.33	NE	0.31	NE	- .46	NE
Anderson						
Residential	NE	-1.12	NE	0.30	NE	0.80
Industrial	-1.94	NE	NE	NE	NE	NE
Mount, Chapman and Tyrrell						
Residential	-0.14	-1.20	0.02	0.19	0.02	0.20
Commercial	-0.17	-1.36	0.01	0.06	0.11	0.86
Industrial	-0.22	1.82	0.00	0.00	0.06	0.51
Houthakker, Verleger and Sheehan						
Residential	-0.09	-1.02	NE	NE	.14	1.64
Mount & Tyrrell						
Residential-Commercial	- .23	-1.09	- .01	- .05	.22	1.05
Industrial	- .12	- .57	.03	.14	.03	.14
Randell, Ives & Ryan						
Residential	-1.06	NE	.25	NE	.27	NE
Commercial	-2.48	NE	- .09	NE	.13	NE

Table 4. (Continued)

Study	Price Elasticity		Cross Price Elasticity with Natural Gas		Income Elasticity	
	Short Run	Long Run	Short Run	Long Run	Short Run	Long Run
Beierlein, Dunn & McConnon						
Residential	- .24	- .98	-0.00	-0.01	.06	.25
Commercial	- .03	- .07	-0.10	-0.24	.02	.05
Industrial	- .16	- .53	-0.02	-0.08	.13	.45

References

1. Anderson, K. P. Residential Energy Use: An Econometric Analysis. The Rand Corporation (R-1297-NSF), October 1973.

2. Anderson, K. P. Toward Econometric Estimation of Industrial Energy Demand: An Experimental Application to the Primary Metals Industry. The Rand Corporation (R-719-NSF), December 1971.

3. Avery, Robert B. Error Components and Seemingly Unrelated Regressions, Econometrica 45(1):199-209, 1977.

4. Balestra, P., and M. Nerlove. Pooling Cross Section and Time Series Data in Estimation of a Dynamic Model: The Demand for Natural Gas. Econometrica 34:585-611, 1966.

5. Edison Electric Institute. Statistical Yearbook. Annual.

6. Federal Energy Administration, "1976 National Energy Outlook," 1966.

7. Federal Power Commission. Typical Electric Bills 1960-1977. Washington, D.C., 1977.

8. Fisher, F. M. and C. Kaysen. A Study in Econometrics: The Demand for Electricity in the United States. Amsterdam: North Holland Publishing Co., 1962.

9. Gas Facts Yearbook. American Gas Association. Annual.

10. Houthakker, H. S. Electricity Tariffs in Theory and Practice. Electricity in the United States. Amsterdam: North Holland Publishing Co., 1962.

11. Houthakker, H. S. and L. D. Taylor. Consumer Demand in the United States, 2nd ed. Cambridge: Harvard University Press, 1970.

12. Houthakker, H. S., P. K. Verleger, and D. P. Sheehan. Dynamic Demand Analyses for Gasoline and Residential Electricity. Lexington, Massachusetts. Data Resources Inc., 1973.

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

14. Mount, J., and T. Tyrrell. Energy Demand: Conservation, Taxation and Growth," Cornell University, Agricultural Economics Staff Paper 77-3, 1977.

15. Nerlove, M. Distributed Lags and Demand Analysis for Agricultural and Other Commodities. Agricultural Marketing Service, U.S.D.A. (Agricultural Handbook No. 141), 1958.

16. Nerlove, M. Further Evidence on the Estimation of Dynamic Economic Relations from a Time Series of Cross Sections. Econometrica 39(2): 359-382, 1971.

17. Randell, A., B. C. Ives, and J. T. Ryan. The Demand for Electricity and Natural Gas in the Southwest. New Mexico State University Agricultural Experiment Station Research Report 284, Las Cruces, New Mexico, June 1974.

18. Statistical Abstract of the United States. Washington, D.C., Annual.

19. Taylor, L. D. The Demand for Electricity: A Survey. The Bell Journal of Economics 6(1):74-110, 1975.

20. U.S. Department of Commerce. Climatological Data: Natural Summary. Washington, D.C., U.S. Government Printing Office, 1970.

21. Wilson, J. W. Electricity Consumption: Supply Requirements, Demand Elasticity and Rate Design. American Journal of Agricultural Economics. 56(2):419-427, 1974.