ENERGY SUBSTITUTION IN IRRIGATION

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Introduction

Demand for electricity has become a concern of increasing importance for public utilities. Prior to 1973, the issue of energy appeared almost academic. The real price of energy had been decreasing. But the OPEC cartel and the subsequent escalating fuel prices have drawn an increasing amount of public attention to substituting one form of energy for another.

In addition to electricity, consumers generally have a choice among solid, liquid, and gaseous types of fuel. The decision as to which form of energy will be utilized will depend partly on their relative prices.

Studies to determine the effects of changes in fuel prices on the consumption of energy have been done with increasing regularity[1, 3, 4, 5]. However, while some studies mention that energy consumption involves a fuel choice, they have not investigated fuel substitution over time. In this paper we attempt to estimate the effects of fuel prices on the fuel choice decision. We present the empirical evidence of energy substitution in the case of irrigation in Nebraska.

These choices have direct relevance for public policy because the electrical industry may be publicly owned (as in Nebraska) or publicly regulated. Further, use of electricity for irrigation occurs during peak demand. Suppliers are obligated to meet his demand on any day. An additional problem for public policy is that the cost per kilowatt hour of electricity consumed at the peak (as irrigation frequently does) is much higher than that same quantity of energy used during the off-peak period [4].

Method

Cross-elasticity of demand is essential for efficient selection of inputs into a production operation. This technical term describes the degree of responsiveness of demand for a good to a change in the price of a related good.

In this study we are concerned with various types of energy input for purposes of running irrigation pumps. Suppose the price of diesel increases more than the price of electricity. Some farmers, over time, will shift to electricity because it has become relatively less expensive. Hence, demand for electricity increases.

The model used in this study captures the responsiveness of farmers usage of electricity resulting from changes in relative energy prices. Other factors which may influence demand are held constant. The factors which are held

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constant are farmers income, relative prices of irrigation pumps, the price of electricity used for irrigation and personal preferences of farmers regarding different types of energy consuming irrigation systems.

Energy is a good which is consumed indirectly. It is an intermediate good used as input to produce something which is consumed later. As a consequence of this indirection, energy is consumed in conjunction with other capital inputs. In the case of irrigation, as long as the capital stock remains in place, the possibility of substitution is limited. Hence, in the short-run substitution to cheaper fuel types is difficult. Over time, as irrigation pumps are replaced, farmers have the option of substituting one fuel type for another. Thus, we expect long-run cross-elasticities to be larger than short-run cross-elasticities.

The cross-elasticity coefficient (E_{AB}) refers to the percentage change in the demand for energy type A in response to a one percent change in the price of energy type B. Let A and B represent types of energy, and Price of B is the average price for energy type B over some specified time period.

$$E_{AB} = \frac{\partial \text{Sales of A}}{\partial \text{Price of B}} \cdot \frac{\text{Price of B}}{\text{Sales of A}}$$

We use time-series data for 1960-1980 of electricity sales used for irrigation in Nebraska. It is assumed this time frame is of adequate length to capture the dynamic substitution process caused by influences such as changing relative prices. All estimation was done using the SHAZAM computer program for econometric methods [White 1978].

Empirical Results and Conclusions

All of the cross-elasticity coefficients resulted in a positive relationship. This indicates that diesel fuel and liquid propane gas are substitutes for electricity for running irrigation pumps.

Time is an important determinant of the cross-elasticity coefficient. We find the longer the time period, the more elastic (responsive) substitution becomes.

The mean-cross-elasticity coefficient for the period 1975 through 1980 of electricity, resulting uniquely from a one percent increase in the price of diesel fuel, is +.13. This indicates, a one percent increase in the price of diesel fuel causes a .13 percent increase in the use of electricity. For liquid propane fuel, the cross-elasticity coefficient for the same period of time is +.28. Thus, a one percent increase in the price of liquid propane brings about a .28 percent increase in the use of electricity. The statistical results for this short time period (six observations) does not lend itself to meaningful interpretation. A longer time frame is needed for the model to capture explanatory power which can be interpreted statistically.

One would expect more response of substitution over a longer period of time. The regression equation for electrical sales, using the price of diesel fuel as the independent variable, from 1960 through 1980 is:

$$\text{KWHs} = 5190 + .110390 * \text{Price of Diesel Fuel}$$
$$(1.325) \quad (6.55)$$
$$\bar{R}^2 = .69 \quad \text{D-W} = .93 \quad \text{Rho} = .51$$

Cross-elasticity at the mean = .8003

The items relating to the equation consist of the dependent variable on the left side of the equals sign, a constant term, the independent variable on the right side of the equals sign and its coefficient, t-ratios in parentheses, the Durbin-Watson coefficient (D-W), the autocorrelation coefficient (Rho), the adjusted correlation coefficient ($\bar{R}^2$) and the cross-elasticity coefficient at the mean.

The mean cross-elasticity coefficient for the 21 year period from 1960 through 1980 for electricity, resulting uniquely from a one percent increase in the price of diesel fuel, is +.80. This indicates that when the price of diesel increases by one percent, farmers respond by increasing the consumption of electricity by .80 percent.

The regression equation for electrical sales, using the price of liquid propane gas as the independent variable, from 1960 through 1980 is:

$$\text{KWHs} = 3105 + 157590 * \text{Price of LP Gas}$$
$$(.876) \quad (8.553)$$
$$\bar{R}^2 = .79 \quad \text{D-W} = .95 \quad \text{Rho} = .48$$

Cross-elasticity at the mean = .9881

For liquid propane fuel, the cross-elasticity coefficient for the 21 year period is +.98. Hence, a one percent increase in the price of liquid propane causes a .98 percent increase in the consumption of electricity.

The cross-elasticity coefficients indicate the response that consumers of electricity, in the irrigation sector, make to any given change in the price of energy. This response depends on the amount of time the new price signals have been in place. Since energy is utilized in conjunction with irrigation pumps to produce a useful product, the length of time a new price is in place is important for analysis of energy substitution.

We conclude that farmers, given time, do respond to changes in relative energy prices. This study also suggests that long-run cross-elasticity coefficients are meaningful as input to policy determination related to the regulation of irrigation.

Appendix: Data Used in Cross-elasticity Calculations for Nebraska

Year	Electricity Consumption for Irrigation (millions of KWHs)	Price of Diesel Fuel (%/BTU X 10^6)	Price of Liquid Propane Gas ($/BTU X 10^6)
	(I)	(II)	(III)
1960	45.3	.93	.96
1961	59.4	.96	.96
1962	38.7	.95	.82
1963	84.4	.99	.87
1964	84.3	.91	.88
1965	70.9	.92	.88
1966	98.4	.95	.94
1967	110.0	.98	.94
1968	133.6	1.00	.81
1969	150.0	1.04	.78
1970	235.3	1.08	1.02
1971	358.0	1.11	1.03
1972	242.5	1.10	1.03
1973	277.5	1.33	1.33
1974	401.6	2.34	1.99
1975	442.0	2.48	2.21
1976	569.2	2.70	2.54
1977	406.8	3.09	3.03
1978	514.3	3.21	2.98
1979	409.3	4.93	3.41
1980	610.4	5.10	4.13

Source:

Column I: U.S. Department of Agriculture-Rural Electric Association Bulletin, *Annual Statistical Reports*.

Column II and III: U.S. Department of Energy-Energy Information Administration, *State Energy Fuel Prices*.

REFERENCES

1. Baughman, Martin and Joskow, Paul. 1975. "The Effects of Fuel Prices on Residential Appliance Choice in the United States," *Land Economics* 51 (February): 41-49.

2. Dobitz, Clifford P. 1982. *Forecasting Demand For Electricity In Nebraska Through 1990: An Econometric Analysis.* Bureau of Business Research, University of Nebraska-Lincoln.

3. Lee, Albert Yin-Po. 1981. "Voluntary Conservation and Electric Peak Demand: A Case Study of the Modesto Irrigation District," *Land Economics* 57 (August): 436-447.

4. Scherer, Charles R. 1976. "Estimating Peak and Off-Peak Marginal Costs for an Electric Power System: An ExAnte Approach," *The Bell Journal of Economics* 7 (Autumn): 575-601.

5. Taylor, Lester D. 1975. "The Demand for Electricity: A Survey," *The Bell Journal of Economics* 6 (Spring): 74-110.

6. Vermetten, J. B. and Joh Plantinga. 1953. "The Elasticity of Substitution of Gas With Respect to Other Fuels in the United States," *The Review of Economics and Statistics* 35 (May): 140-143.

7. Wenders, John T. and Lester D. Taylor. 1976. "Experiments in Seasonal-Time-of-Day Pricing of Electricity to Residential Users," *The Bell Journal of Economics* 7 (Autumn): 531-552.

8. White, K. J. 1978. "A General Computer Program for Econometric Methods-SHAZAM," *Econometrica* 46 (January): 239-240.

9. Wilson, John W. 1971. "Residential Demand for Electricity," *The Quarterly Review of Economics and Business* (Spring): 7-19.